SMALL DIESEL ENGINE

service manual • 1st edition

Maintain and Repair Small Diesel Engines Up To 160 Cubic Inches (2600cc) Displacement

CAL PUBLICATIONS

SMALL DIESEL ENGINE SERVICE MANUAL

(1st Edition)

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CONTINENTAL

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DIVISION

700 Terrace Street
Muskegon, Michigan 49443

Model	No. Cyls.	Bore	Stroke	Displ.
TMD27	4	91 mm	103.2 mm	2680 cc

The Model TMD27 engine is a water-cooled, four-cylinder, four-stroke diesel engine. Crankshaft rotation is counter-clockwise at pto end and number 1 cylinder is cylinder nearest pto end of engine. Firing order is 1-3-4-2.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 5W-20 for temperatures below minus 18° C.(0° F.), SAE 10W for temperatures between minus 18°C.(0° F.) and 0° C.(32° F.), SAE 20W for temperatures between 0° C.(32° F.) and 24° C.(75° F.). API oil classification should be CD or CE. Oil sump capacity is 5.7 liters while an additional liter of oil is contained in the oil filter. Manufacturer recommends renewing oil after every 50 hours of operation.

ENGINE SPEED ADJUSTMENT

Idle speed should be 800-1000 rpm and is adjusted by turning idle speed screw (I–Fig. C1-1). Maximum governed speed is determined by engine application and is adjusted by turning high speed screw (H).

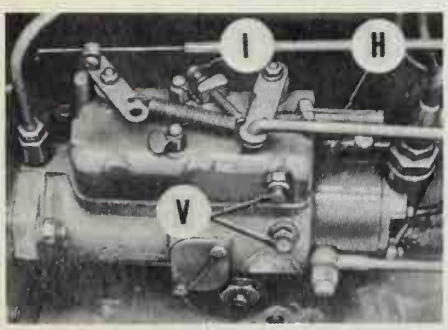


Fig. C1-1—Typical view of fuel injection pump. Loosen vent screws (V) to bleed fuel. Turn screw (I) to adjust idle speed or screw (H) to adjust high speed.

FUEL SYSTEM

FUEL FILTERS. An external fuel filter is mounted on side of engine. Renew fuel filter after every 400 hours of operation or sooner if required.

BLEED FUEL SYSTEM. To bleed fuel system, remove bleed screw on fuel filter body. Allow gravity to force fuel flow or operate priming lever on fuel transfer pump until air-free fuel flows, then reinstall filter body bleed screw. Loosen injection pump bleed screws (V–Fig. C1-1) and operate fuel transfer pump priming lever until air-free fuel flows, then tighten bleed screws (V). Loosen fittings for high pressure injection lines at injectors. Rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection lines. Retighten injection lines.

INJECTION PUMP TIMING

The injection pump should be properly timed when timing marks scribed on timing gear cover, adapter plate and pump mounting flange are aligned. Loosen adapter plate and injection pump mounting nuts, then rotate plate or pump as required to align marks.

If timing marks are not present or believed false, rotate engine so number 1 piston is at top dead center on compression. Remove inspection plate on side of injection pump, loosen pump mounting nuts then rotate pump so line "A" on pump drive plate is aligned with flat end of snap ring as shown in Fig. C1-2. It may be necessary to loosen and rotate adapter plate if rotating pump will not align line "A" and snap ring end.

Injection timing should occur at 15-17 degrees before top dead center with engine running at 1600 rpm. Manufacturer recommends using a suitable timing light to set injection timing.

If injection timing cannot be correctly set as outlined previously, refer to INJECTION PUMP section as injection pump gear may be improperly timed.

COOLING SYSTEM

Model TMD 27 is liquid cooled and uses a water pump mounted on the engine front to circulate coolant. Corrosion resistant anti-freeze or an anti-corrosion additive should be used in the engine coolant.

A thermostat is located under the coolant outlet. Thermostat opening temperature is 81° C.(180° F.).

BELT TENSION

Belt deflection measured midway between water pump and crankshaft pulleys should be approximately 13 mm using thumb pressure. Belt tension is adjusted by repositioning alternator.

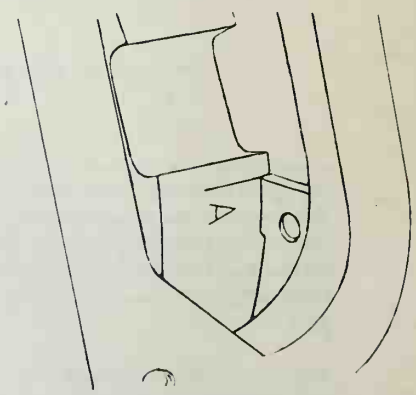


Fig. C1-2—Injection timing is correct when scribed line "A" aligns with snap ring end and number 1 piston is at top dead center on compression.

REPAIRS

TIGHTENING TORQUES

Refer to following table for tightening torques. All values are in newton meters.

Camshaft nut	88-95
Connecting rod	61-68
Crankshaft pulley	163-176
Cylinder head	
M10	68-75
M12	122-129
Flywheel	68-75
Flywheel housing	61-68
Glow plug	31-38
Injection pump gear	27-34
Injector	68-75
Main bearing	150-162
Manifolds	
M8	20-24
M10	34-40
Oil pan	14-19
Oil pump	20-24
Rocker cover	7-8
Rocker arm shaft	23-27

WATER PUMP

R&R AND OVERHAUL. To remove water pump, drain coolant, disconnect hoses and remove drive belt. Unbolt and remove water pump.

Refer to Fig. C1-3 and disassemble pump as follows: Pull pulley (10) off shaft then remove cover (1). Pull impeller (3) off shaft and remove seal assembly (4). Detach snap rings (6). Drive or press shaft (9) out of housing towards pulley side of pump. Housing will be damaged if shaft is removed from impeller side of pump.

Reverse disassembly procedure for reassembly, however, install pulley (10) before impeller (3). However, do not install cover (1) until pulley (10) is installed so shaft can be supported to prevent damage to bushing and seal.

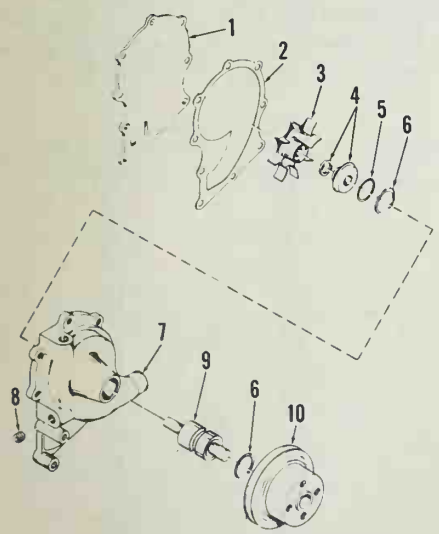


Fig. C1-3—Exploded view of water pump.

1. Cover
2. Gasket
3. Impeller
4. Seal assy.
5. "O" ring
6. Snap ring
7. Pump housing
8. Plug
9. Shaft assy.
10. Pulley

VALVE TAPPET GAP

Valve tappet gap is adjusted with engine at normal operating temperature. Remove rocker cover for access to rocker arms and adjust valve tappet gap to 0.36 mm for intake valves and 0.46 mm for exhaust valves.

CYLINDER HEAD

R&R AND OVERHAUL. Drain coolant, then detach coolant hoses. Remove intake and exhaust manifolds. Detach glow plug wire. Disconnect fuel injection lines, remove injectors and cap or plug fuel openings to prevent contamination. Remove rocker cover and rocker arm shaft assembly. Extract push rods being careful not to dislodge tappets. Unscrew cylinder head screws and remove head.

Maximum allowable head surface warpage is 0.10 mm measured lengthwise or 0.075 mm measured across head. Precombustion chamber inserts must be flush or project up to 0.076 mm above head surface.

Intake valve seat angle is 30° 15' and exhaust valve seat angle is 45° 15'. Valve guides are renewable. Bottom of valve guide should be 40.0 mm from head surface. Valve guide inside diameter is 8.692-8.717 mm with a maximum allowable diameter of 8.775 mm.

Maximum allowable clearance between rocker arms and shaft is 0.13 mm.

Install cylinder head by reversing removal procedure. Use three steps when tightening cylinder head screws and follow sequence shown in Fig. C1-4. Tighten M10 cylinder head screws to 68-75 N·m and M12 screws to 122-129 N·m. Retighten cylinder head screws with engine at normal operating temperature.

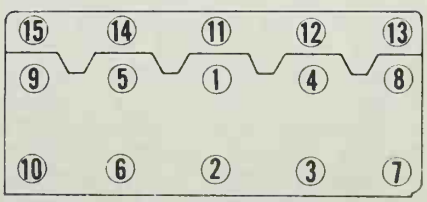


Fig. C1-4—Cylinder head tightening sequence.

VALVE SYSTEM

Both valves ride in renewable valve guides. Refer to CYLINDER HEAD section for valve guide installation.

Intake valve face angle is 29° 45' and valve seat angle is 30° 15'. Exhaust valve face angle is 44° 45' and valve seat angle is 45° 15'. Valve seat width for all valves should be 1.62-3.2 mm.

Intake and exhaust valve guide inner diameter is 8.692-8.717 mm. Intake valve stem diameter is 8.642-8.660 mm. Intake valve stem clearance should be 0.032-0.075 mm with a maximum allowable clearance of 0.125 mm. Exhaust valve stem diameter is 8.622-8.640 mm. Exhaust valve stem clearance should be 0.052-0.095 mm with a maximum allowable clearance of 0.142 mm.

Valve spring pressure should be 235 newtons at 42.0 mm and 466 newtons at 32.88 mm. Installed spring height is 42.0 mm.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE AND REINSTALL. Before removing an injector or loosening injector lines, thoroughly clean injector, lines and adjacent area with a suitable solvent and compressed air. Disconnect high pressure and by-pass lines from injector, then cap lines to prevent contamination. Unscrew injector from cylinder head, then remove and discard heat shield (9—Fig. C1-5).

Before installing injector, be sure in-

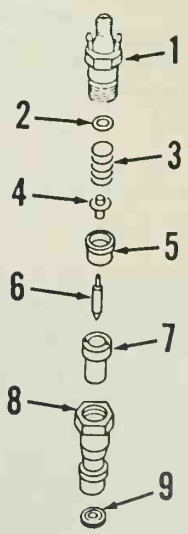


Fig. C1-5—Exploded view of fuel injector.

1. Body
2. Shim
3. Spring
4. Pressure pin
5. Spacer
6. Valve
7. Nozzle
8. Nozzle nut
9. Heat shield

jector bore and seating surface in head are clean and free of carbon. Install a new heat shield (9). Install injector and tighten to 68-75 N·m. Reconnect injector lines.

TESTING. A complete job of testing and adjusting injectors requires use of special test equipment. Only clean, approved testing oil should be used to test injectors. Injector nozzle should be tested for opening pressure, seat leakage and spray pattern.

When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Before conducting test, operate tester lever until test oil flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, which would indicate that injector may be serviceable without disassembly.

OPENING PRESSURE. Open valve to tester gage and operate tester lever slowly while observing gage reading. Opening pressure should be 13.0-13.5 MPa (1885-1960 psi).

Opening pressure is adjusted by varying thickness of shim (2–Fig. C1-5).

SEAT LEAKAGE. Injector nozzle tip should not leak at a pressure less than 10.8 MPa (1560 psi). To check for leakage, actuate tester lever slowly and as gage needle approaches suggested test pressure, observe nozzle tip. Hold pressure for 10 seconds; if drops appear or nozzle tip becomes wet, valve is not seating and injector must be disassembled and overhauled as later outlined.

NOTE: Leakage of tester check valve or connections will cause a false reading, showing up in this test as fast leakback. If a series of injectors fail to pass this test, the tester rather than injector units should be suspected.

SPRAY PATTERN. Spray pattern should be well atomized and slightly conical, emerging in a straight axis from nozzle tip. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

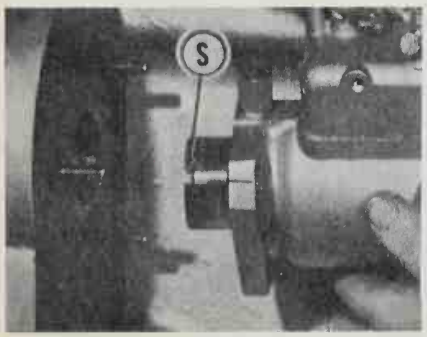


Fig. C1-6—View of slot (S) which must engage pin in pump gear.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder assembly. Refer to Fig. C1-5 for exploded view and proceed as follows:

Secure injector body (1) in a soft jawed vise or holding fixture and remove nozzle nut (8). Place all parts in clean calibrating oil or diesel fuel as they are removed, using a compartmented pan and using extra care to keep parts from each injector together and separate from other units.

Clean exterior surfaces with a brass wire brush, soaking in an approved carbon solvent if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces. Tighten nozzle nut (8) to 68-75 N·m when installing on injector body (1).

GLOW PLUGS

Each cylinder is equipped with a glow plug. Glow plugs are connected in parallel with each glow plug grounded through mounting threads. Before suspecting a glow plug malfunction, determine that current is reaching glow plugs. Tighten glow plugs to 31-38 N·m.

INJECTION PUMP

REMOVE AND REINSTALL. To remove injection pump, disconnect fuel lines and cap openings to prevent contamination. Remove pump adapter plate retaining nuts and remove injection pump.

The injection pump should be tested and overhauled by a shop qualified in diesel injection pump repair.

Proceed as follows to assemble pump, adapter plate and gear and install pump on engine: Place adapter plate on pump and loosely install pump retaining nuts. Install pump gear on pump shaft so pin in gear hub mates with slot (S–Fig. C1-6) in pump shaft. Tighten gear retaining screws to 27-34 N·m. Rotate engine crankshaft so number 1 piston is at top dead center on compression–beveled tooth on pump drive gear (behind camshaft gear) should be centered in opening in rear of timing gear case. Unscrew plug in front of timing gear cover and install a timing pin. Install injection pump so pump gear mates with drive gear and aligns with timing pin. Refer to INJECTION PUMP TIMING section and time pump.

OIL PAN

The oil pan is sealed by RTV form-in-place gasket. Apply a 2 mm bead of gasket material as shown in Fig. C1-7. Gasket surfaces of oil pan and crankcase must be clean and dry before applying gasket material.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod are removed as a unit after removing cylinder head and oil pan. If not present, make marks on rod and cap for reassembly. Unscrew rod cap retaining screws, detach rod cap and extract piston and rod.

When assembling piston and rod, piston pin installation is easier if the piston is heated prior to pin insertion. Install piston and rod assembly so notch (N–Fig. C1-8) is towards water pump end of engine. Tighten connecting rod screws to 61-68 N·m.

PISTON, PIN AND RINGS

All pistons are equipped with two compression rings and an oil control ring. The piston pin is fully floating in piston and rod.

Piston clearance is measured using a 13 mm wide, 0.08 mm thick feeler gage and a suitable pull scale. Invert the piston, keeping pin bore parallel to crankpin, and insert piston with feeler gage 90 degrees from pin bore into cylinder until piston is approximately 50 mm into cylinder bore. Slowly withdraw the feeler gage with the pull scale and note scale reading. Piston fit is correct

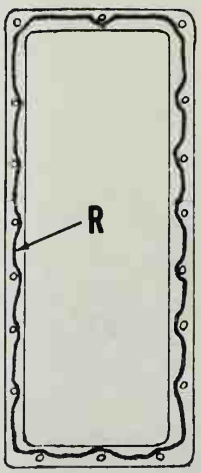


Fig. C1-7—Apply RTV form-in-place gasket in a 2 mm bead (R) to oil pan flange as shown.

when 2.3-4.5 kg pull is required to withdraw feeler gage.

Piston ring end gap should be 0.40-0.65 mm for compression rings and 0.30-0.60 mm for the oil control ring. Piston ring side clearance for all rings should be 0.050-0.082 mm.

Piston pin diameter is 28.571-28.575 mm with a maximum wear limit of 28.562 mm. Piston pin bore in piston should be 28.578-28.583 mm. Piston pin clearance in connecting rod should be 0.013-0.028 mm.

CONNECTING ROD AND BEARINGS

Connecting rod is equipped with a renewable bushing in the small end and insert type bearings in the big end.

Clearance between rod bearing and crankpin should be 0.016-0.080 mm. Maximum bearing clearance is 0.091 mm. Standard crankpin diameter is 49.187-49.212 mm. Rod side play should be 0.15-0.28 mm.

The small end bushing inner diameter is 30.150-30.175 mm. Install bushing so oil holes are aligned then, if necessary, ream to desired diameter.

CAMSHAFT AND TAPPETS

R&R AND OVERHAUL. Remove water pump belt and crankshaft pulley. Remove cylinder head as previously outlined. Remove timing gear cover (note that oil pan is attached to timing gear cover). Unscrew camshaft nut, then use suitable pullers to slide camshaft gear and injection pump gear off end of camshaft. Remove tappets, camshaft retainer plate and camshaft.

Diameter of camshaft bearing journal nearest gear end is 47.511-47.536 mm while diameter of bearing journal at opposite end is 42.748-42.774 mm. Center bearing journal diameter is 44.336-44.361 mm. Camshaft bearing clearance should be 0.064-0.114 mm. Tappet outside diameter is 25.311-25.324 mm. Maximum allowable tappet clearance is 0.13 mm.

Reverse camshaft removal procedure for installation while noting the following: Align crankshaft and camshaft gear marks shown in Fig. C1-9. Insert a suitable bar through the fuel transfer pump opening in cylinder block to prevent camshaft movement from knocking out rear expansion plug while driving injection pump gear and camshaft gear onto camshaft. Do not attempt to force gears onto camshaft with camshaft nut as camshaft end may break. Tighten camshaft nut to 88-95 N·m. Camshaft end play should be 0.038-0.175 mm and is maintained by a thrust plate located between the camshaft retainer and cylinder block. Renew thrust plate if end play is excessive.

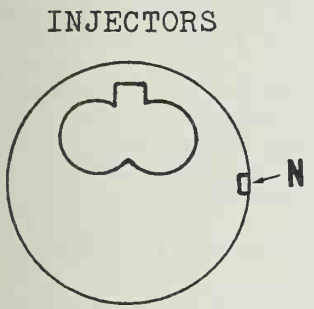


Fig. C1-8—Instaii piston so notch (N) in piston crown is towards water pump end of engine.

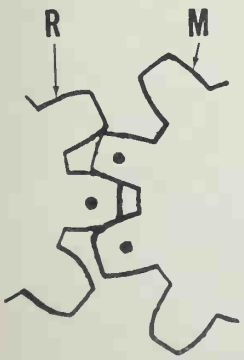


Fig. C1-9—Diagram showing crankshaft (R) and camshaft (M) timing gear marks.

OIL PUMP

R&R AND OVERHAUL. To remove oil pump, remove water pump belt and crankshaft pulley. Remove oil pan and timing gear cover. Unscrew camshaft nut, then use a suitable puller to remove camshaft and crankshaft gears. Unscrew oil pickup bracket, then remove oil pump.

Remove cover (5—Fig. C1-10) and inspect gears and pump body for excessive wear or damage. The oil pressure relief valve is accessible after removing snap ring (9). Be sure "O" ring located between pickup tube and pump body seals properly. If oil pickup screen is renewed, position new screen on pickup bowl so lead disc is directly across from pickup tube opening.

Reverse removal procedure for installation. Tighten oil pump mounting screws to 20-24 N·m. Refer to CAMSHAFT AND TAPPETS section when installing camshaft gear. Refer to OIL PAN section for oil pan installation.

FLYWHEEL AND FLYWHEEL HOUSING

The flywheel housing is secured to the cylinder block by special cap screws in the upper holes which have sealing bands. Failure to use these special cap screws will result in oil leakage. Flywheel runout should not exceed 0.20 mm. Tighten flywheel housing screws to 61-68 N·m and flywheel screws to 68-75 N·m.

REAR CRANKSHAFT SEAL

REMOVE AND REINSTALL. The rear crankshaft seal may be removed and installed without removing crankshaft. To remove rear crankshaft seal, remove flywheel, flywheel housing and oil pan. Remove rear main bearing cap and remove seal halves from cap and block.

To install seal, lubricate seal lip, apply a light grease to back of seal half and carefully slide seal into position in block with lip pointing towards engine. Install seal half in rear main bearing cap with lip towards engine.

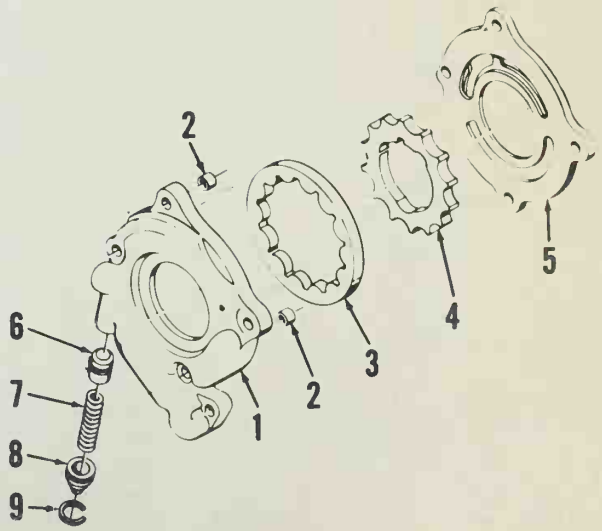


Fig. C1-10—Exploded view of oil pump.

1. Pump body
2. Hollow dowel
3. Outer gear
4. Inner gear
5. Cover
6. Pressure relief valve
7. Spring
8. Plug
9. Snap ring

To install rear main bearing cap, apply a light coat of RTV sealer to surface (S–Fig. C1-11) of bearing cap. Install rear main bearing cap in cylinder block and tighten cap screws to 150-162 N·m. Inject RTV sealer into bearing cap cavities (C) until sealer is expelled from bottom corners. Be sure cavity is full. Insert side seals (E) into cavities (C) so ends are flush with bottom surface of cylinder block then wipe away excess sealer.

Install oil pan and flywheel as previously outlined.

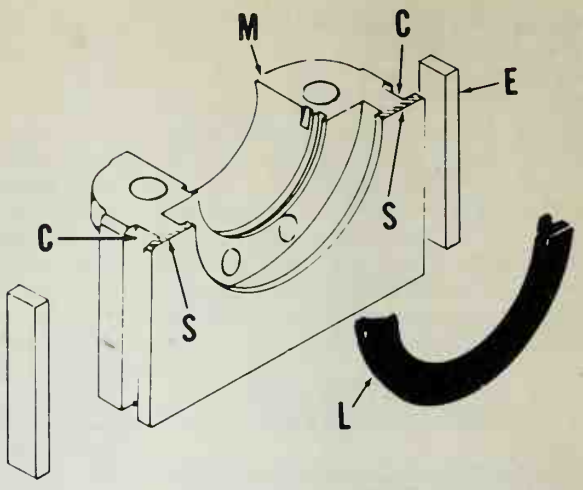


Fig. C1-11 – Refer to text for installation of rear crankshaft seal (L) and rear main bearing cap (M).

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove oil pump, pistons and rods, and flywheel as previously outlined. The crankshaft can be removed after detaching main bearing caps.

Main bearing journal diameter is 72.944-72.974 mm and main bearing clearance should be 0.058-0.133 mm. Crankshaft end play should be 0.04-0.17 mm with a maximum allowable limit of 0.18 mm. End play is controlled by center main bearing.

Tighten main bearing cap screws to 150-162 N·m. Refer to REAR MAIN BEARING SEAL section for proper installation of rear main bearing cap.

FARYMANN

BRIGGS & STRATTON CORP.

Milwaukee, Wisconsin 53201

Model	No. Cyl.	Bore	Stroke	Displ.
15A430	1	75 mm	55 mm	243 cc
18A430	1	82 mm	55 mm	290 cc

Engines covered in this section are single-cylinder, air-cooled, diesel engines. Crankshaft rotation is counter-clockwise at flywheel end of engine.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below O° C.(32° F.), SAE 20W20 for temperatures between O° C.(32° F.) and 30° C.(86° F.), and SAE 30 for temperatures above 30° C.(86° F.). API classification for oil should be CD. Fill oil sump to full level on dipstick. Manufacturer recommends renewing oil after first 20 hours of operation and after every 100 hours thereafter.

Both models are equipped with an oil pump to provide pressurized oil for lubrication. The oil pickup (2–Fig. F1-1) may be removed from the gear cover for periodic cleaning and inspection.

ENGINE SPEED ADJUSTMENT

Low idle speed is determined by detents in the speed control lever and is not adjustable. Maximum governed speed is determined by engine application.

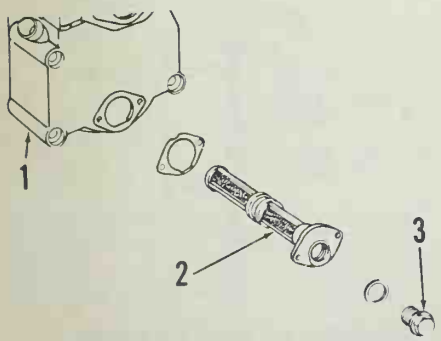


Fig. F1-1–Oil pickup and screen (2) is removable from front cover (1). Oil drain plug (3) screws into pickup mounting flange.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter is located in the fuel tank. Renew filter after every 50 hours of operation or sooner if required.

BLEED FUEL SYSTEM. Due to gravity feed type of fuel system, air should be bled from system as fuel injection pump operates. However, bleeding time may be shortened by loosening then retightening fuel line fittings, starting first at fuel tank and working to fuel injection pump. Retighten fitting when air-free fuel flows.

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G–Fig. F1-2) between pump body and mounting surface on crankcase. To check injection timing proceed as follows: Disconnect high pressure line from injection pump, then unscrew delivery valve holder (1) and remove spring (6), shim (5), spring guide (4) and delivery valve (7); do not remove valve seat. Reinstall delivery valve holder (1) and connect a suitable spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full open position. Rotate engine flywheel slowly in counter-clockwise direction until fuel just stops flowing from spill pipe. Measure distance from reference mark on flywheel housing to top dead center mark on flywheel. Measured distance should be 18 mm if maximum governed rpm is 2000 rpm or less, 21 mm if maximum governed rpm is between 2000 rpm and 3300 rpm, or 27 mm if maximum governed rpm is 3300 rpm or more. Measured distance should be within plus or minus 2 mm of desired distance.

If injection timing is incorrect, remove injection pump and remove or install shims (G–Fig. F1-2) as required. Adding shims will retard injection timing while removing shims advances injection timing. Be sure to reinstall removed pump parts after checking timing.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques. All values are in newton meters.

Connecting rod	30
Cylinder head	30
Injection pump	30
Injector retainer plate	5-6
Main bearing support	30
Rocker arm cover	8.4-9.6

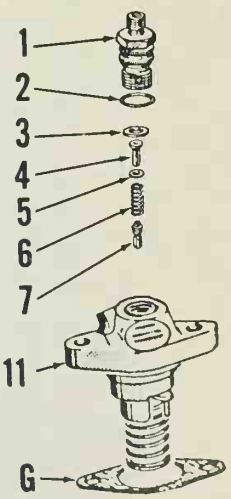


Fig. F1-2–Partial exploded view of fuel injection pump. Injection timing is adjusted using shim gaskets (G).

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Shim
6. Spring
7. Delivery valve
11. Fuel injection pump

VALVE TAPPET GAP

Valve tappet gap may be adjusted after removing rocker arm cover. Compression release must be in "off" position. Valve tappet gap should be 0.1 mm for both valves with engine cold.

CYLINDER HEAD AND VALVE SYSTEM

Valve face and valve seat angles are 45 degrees for intake and exhaust valves. Minimum allowable depth of valve in head measured from top of valve to cylinder head surface is 0.0-0.1 mm. Valve guides (15 – Fig. F1-3) are renewable and identical. Valve springs are dissimilar. Note that rotator (12) is located under the exhaust valve spring and valve stem seal (23) is used on the intake valve.

Install a new "O" ring (27 – Fig. F1-4) around push rod tube before installing cylinder head. Model 18A430 is equipped with a head gasket while Model 15A430 is not so equipped. Tighten cylinder head retaining nuts in a crossing pattern to a torque of 30 N·m. Install clip (20 – Fig. F1-3) so clip bears against end of push rod tube. Push rod nearer cylinder is connected to intake valve rocker arm.

COMPRESSION RELEASE

Compression release (31 – Fig. F1-4) is manually operated to raise the intake valve to aid engine starting. Compression release is not adjustable. Install a new "O" ring (30) on push rod tube when reassembling.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and high pressure injection line and immediately cap or plug all openings. Unscrew retainer plate and remove injector and asbestos washer.

Reverse removal procedure to reinstall injector. Install a new asbestos washer (8 – Fig. F1-5). Tighten injector retainer plate nuts to 5-6 N·m.

TESTING. WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector operation may be checked. Only clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Opening pressure should be 20.0 MPa. Opening pressure is adjusted by varying thickness of shims (2 – Fig. F1-5).

OVERHAUL. Clamp injector body (1 – Fig. F1-5) in a vise with nozzle pointing upward, unscrew nozzle holder nut (7), then remove injector components shown in Fig. F1-5. Thoroughly clean all parts in a suitable solvent. Clean inside orifice of nozzle tip with a wooden cleaning stick. When reassembling injector,

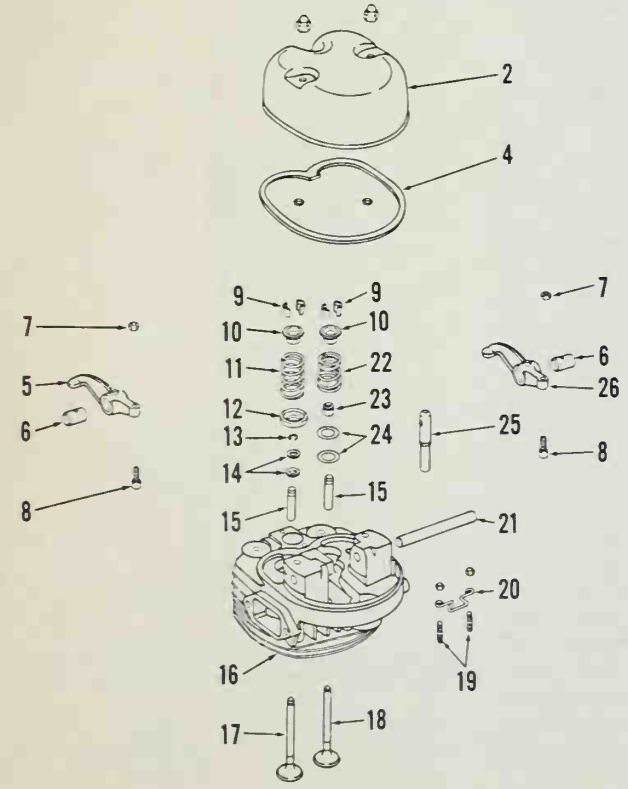


Fig. F1-3 – Exploded view of cylinder head.

2. Rocker arm cover
4. Gasket
5. Exhaust rocker arm
6. Bushing
7. Locknut
8. Adjuster
9. Valve keys
10. Retainer
11. Exhaust valve spring
12. Valve rotator
13. Circlip
14. Washers
15. Valve guide
16. Cylinder head
17. Exhaust valve
18. Intake valve
19. Studs
20. Push rod tube retainer
21. Rocker arm shaft
22. Intake valve spring
23. Valve seal
24. Washers
25. Breather
26. Intake rocker arm

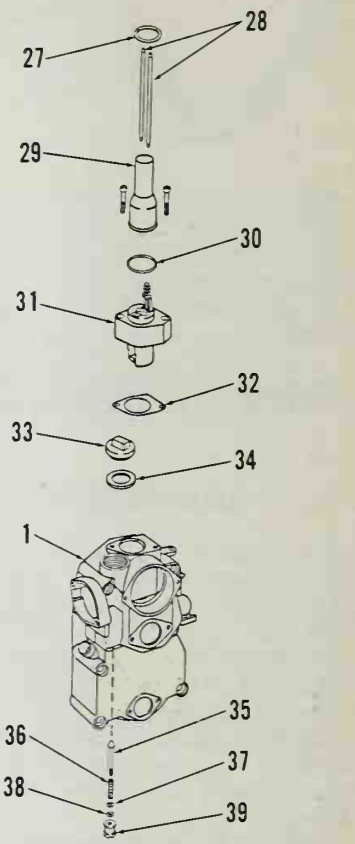


Fig. F1-4 – Exploded view of push rod tube and excess fuel assemblies. Excess fuel components (35 through 39) are not used on Model 15A430.

1. Front cover
27. "O" ring
28. Push rods
29. Push rod tube
30. "O" ring
31. Tappet housing & compression release
32. Gasket
33. Oil fill plug
34. Gasket
35. Excess fuel shaft
36. Spring
37. Washer
38. "O" ring
39. Knob

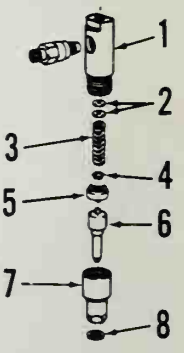


Fig. F1-5 – Exploded view of injector.

1. Injector body
2. Shims
3. Spring
4. Push piece
5. Spacer
6. Nozzle & valve
7. Nozzle holder nut
8. Asbestos washer

make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle holder nut (7) to 24-29 N·m.

INJECTION PUMP

R&R AND OVERHAUL. To remove fuel injection pump, disconnect fuel lines and immediately cap or plug all openings. Unscrew pump retaining nuts and remove fuel injection pump. Do not lose shim gaskets (G – Fig. F1-2). Pump components (17 through 21 – Fig. F1-6) will remain in crankcase, and timing gear cover must be removed for access.

Refer to Fig. F1-6 for an exploded view of fuel injection pump. The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

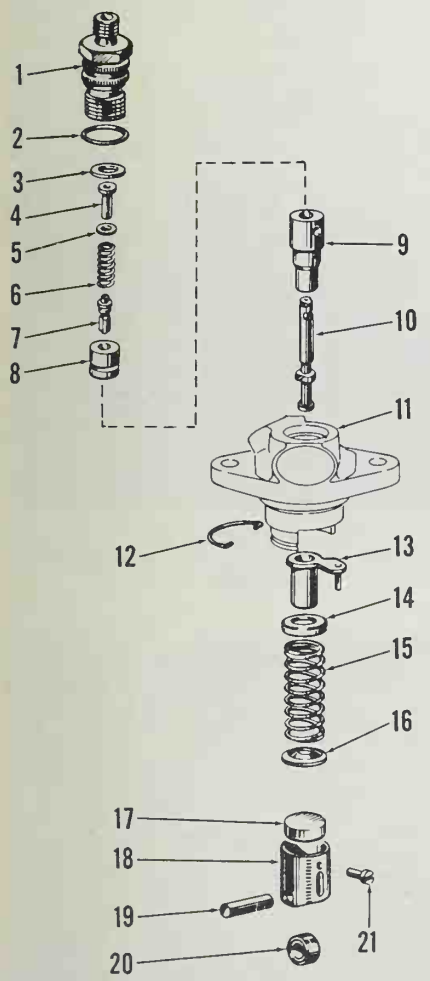


Fig. F1-6 – Exploded view of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Shim
6. Spring
7. Delivery valve
8. Delivery valve seat
9. Barrel
10. Plunger
11. Body
12. Clip
13. Control sleeve
14. Spring seat
15. Spring
16. Spring retainer
17. Spacer
18. Tappet
19. Pin
20. Roller
21. Pin

Model 18A430 is equipped with an excess fuel device (35 through 39 – Fig. F1-4) to aid starting. Pushing up on starter knob (39) forces shaft (35) against governor arm which moves fuel injection pump control arm to intermediate position for additional fuel.

Reverse removal procedure to reinstall pump. Tighten pump mounting nuts to 30 N·m. If pump is renewed or overhauled, or original shim gaskets are not used, refer to INJECTION PUMP TIMING section and adjust pump timing.

CYLINDER, PISTON, PIN AND RINGS

R&R AND OVERHAUL. The cylinder is removable after removing cylinder head. After cylinder is removed, cover crankcase opening to prevent entry of foreign material. Extract piston pin retainers (63 – Fig. F1-7), remove piston pin, then separate piston from connecting rod.

Nominal standard cylinder bore diameter measured at top of cylinder is 74.86-74.88 mm on Model 15A430 governed at 1800 rpm or less, and 74.91-74.93 mm on Model 15A430 governed at engine speeds above 1800 rpm. Nominal standard cylinder bore diameter measured at top of cylinder is 81.88-81.90 mm on Model 18A430 governed at 1800 rpm or less, and 81.94-81.96 mm on Model 18A430 governed at engine speeds above 1800 rpm. Cylinder and piston are available in standard size only.

Piston ring end gap should be 0.2-0.8 mm with piston ring located 25 mm from top of cylinder.

Reverse removal procedure for installation. With cylinder installed and held against crankcase, measure height of piston from top edge of cylinder. Piston on Model 15A430 should be beneath top of cylinder a distance of 0.475-0.800 mm. Piston height above top edge of cylinder on Model 18A430 should be 0.650-0.975 mm. Note that Model 15A430 is not equipped with a cylinder head gasket while Model 18A430 is so equipped.

CONNECTING ROD

REMOVE AND REINSTALL. To remove connecting rod, drain oil and remove cylinder. Detach cover (68 – Fig. F1-7) on crankcase bottom. Reach through cover opening, unscrew rod cap retaining nuts and withdraw rod cap through cover opening. Remove piston and rod unit from top of engine. If required, separate piston from rod.

An insert type bearing is used in connecting rod big end while a non-renewable bushing is located in rod small end. Standard crankpin diameter is 40.020-40.030 mm. Big end bearing clearance for both models should be 0.03-0.05 mm. Connecting rod big end bearing is available in standard size and undersizes of 0.25 and 0.50 mm.

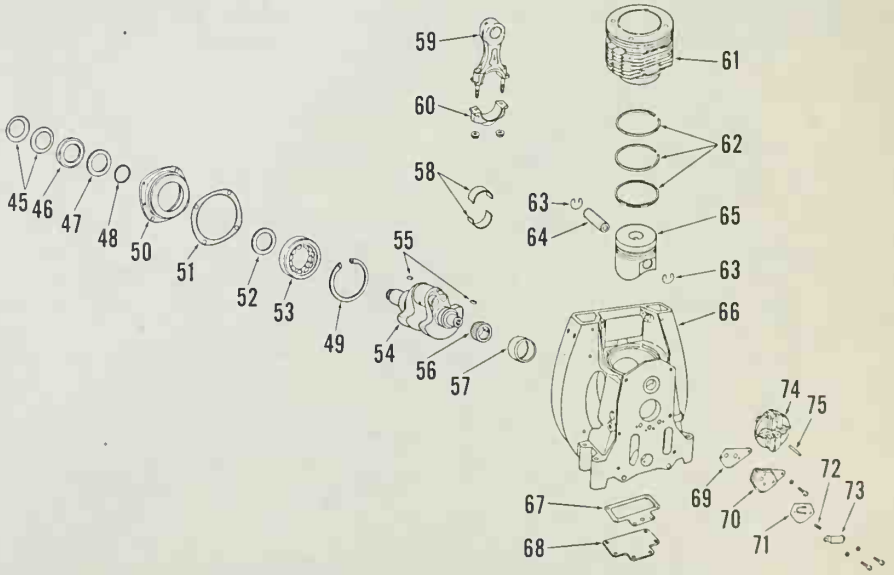


Fig. F1-7 – Exploded view of crankcase assembly.

45. Belleville washers
46. Seal
47. "O" ring retainer
48. "O" ring
49. Snap ring
50. Main bearing support
51. Gasket
52. Washer
53. Bearing
54. Crankshaft
55. Keys
56. Gear
57. Bushing
58. Rod bearing
59. Connecting rod
60. Rod cap
61. Cylinder
62. Piston rings
63. Piston pin retainer
64. Piston pin
65. Piston
66. Crankcase
67. Gasket
68. Cover
69. Gasket
70. Oil pump
71. Relief valve plate
72. Relief valve spring
73. Spring retainer
74. Governor flyweight assy.
75. Pin

Reverse removal procedure to install connecting rod while noting the following: The connecting rod side with a paint mark should be towards the fuel injection pump. Install rod cap so stamped numbers (N – Fig. F1-8) on rod and cap are on same side. Tighten connecting rod nuts to 30 N·m.

FRONT COVER

REMOVE AND REINSTALL. To remove front cover (1 – Fig. F1-9), drain oil, then remove rocker arm cover and extract push rods. Remove push rod tube hold down clip (20 – Fig. F1-3) and slide push rod tube up into cylinder head. Remove fuel injection pump. Unscrew six front cover screws and remove front cover; it may be necessary to rotate engine crankshaft if governor mechanism snags.

When reinstalling front cover, camshaft and crankshaft gears must be correctly timed using the following procedure: Rotate crankshaft so top dead center mark on flywheel is aligned with reference mark on crankcase as shown in Fig. F1-10. Rotate camshaft gear so gear mark is aligned with mark in tappet housing bore of front cover as shown in Fig. F1-11. Install gasket and front cover on crankcase being careful not to disturb camshaft gear (three long screws are located in top two holes and bottom left hole). After tightening front cover screws, recheck timing marks (M – Fig. F1-10 and T – Fig. F1-11). Gear timing is correct if marks (M – Fig. F1-10) are within 6.35 mm of alignment when marks (T – Fig. F1-11) are aligned.

NOTE: Do not attempt to force front cover into place. Interference of governor mechanism may prevent front cover from mating with crankcase. Use procedure in following paragraph to install front cover.

If front cover cannot be installed using preceding procedure, use the following procedure: Rotate engine crankshaft so flywheel top dead center mark (M – Fig. F1-12) is aligned with threaded hole (H) in crankcase. Position camshaft gear so gear mark is three teeth to left of timing mark in tappet housing bore in cover as shown in Fig. F1-13. Install gasket and front cover on crankcase being careful not to disturb camshaft gear (three long screws are located in top two holes and bottom left hole). After tightening front cover screws, recheck timing marks. Gear timing is correct if marks (M – Fig. F1-10) are within 6.35 mm of alignment when marks (T – Fig. F1-11) are aligned.

Complete remainder of assembly by reversing disassembly procedure.

OIL PUMP

R&R AND OVERHAUL. Remove the front cover as previously outlined for access to the oil pump. Remove oil pump components (69 through 73 – Fig. F1-7). Be careful when handling oil

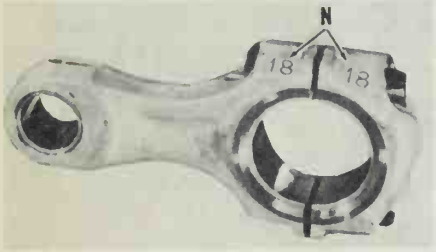


Fig. F1-8 – View of connecting rod and cap showing location of stamped numbers (N) which must be on same side after assembly.

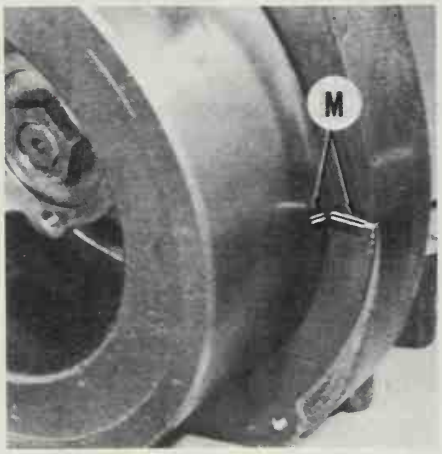


Fig. F1-10 – Piston is at top dead center when marks (M) on flywheel and crankcase are aligned.

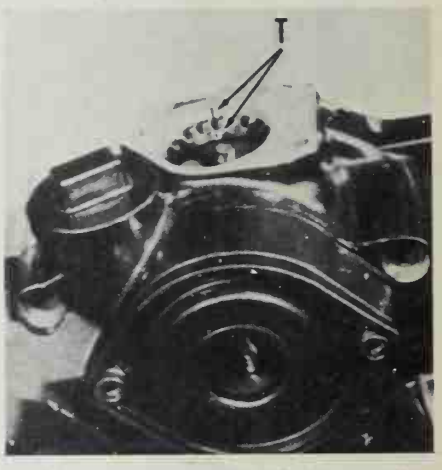


Fig. F1-11 – View of timing marks (T) on camshaft gear and tappet housing opening in front cover.

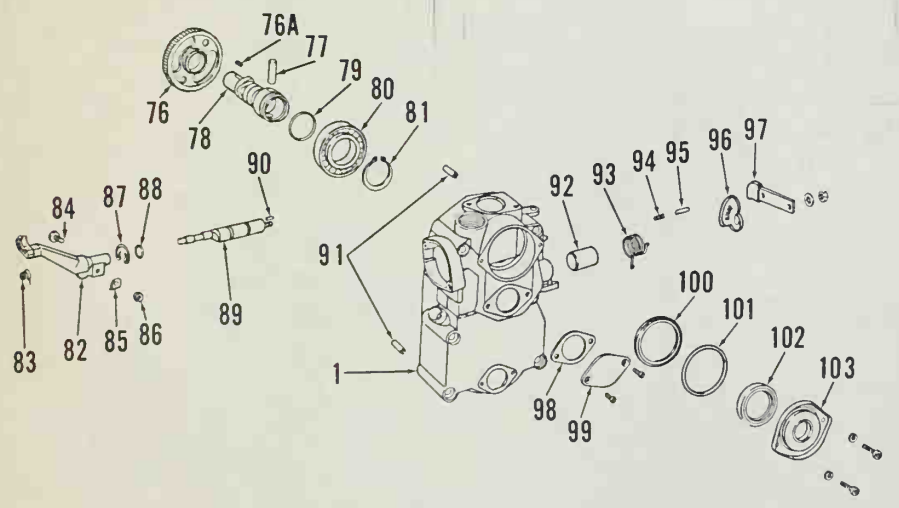


Fig. F1-9 – Exploded view of front cover assembly.

1. Front cover
76. Gear
76A. Key
77. Starter pin
78. Camshaft
79. "O" ring
80. Bearing
81. Snap ring
82. Governor arm
83. Spring
84. Flat-head screw
85. Lockwasher
86. Locknut
87. Retaining ring
88. "O" ring
89. Shaft
90. Pin
91. Dowel pins
92. Bushing
93. Spring
94. Spring
95. Detent pin
96. Detent plate
97. Speed control lever
98. Gasket
99. Cover
100. "O" ring retainer
101. "O" ring
102. Seal
103. Starter guide

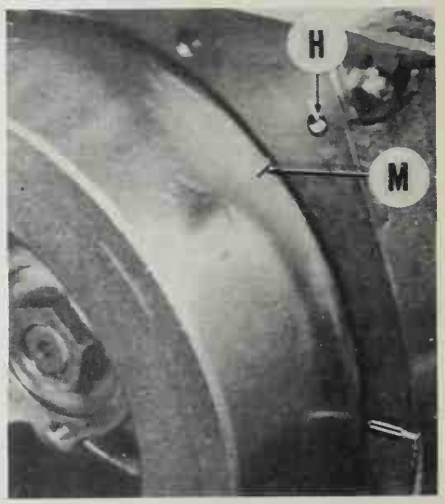


Fig. F1-12 – Align flywheel mark (M) with threaded hole (H) when using alternate front cover installation method outlined in text.

pressure relief valve plate (71) and spring (72) as oil pressure may be affected. Oil pump (70) is available only as a unit assembly. Install oil pump by reversing removal procedure. Do not overtighten oil pump screws.

Oil pressure may be measured by removing plug in injection pump side of crankcase and connecting a suitable gage to plug hole. Oil pressure with engine at normal operating temperature should be at least 80 kPa at low idle speed and no more than 400 kPa at maximum engine speed. Oil pressure is not adjustable.

GOVERNOR

R&R AND OVERHAUL. Remove front cover as previously outlined for access to governor. Governor shaft assembly may be disassembled after detaching retaining ring (87 – Fig. F1-9). Remove pin (75 – Fig. F1-7) and unscrew governor flyweight assembly (74) from crankshaft; **note that stud has left-hand threads.**

Governor flyweight assembly (74) is available as a unit assembly. Flyweight springs are available, however, be sure correct governor flyweight assembly or springs are installed so engine will operate at rpm stamped on engine identification plate.

Reassemble governor as follows: Install flyweight assembly (74) on crankshaft and tighten to 34 N·m; **note that stud has left-hand threads.** Install flathead screw (84 – Fig. F1-9), lockwasher (85) and nut (86) so flat head is opposite governor arm. Place governor arm (82) in front cover. Install pin (90) spring (93), plate (96), lever (97) and "O" ring (88) on shaft (89). Insert shaft assembly into front cover and governor arm (82). Turn lever (97) so it points toward bottom of front cover (away from camshaft), then install spring (83) so small spring end engages slot in shaft end and long spring end is on same side as nut (86). Install retaining ring (87), then engage long end of spring (93) with boss on side of front cover. Engage short end of spring (93) in middle notch of plate (96) then install retaining ring (87) in shaft groove. Engage long end of spring (93) with pin on side of front cover. Note that spring (93) should return lever (97) from stop position to idle position and it may be necessary to relocate short spring end in another notch to increase spring tension. Install front cover as previously outlined.

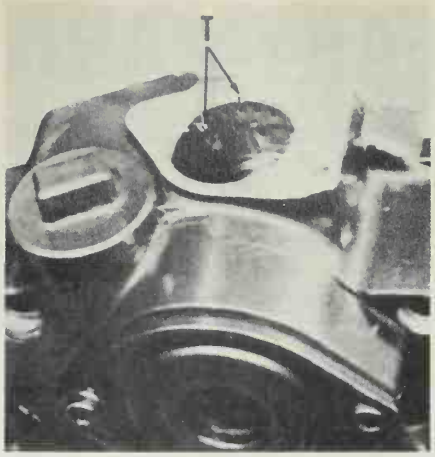


Fig. F1-13 – Position camshaft gear so timing marks (T) on gear and tappet housing opening are three teeth apart as shown. Refer to text.

With front cover installed, adjust position of flat-head screw (84) as follows: Remove cover (99) then rotate crankshaft so governor flyweights are positioned with mating surfaces vertical. Loosen locknut (86). Using a small screwdriver, spread flyweights apart as far as they will go. Turn screw (84) so it just contacts pin (75 – Fig. F1-7), release flyweights, then turn screw (84 – Fig. F1-9) in an additional ½-turn. Without disturbing screw, tighten locknut.

CAMSHAFT AND TAPPETS

R&R AND OVERHAUL. To remove camshaft, remove front cover as outlined in FRONT COVER section. Remove tappet and compression release housing (31 – Fig. F1-4), and components (100 through 103 – Fig. F1-9). Remove snap ring (81) and press camshaft (78) out of bearing (80). Then, press bearing (80) out of front cover (1).

Inspect cam lobes and bearing journals and renew camshaft if excessively worn or damaged. Inspect tappets and tappet housing bores. The manual starter handle is supported by guide (103) and starter end engages pin (77) in camshaft end. Inspect guide (103), pin (77) and camshaft end for damage.

Reverse removal procedure for installation. It is necessary to twist rather than drive guide (103) into position in front cover. Install front cover as outlined in FRONT COVER section to properly time camshaft and crankshaft gears.

CRANKSHAFT AND CRANKCASE

R&R AND OVERHAUL. To remove crankshaft, drain oil and remove flywheel, front cover and connecting rod. Remove governor flyweight assembly (74 – Fig. F1-7) from crankshaft. Remove Belleville washers (45), washers (47 and 52) and "O" ring (48). Unscrew main bearing support nuts and remove main bearing support (50). If main bearing support will not remove easily, jack screws may be threaded into holes provided in support to push support free from crankcase. Remove crankshaft.

The governor end of crankshaft is supported by bushing (57). Standard crankshaft journal diameter at governor end should be 40.020-40.030 mm. Clearance between crankshaft journal and bushing should be 0.04-0.06 mm. Bushing (57) is available in standard size and undersizes of 0.25 and 0.50 mm.

Reverse removal procedure to install crankshaft while noting the following: Tighten main bearing support nuts to 30 N·m. Install "O" ring retainer (47) with beveled face towards "O" ring. Install Belleville washers (45) with concave faces towards each other.

FARYMANN

Model	No. Cyl.	Bore	Stroke	Displ.
25A430	1	80 mm	82 mm	412 cc
36A430	1	95 mm	82 mm	581 cc
36E435	1	95 mm	82 mm	581 cc
71A437	2	95 mm	82 mm	1162 cc
95A437	2	105 mm	90 mm	1558 cc

Engines covered in this section are four-stroke, air-cooled diesel engines. Crankshaft rotation is counterclockwise at flywheel end of engine. Number 1 cylinder on two-cylinder models is nearer flywheel.

Metric fasteners are used throughout engine.

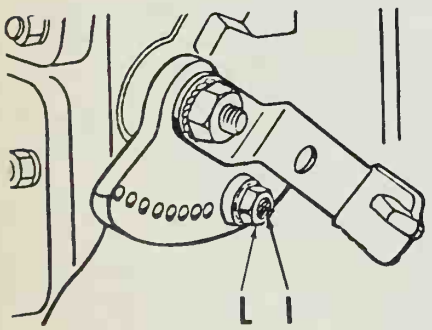
MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0° C(32° F), SAE 20W20 for temperatures between 0° C(32° F) and 30° C(86° F), and SAE 30 for temperatures above 30° C(86° F). API classification for oil should be CD. Fill oil sump to full level on dipstick. Manufacturer recommends renewing oil after first 20 hours of operation and after every 100 hours thereafter.

ENGINE SPEED ADJUSTMENT

Low idle speed may be adjusted by loosening locknut (L–Fig. F2-1) and turning screw (I) so detent can be relocated in plate. Maximum governed speed is determined by governor and engine application.



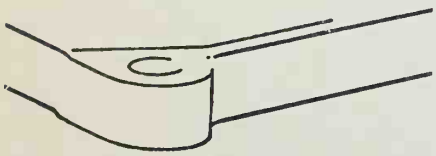


Fig. F2-1—Adjust low idle speed by loosening locknut (L), then turn screw (I) so detent can be relocated in plate.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter is located in the fuel tank. Renew filter after every 500 hours of operation or sooner if required.

BLEED FUEL SYSTEM. To bleed fuel system, loosen fuel line fitting at fuel injection pump or bleed screw on pump, if so equipped. On gravity flow systems, open fuel valve until air-free fuel flows at pump then tighten fuel line fitting or bleed screw. On engines equipped with a fuel transfer pump, open fuel valve and operate pump primer lever until air-free fuel flows at pump then tighten fuel line fitting or bleed screw. On all engines, loosen high pressure injection line at injector, then rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection line. Retighten injection line.

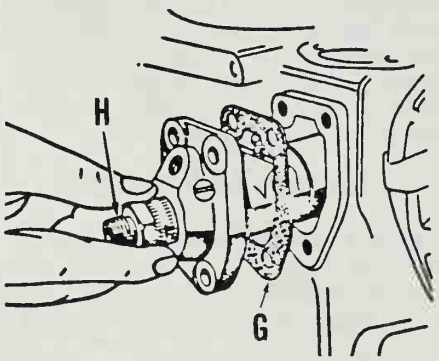


Fig. F2-2—View showing fuel injection pump timing shim gaskets (G) and delivery valve holder (H).

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G–Fig. F2-2) between pump body and mounting surface on crankcase. To check injection timing proceed as follows: Disconnect high pressure line for number 1 cylinder from injection pump, then unscrew delivery valve holder (H) and remove spring and delivery valve; do not remove valve seat. Reinstall delivery valve holder (H) and connect a suitable spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full open position. Rotate engine flywheel slowly in counterclockwise direction until fuel just stops flowing from spill pipe. Measure distance from reference mark on flywheel housing to top dead center mark on flywheel. Refer to Fig. F2-3 for desired measured distance for correct injection timing. Measured distance should be within plus or minus 2 mm of distance listed in Fig. F2-3.

If injection timing is incorrect, remove injection pump and remove or install shims (G–Fig. F2-2) as required. Adding shims will retard injection timing while removing shims advances injection timing. Be sure to reinstall delivery valve and spring into pump.

Fig. F2-3—Table listing flywheel TDC position for proper ignition timing. Refer to text.

MODEL	MAX. GOVERNED RPM					
	1500	1800	2000	2500	2800	3000
25A430	15	20	25	30	35	40
36A430	10	15	22	30	33	37
36E435	10	14	20	25	27	30
71A437	21	21	23	27	****	****
95A437	25	29	31	38	****	****

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques. All values are in newton meters.

Connecting rod,	
95A437	80
All other models	65
Cylinder head,	
25A430	45
36A430, 36E435	54
71A437	58
95A437	65
Injection pump	19
Injector retainer plate	30
Main bearing support	30
Rocker arm bracket	80
Rocker arm cover	10

VALVE TAPPET GAP

Valve tappet gap may be adjusted after removing rocker arm cover. Compression release lever must be in "off" position. Valve tappet gap should be 0.1 mm for both valves with engine cold.

COMPRESSION RELEASE

On single-cylinder models, the intake valve is held open by rotating compression release lever (L – Fig. F2-4) located in valve tappet housing (H). The compression release lever forces spindle (S) against nuts (N) on intake push rod thereby opening the intake valve. The intake valve should open 1.0 mm when actuated by compression release lever. Remove rocker arm shaft, extract intake push rod and turn push rod nuts (N) to adjust intake valve opening.

When the compression release lever (L – Fig. F2-5 and F2-6) on twin-cylinder models is turned, tangs (T – Fig. F2-5) on spindle force cam followers (F) to open exhaust valves on Model 71A437 or intake valves on Model 95A437. To adjust compression release, loosen nuts (N – Fig. F2-5 and F2-6), then move lever (L) until resistance is felt indicating spindle tangs are contacting cam followers. Retighten nuts (N). Turn adjusting screw (S – Fig. F2-6) so exhaust valves on Model 71A437 or intake valves on Model 95A437 are opened 1.0 mm when compression release lever is operated.

CYLINDER HEAD AND VALVE SYSTEM

Cylinder heads and valve components are identical on twin-cylinder engines, however, do not interchange components when servicing engines.

Valve face and valve seat angles are 45 degrees for intake and exhaust valves. Minimum allowable depth of valve in head measured from top of valve to cylinder head surface on Model 25A430 is 1.1-1.2 mm for intake valve and 0.4-0.5 mm for exhaust valve. Minimum allowable valve depth on Models 36A430 and 36E435 is 1.1 mm for intake valve and 1.4 mm for exhaust valve. Minimum allowable valve depth on Models 71A437 and 95A437 is 1.0-1.1 mm for all valves. Valve seats are renewable and must be installed with head heated to 80°-90° C(176°-194° F).

Install a new "O" ring around push rod tube before installing cylinder head. Tighten cylinder head retaining nuts in a crossing pattern starting on injector side of head. Tighten nuts to torque listed in TIGHTENING TORQUES section. Push rod nearer cylinder is connected to exhaust valve rocker arm on single-cylinder models or to intake valve rocker arm on twin-cylinder models.

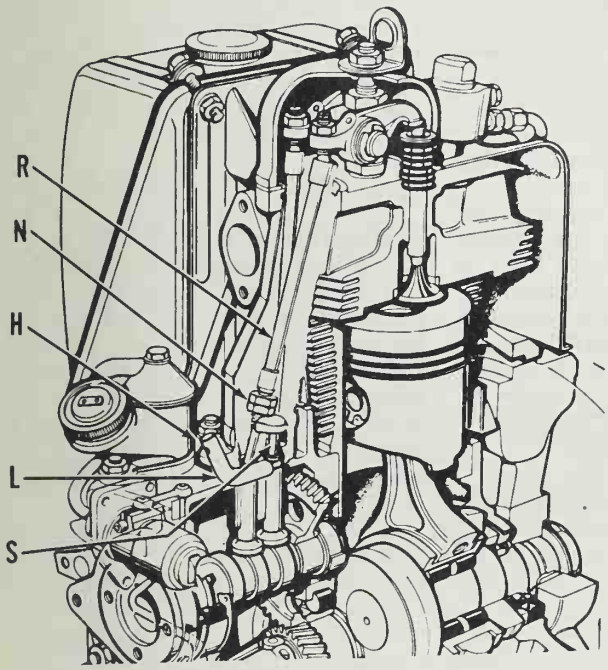


Fig. F2-4 – View of compression release on single-cylinder models.

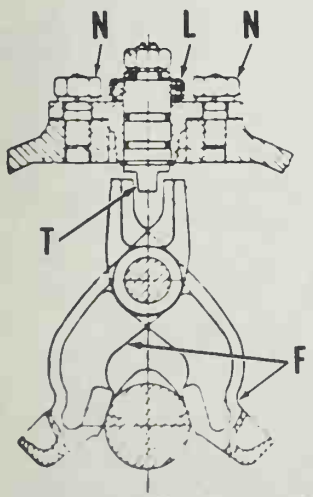


Fig. F2-5 – Cross-sectional view of compression release on twin-cylinder models.

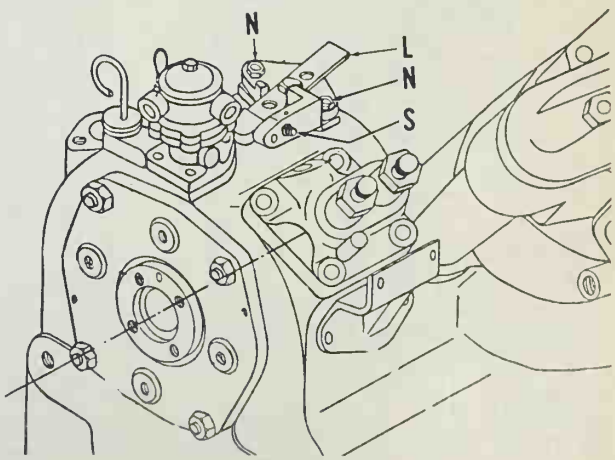


Fig. F2-6 – View showing location of compression release on twin-cylinder models.

FUEL TRANSFER PUMP

REMOVE AND REINSTALL. Clean area around fuel pump then disconnect fuel lines. Immediately cap or plug all openings to prevent contamination. Remove fuel pump being careful not to lose or damage shims between pump and crankcase. Refer to Fig. F2-7 for a cross-sectional view of pump.

Before installing fuel pump, measure plunger height (H – Fig. F2-7) and distance from pump mounting surface on crankcase to pump lobe base circle on camshaft. Install shims between pump and crankcase so plunger height is 1 mm greater than distance from crankcase surface to cam. For instance, if plunger height is 62.5 mm and distance from crankcase to cam is 61.0 mm, then a 0.5 mm shim would be installed. Do not overtighten mounting screws when installing pump. Bleed fuel system as previously outlined after connecting fuel lines.

INJECTOR

R&R AND OVERHAUL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and injection line and immediately cap or plug all openings. Remove injector.

If a suitable test stand is available, injector may be checked.

WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Only clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat. Opening pressure should be 19.6 MPa.

Thoroughly clean all injector components in a suitable solvent. Clean inside orifice end of nozzle tip with a wooden cleaning stick. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil.

INJECTION PUMP

R&R AND OVERHAUL. To remove injection pump, clean area around injection pump, disconnect all fuel lines from pump and immediately cap or plug all openings to prevent contamination. Remove crankcase breather, then reach through crankcase opening and disconnect governor link from pump. Unscrew pump retaining screws and remove pump being careful not to lose or damage shim gaskets (G – Fig. F2-2).

The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

When installing pump, engage governor link with pump control rack. Tighten injection pump screws to 19 N·m. If pump is renewed or overhauled, or original shim gaskets are not used, refer to INJECTION PUMP TIMING section and adjust pump timing.

CYLINDER, PISTON, PIN AND RINGS

R&R AND OVERHAUL. The cylinder is removable after removing cylinder head. After cylinder is removed, cover crankcase opening to prevent entry of foreign material. Detach snap rings retaining piston pin, remove piston pin, then separate piston from connecting rod. Do not interchange components between cylinders on twin-cylinder models.

Nominal standard cylinder bore diameter is 80.02-80.04 mm on Model 25A430, 105.00-105.02 mm on Model 95A437, and 95.04-95.06 mm on all other models. Piston ring end gap should be 0.3-1.0 mm on Model 25A430, 0.5-1.5 mm on Model 95A437, and 0.4-1.0 mm on all other models.

Position piston on rod so combustion chamber in piston crown is located as shown in Fig. F2-8 and install piston pin. Compress piston rings and slide cylinder down over piston and studs. With cylinder installed and held against crankcase, position piston at top dead center and measure distance from piston crown to top edge of cylinder. Piston crown height should be 0.7-1.0 mm on Model 25A430, 0.8-1.05 mm on Models 36A430 and 36E435, 0.775-1.05 mm on Model 71A437 and 0.775-1.075 mm on Model 95A437.

CONNECTING ROD

REMOVE AND REINSTALL. The connecting rod and crankshaft on Model 25A430 are a unit assembly; refer to crankshaft section for removal. To remove connecting rod on all other models, remove cylinder(s), then remove crankcase side cover. Reach through cover opening, unscrew rod cap retaining screws, remove rod cap through side cover opening and remove rod and piston.

Models 36A430 and 36E435 are equipped with a roller type rod bearing while Models 71A437 and 95A437 are

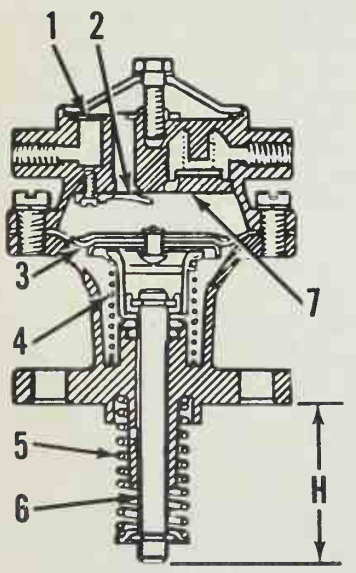


Fig. F2-7 – Cross-sectional view of fuel transfer pump. Measure plunger height (H) as outlined in text.

1. Screen
2. Inlet valve
3. Diaphragm
4. Spring
5. Spring
6. Plunger
7. Exhaust valve

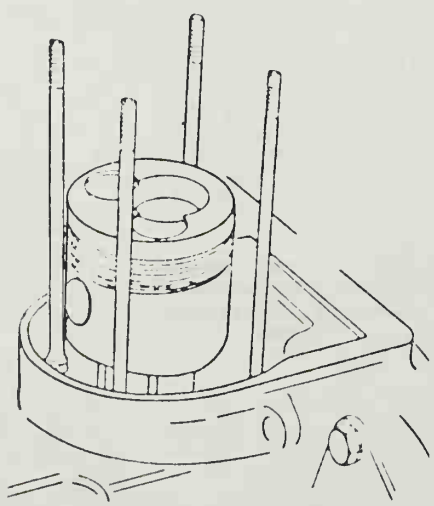


Fig. F2-8 – Install piston so indentations in crown are positioned as shown.

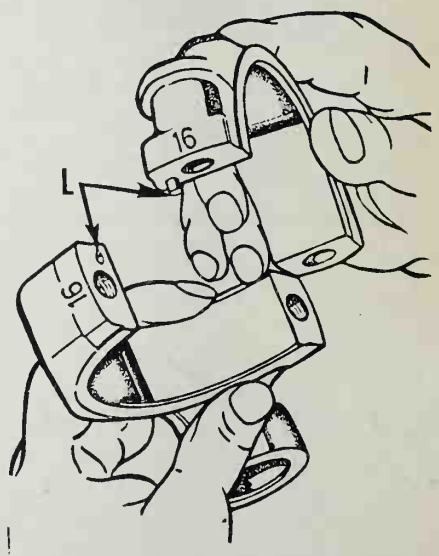


Fig. F2-9 – Assemble cap on rod so locating pin and hole (L) are properly mated.

equipped with an insert type bearing. Undersize rod bearings are available for Models 71A437 and 95A437. Standard crankpin journal diameter is 64.985-65.015 mm on Model 71A437 and 74.985-75.015 on Model 95A437 with a bearing clearance of 0.03-0.05 mm for both models.

Reverse removal procedure to install connecting rod. Be sure locating pin and hole (L–Fig. F2-9) are properly mated when installing rod cap on rod. Tighten rod screws to 80 N·m on Model 95A437 or to 65 N·m on all other models.

CAMSHAFT AND TAPPETS

Single-Cylinder Models

REMOVE AND REINSTALL. To remove camshaft, remove cylinder head and push rod tube. Unscrew retaining nuts and remove tappet housing from crankcase. Remove fuel injection pump. Unscrew camshaft bearing housing screws and remove camshaft assembly. If bearing housing will not remove easily, jack screws may be threaded into holes provided in housing to push housing free.

Inspect cam lobes and renew camshaft if excessively worn or damaged. Remove snap rings to separate bearing from camshaft bearing housing. The gear end of the camshaft rides in a bushing in the crankcase and is accessible after removing crankshaft. Inspect tappets and tappet housing bores.

Reassembly is reverse of disassembly. When installing camshaft assembly in crankcase, rotate crankshaft so piston is at top dead center, then insert camshaft so mark on camshaft gear is aligned with mark (M–Fig. F2-10) in tappet housing opening of crankcase. On Model 25A430, the camshaft mark will be slightly to left of crankcase mark (M).

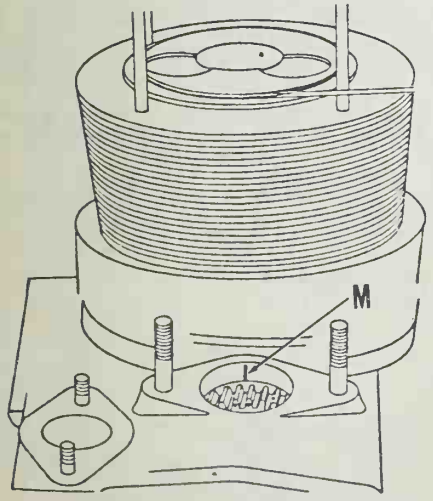


Fig. F2-10–Camshaft gear mark on single-cylinder models must align with mark (M) in tappet housing opening in crankcase when piston is at top dead center.

Twin-Cylinder Models

REMOVE AND REINSTALL. To remove the camshaft on twin-cylinder models, remove cylinder heads, push rod tubes and compression release assembly. Install tool number 7480634 (T–Fig. F2-11) in compression release opening and attach tool to cam followers so followers are held away from cam lobes. Remove fuel injection pump, fuel transfer pump and oil dipstick. Rotate camshaft so "O" mark (O) on camshaft end is towards top of engine. Unscrew camshaft bearing housing screws and remove camshaft assembly. If bearing housing will not remove easily, jack screws may be threaded into holes provided in housing to push housing free.

Inspect cam lobes and renew camshaft if excessively worn or damaged. Inspect tappets and tappet housing bores.

Reassembly is reverse of disassembly. When installing camshaft assembly in crankcase, place tool number 7480676 (N–Fig. F2-11) in rear injection pump mounting holes as shown in Fig. F2-11. Rotate crankshaft so number 1 piston is at top dead center on exhaust stroke. Insert camshaft assembly and mate camshaft and crankshaft gears so mark on camshaft gear is aligned with pointer on tool (N). Remove special tools and complete assembly.

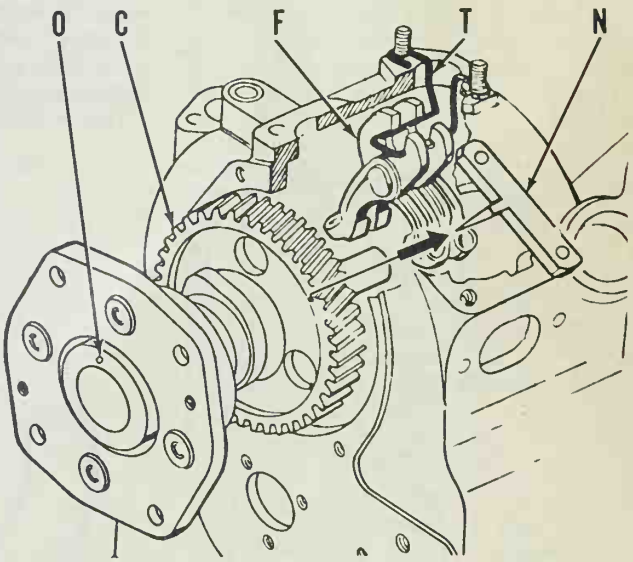


Fig. F2-11–Install tools 7480634 (T) and 7480676 (N) as outlined in text for twin-cylinder camshaft service.

C. Camshaft gear
F. Cam followers
N. Tool 7480676
O. Camshaft "O" mark
T. Tool 7480634

GOVERNOR

Single-Cylinder Models

REMOVE AND REINSTALL. To remove governor, remove breather on top of crankcase then reach through opening and disconnect governor link (4–Fig. F2-12) from injection pump. Detach speed control lever (21), spring retainer (18) and spring (17) from shaft (10). Remove crankcase end cover adjacent to camshaft end. Unscrew and remove stud (11) from shaft. Detach "E"

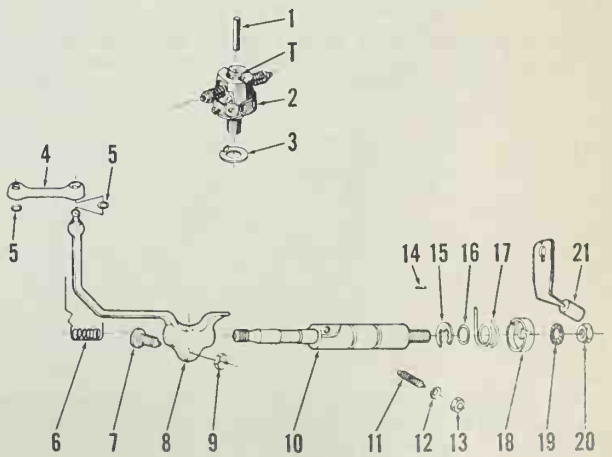


Fig. F2-12–Exploded view of single-cylinder model governor mechanism. Twin-cylinder models are similar.

1. Pin
2. Flyweight assy.
3. Tab washer
4. Link
5. Clips
6. Governor spring
7. Screw
8. Governor arm
9. Nut
10. Shaft
11. Stud
12. Lockwasher
13. Nut
14. Pin
15. "E" ring
16. "O" ring
17. Spring
18. Spring retainer
19. Lockwasher
20. Nut
21. Lever

ring (15) and withdraw governor shaft (10) from side of crankcase while removing governor fork (8) assembly through end of crankcase. Remove pin (1), turn governor flyweight stud (T) clockwise (left-hand threads) and remove governor flyweight assembly.

Flyweight assembly is designed according to engine governed speed and is available as a unit assembly. Be sure correct flyweight assembly is installed.

Reverse disassembly procedure to install governor components. Long end of governor spring (6) must engage notch in crankcase while short end of spring is against back side of governor arm (8) so spring tension will force fork arm towards end of crankcase. With all governor components installed, adjust position of screw (7) as follows: Rotate crankshaft so flyweights (2) are positioned with mating surfaces vertical. Loosen locknut (9). Using a small screwdriver, spread flyweights apart as far as they will go. Turn screw (7) so it just contacts pin (1), release flyweights, then turn screw in an additional ½-turn. Without disturbing screw, tighten locknut.

Twin-Cylinder Models

REMOVE AND REINSTALL. Governor service is similar to single-cylinder governor outlined in preceding section. However, governor is mounted on oil pump and governor/oil pump assembly is removed as a unit through crankcase end cover opening. Separate governor from oil pump after removal. Carefully align oil pump mounting screw holes when installing governor/oil pump assembly. Reverse disassembly procedure to install governor. Refer to single-cylinder governor section and adjust position of screw (7–Fig. F2-12) as outlined.

CRANKSHAFT AND CRANKCASE

R&R AND OVERHAUL. To remove crankshaft, remove camshaft, flywheel, governor and connecting rod (On Model 25A430 the connecting rod must remain with crankshaft). Unscrew main bearing support nuts and remove main bearing support (P–Fig. 2-13). If main bearing support will not remove easily, jack screws (J) may be threaded into holes provided in support to push support free from crankcase. Remove crankshaft.

The governor end of crankshaft on Models 71A437 and 95A437 is supported by a bushing. Standard crankshaft journal diameter at governor end should be 64.985-65.015 mm on Model 71A437 or 79.985-80.015 mm on Model 95A437. Clearance between crankshaft journal and bushing should be 0.04-0.08 mm. Bushing is available in standard size and in 0.5 and 1.0 mm undersizes.

Flywheel end main bearing on Models 71A437 and 95A437, and main bearings on all other models are anti-friction type bearings. Inspect bearings and crankshaft on all models and renew if damaged or excessively worn. Inner bearing races should be heated to approximately 100° C(212° F) before installation on crankshaft. The crankshaft gear is removable and should be heated to approximately 180° C(360° F) before installation on crankshaft. Install crankshaft gear so when gear is viewed from crankshaft end, keyway (K–Fig. F2-14) is centered on two gear teeth (T).

Connecting rod, rod bearing and crankshaft are a unit assembly on Model 25A430 and individual components may not be serviced separately.

Reverse removal procedure for installation. Tighten main bearing support retaining nuts to 30 N·m. Note assembly of thrust ring components at flywheel end as shown in Fig. F2-15. Outer circumference of thrust ring should be smooth as it contacts crankcase oil seal. Install Belleville washers (1) so concave sides face each other. Belleville washer (1A) is only used on Model 95A437 and must be installed with concave face towards thrust ring (2).

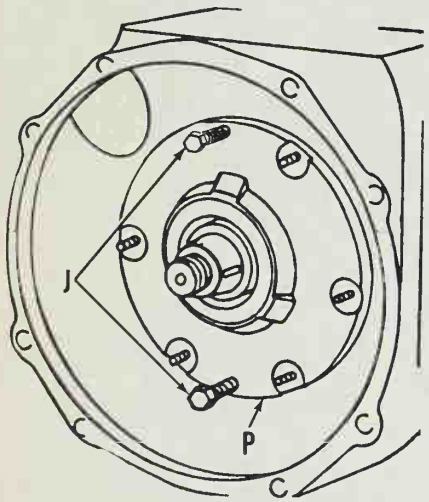


Fig. F2-13–Main bearing support (P) may be dislodged using jackscrews (J) in holes provided.

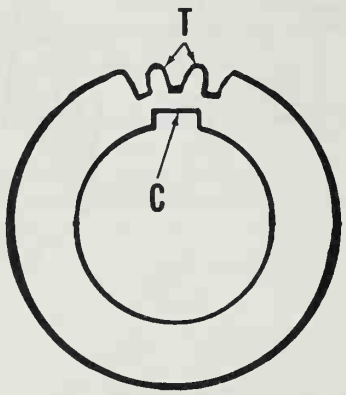


Fig. F2-14–When viewed from end of crankshaft, crankshaft gear keyway (C) should be centered between two gear teeth (T).

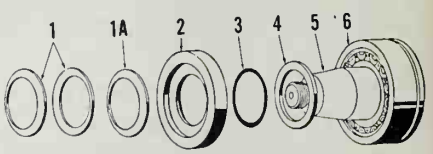


Fig. F2-15–Exploded view of thrust ring components. Belleville washer (1A) is only used on Model 95A437.

1. Belleville washers
1A. Belleville washer
2. Thrust ring
3. "O" ring
4. Thrust washer
5. Crankshaft
6. Bearing

KIRLOSKAR

1401 Cherry Hill Road
Baltimore, Maryland 21225

Model	No. Cyls.	Bore (mm)	Stroke (mm)	Displ. (cc)
KA-27	1	68	76	276

Model KA-27 is an air-cooled, single-cylinder diesel engine. Crankshaft rotation may be clockwise or counterclockwise depending on application.

MAINTENANCE

LUBRICATION

Recommended crankcase oil is SAE 10W for temperatures below 5° C(41° F), SAE 30 for temperatures between 5° C(41° F) and 35° C(95° F) or SAE 40 for temperatures above 35° C(95° F). Crankcase oil should pass specifications for MIL-L-2104A. Crankcase oil capacity is 1.8 liters.

Oil is pressure fed to engine components by a gear type pump. Oil pressure should be 245-294 kPa with engine warm and running at operating speed. An oil pressure gage may be connected after removing plug inside of oil filter housing. To adjust oil pressure, remove oil filter housing and turn adjusting screw in back of filter housing.

The renewable oil filter element should be renewed after every 500 hours of operation.

ENGINE SPEED ADJUSTMENT

To adjust idle speed, remove cover (C–Fig. KR1-1), loosen locknut, then turn idle speed screw (I). Idle speed should be 1200-1250 rpm. Do not turn out screw (I) too far as it must remain in contact with lug on governor arm so engine can be stopped. Maximum speed on variable speed models is adjusted by turning high speed adjusting screw (H–Fig. KR1-2). Maximum governed speed under load should be 1500, 2000, 2500 or 3000 rpm depending on engine model.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter is located below fuel tank on side of engine. Manufacturer recommends renewing fuel filter element after every 500 hours of operation.

BLEED FUEL SYSTEM. Due to gravity feed type of fuel system, air should be bled from system as fuel injection pump operates. However, bleeding time may be shortened by loosening then retightening fuel line fittings, starting first at fuel tank and working to fuel injection pump. Retighten fittings when air-free fuel flows.

INJECTION PUMP TIMING. Injection pump timing is adjusted using shims (G–Fig. KR1-3). To check injection pump timing proceed as follows: Disconnect high pressure line from injection pump then unscrew delivery valve holder (H) and remove spring and delivery valve assembly. Reinstall delivery valve holder (H) and connect a suitable spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full open position. Rotate engine flywheel slowly in running direction (engines are designed for clockwise or counter-clockwise rotation) until fuel just stops flowing from spill pipe. Note rated rpm of engine and refer to following table for desired injection timing:

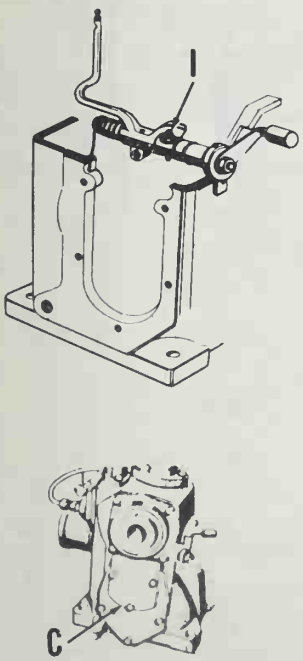


Fig. KR1-1—Remove cover (C) for access to idle speed screw (I) on governor. Refer to text.

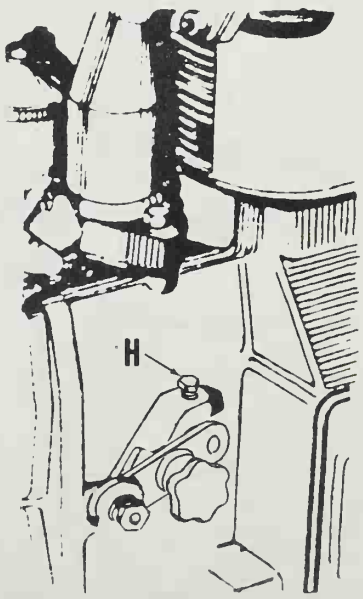


Fig. KR1-2—High speed on variable speed engines is adjusted by turning adjusting screw (H).

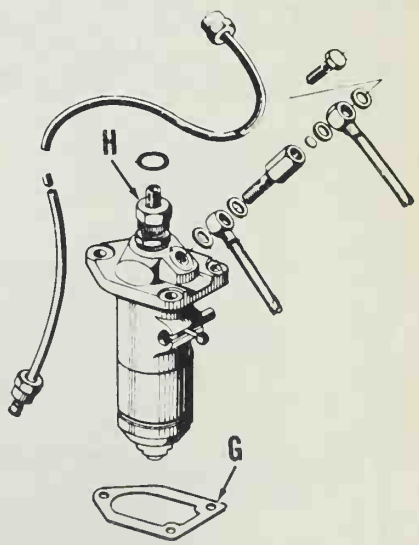


Fig. KR1-3—Injection timing is adjusted by varying thickness of shim gasket (G). Refer to text for timing procedure.

Rated RPM	Injection Timing
1500	22° BTDC
2000	27° BTDC
2500	28° BTDC
3000	31° BTDC

If injection timing is incorrect, remove injection pump and remove or install shims (G) as required. Adding shims will retard injection timing while removing shims advances injection timing. Be sure to reassemble delivery valve in pump after testing.

AIR FILTERS

Manufacturer recommends cleaning air filter after every 50 hours of operation and renewing filter after 500 hours.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques. All values are in newton meters.

Connecting rod	39.2
Cylinder head	29.4
Flywheel	176.4
Injection pump	24.5
Injector retainer plate	24.5
Main bearing support	24.5
Rocker arm stand	78.4

VALVE TAPPET GAP

Valve tappet gap may be adjusted after removing rocker arm cover. Valve tappet gap with engine cold should be 0.10 mm for intake and 0.15 mm for exhaust.

CYLINDER HEAD AND VALVE SYSTEM

Valve face and valve seat angles are 45 degrees. Valve seat width is 2.05-2.33 mm. Valve seats are renewable. Intake valve stem diameter is 8.956-8.968 mm and exhaust valve stem diameter is 8.918-8.930 mm. Intake and exhaust valve guide inside diameter is 9.013-9.035 mm. Intake valve stem clearance is 0.045-0.079 mm and exhaust valve stem clearance is 0.083-0.117 mm. Maximum valve stem clearance for both valves is 0.15 mm. Valve guides are renewable. Valve guide outer diameter is 12.050-12.062 mm and cylinder head bore is 12.000-12.027 mm.

Clearance between rocker shaft and rocker arm bushing should be 0.065-0.101 mm. Maximum allowable clearance is 0.15 mm.

Tighten cylinder head nuts in a crossing pattern to 29.4 N·m. Measure clearance between piston at top dead center and cylinder head by inserting a lead wire (solder) or other suitable tool through injector opening in head. Clearance between head and piston should be 0.7-0.8 mm. Head gaskets are available in varying thicknesses to adjust clearance. Note that push rod nearer cylinder operates exhaust valve while outer push rod operates intake valve. Tighten rocker arm stand nut to 78.4 N·m.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and injection line and immediately cap or plug all openings. Remove injector retainer plate and carefully withdraw injector from head.

Use a new copper washer (3–Fig. KR1-4) when installing injector. Tighten nuts securing injector retainer plate to 24.5 N·m.

TESTING. WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector operation may be checked. Only clean, approved test oil should be used to test injector. When operating properly during test, injector nozzle will emit a

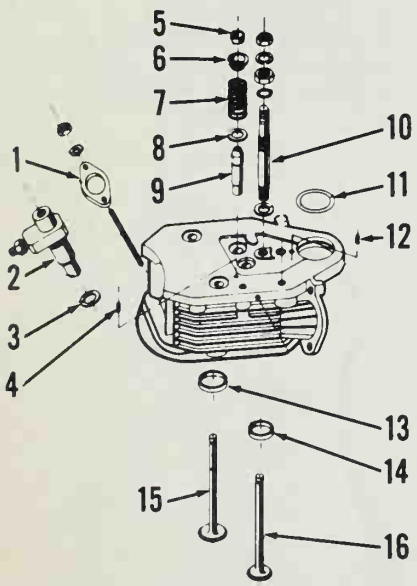


Fig. KR1-4—Exploded view of cylinder head. Rocker arm assembly is not shown.

1. Injector retainer
2. Injector
3. Copper washer
4. Dowel
5. Keys
6. Spring retainer
7. Valve spring
8. Washer
9. Valve guide
10. Rocker stand stud
11. Push rod tube seal
12. Dowel
13. Intake valve seat
14. Exhaust valve seat
15. Intake valve
16. Exhaust valve

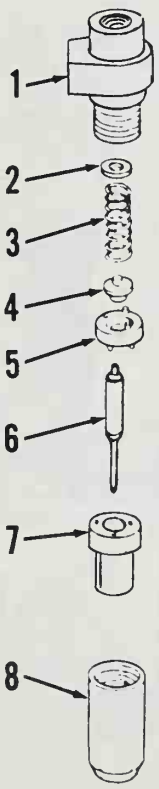


Fig. KR1-5—Exploded view of injector.

1. Body
2. Shim
3. Spring
4. Push pin
5. Spacer
6. Valve
7. Nozzle
8. Nozzle holder

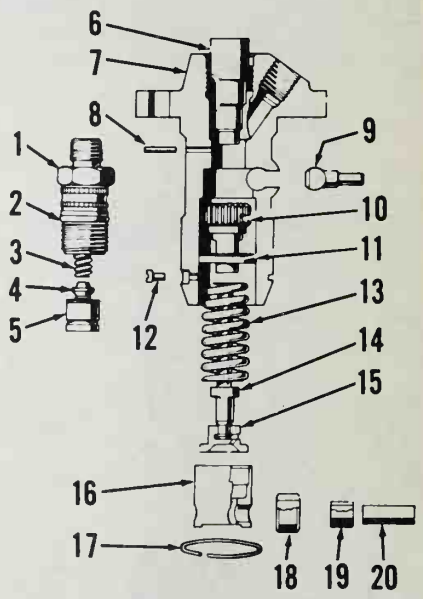


Fig. KR1-6—View of injection pump.

1. Delivery valve holder
2. "O" ring
3. Spring
4. Delivery valve
5. Delivery valve seat
6. Barrel
7. Pump body
8. Pin
9. Control rack
10. Pinion
11. Spring seat
12. Pin
13. Spring
14. Plunger
15. Spring retainer
16. Tappet
17. Circlip
18. Outer roller
19. Inner roller
20. Pin

buzzing sound and cut off quickly with no fluid leakage at seat.

Opening pressure with a new spring (3–Fig. KR1-5) should be 14.2-14.7 MPa while opening pressure with a used spring should be approximately 13.2 MPa. Opening pressure is adjusted by varying number and thickness of shims (2). Valve should not show leakage at orifice spray holes for 10 seconds at 12.2 MPa.

OVERHAUL. Clamp injector body (1–Fig. KR1-5) in a vise with nozzle tip pointing upward. Remove nozzle holder nut (8). Remove nozzle (7) with valve (6) and spacer (5). Invert injector body (1) and remove push pin (4), spring (3) and shims (2). Thoroughly clean all parts in a suitable solvent. Clean inside orifice end of nozzle with a wooden cleaning stick. Orifice spray holes may be cleaned by inserting a cleaning wire slightly smaller than spray holes.

When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle nut (8) to 58.8 N·m.

INJECTION PUMP

REMOVE AND REINSTALL. Remove breather adjacent to pump, then reach through breather opening in crankcase and disconnect governor link (4–Fig. KR1-13) from pump. Disconnect fuel lines from pump and immediately cap all openings to prevent contamination. Remove pump being careful not to lose timing shims.

Injection pump should be serviced by a shop experienced in fuel injection pump repair.

Refer to INJECTION PUMP TIMING section after pump installation if original timing shims were not installed or timing is believed incorrect.

CYLINDER, PISTON, PIN AND RINGS

R&R AND OVERHAUL. The cylinder is removable after removing cylinder head as previously outlined. After cylinder is removed, cover crankcase opening to prevent entry of foreign material. Detach snap rings (2–Fig. KR1-7) then use a suitable puller to withdraw piston pin (3). Remove piston from connecting rod.

Piston ring end gap should be 0.25-0.40 mm for compression rings and 0.20-0.35 mm for oil ring. Maximum piston ring end gap is 0.6 mm for compression rings and 0.5 mm for oil ring. Piston ring side clearance should be 0.11-0.14 mm for top compression ring, 0.09-0.12 mm for second compression ring and 0.05-0.08 mm for oil ring. Maximum ring side clearance is 0.25 mm for top compression ring, 0.20 mm for second compression ring and 0.15 mm for oil ring.

Piston pin bore diameter in piston is 23.996-24.009 mm and piston pin outer diameter is 23.996-24.000 mm. Clearance between piston pin and connecting rod should be 0.030-0.054 mm; maximum allowable clearance is 0.15 mm. Refer to CONNECTING ROD section.

Cylinder standard bore diameter is 68.06-68.08 mm. Standard piston diameter is 67.97 mm. Piston clearance should be 0.09-0.11 mm.

Assembly is reverse of disassembly. Refer to CYLINDER HEAD section for cylinder head installation.

CONNECTING ROD

R&R AND OVERHAUL. To remove connecting rod, remove cylinder as outlined in previous section then remove side cover (C–Fig. KR1-8) for access to connecting rod big end. Unscrew rod screws and remove rod cap through side cover opening then remove rod out top of engine.

Connecting rod big end clearance should be 0.031-0.083 mm. Undersize rod bearings are available. The connecting rod small end bushing is renewable. Inner diameter of small end bushing is 24.03-24.05 mm and clearance between piston pin and rod bushing should be 0.03-0.054 mm.

Install piston and rod so numbered side of rod is away from side cover opening. Install rod cap through side cover opening then install and tighten rod cap screws to 39.2 N·m. Attach side cover to crankcase and refer to previous sections for installation of cylinder and cylinder head.

CAMSHAFT, TAPPETS AND PUSH RODS

R&R AND OVERHAUL. To remove push rods and tappets, remove cylinder head and detach push rod tube (6–Fig. KR1-9). Unscrew retaining nuts and remove tappet guide (2) and tappets from crankcase. Remove fuel injection

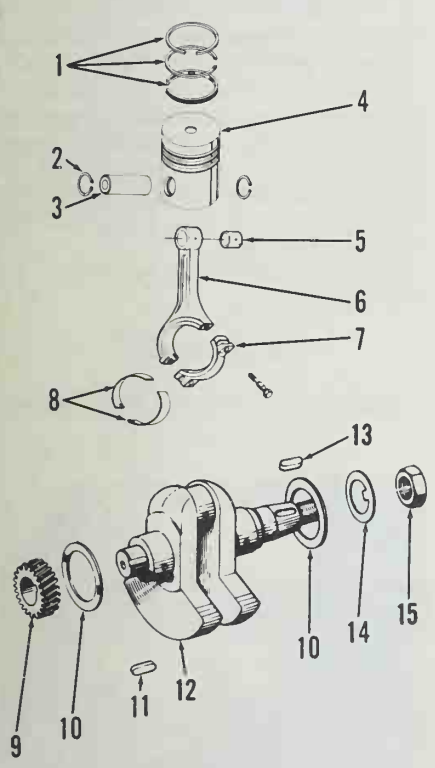


Fig. KR1-7–Exploded view of crankshaft assembly.

1. Piston rings
2. Snap ring
3. Piston pin
4. Piston
5. Bushing
6. Connecting rod
7. Rod cap
8. Rod bearing
9. Gear
10. Thrust washers
11. Key
12. Crankshaft
13. Key
14. Tab washer
15. Nut

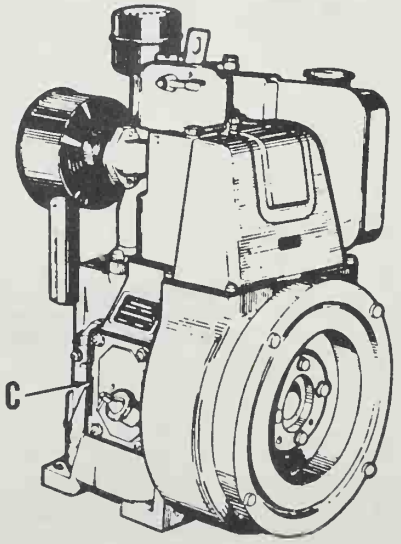


Fig. KR1-8–Remove cover (C) for access to connecting rod.

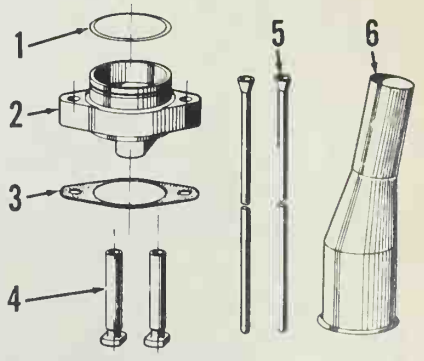


Fig. KR1-9–Exploded view of tappets and push rods.

1. Push rod tube seal
2. Valve tappet guide
3. Gasket
4. Valve tappets
5. Push rods
6. Push rod tube

pump. Unscrew camshaft bearing housing (3–Fig. KR1-10 and KR1-11) screws and remove camshaft assembly. If bearing housing will not remove easily, jack screws may be threaded into holes provided in housing to push housing free.

Two different camshafts are used and are not interchangeable. The camshaft shown in Fig. KR1-10 is supported at outer end by bushing (5) while the camshaft shown in Fig. KR1-11 is supported at outer end by ball bearing (5). To disassemble bushing supported camshaft assembly, remove thrust plate (6–Fig. KR1-10) and slide camshaft out of housing (3). Detach gear (9) from camshaft. Bushing (5) may be renewed if necessary. To disassemble bearing supported camshaft, unscrew Allen screw and remove steel sleeve (12–Fig. KR1-11). Pull gear (9) off shaft, detach snap ring (10) and slide shaft out of bearing (5). Remove snap rings (2) and remove bearing (5) from housing (3).

Inspect components and renew if required. Inner end of camshaft (7–Fig. KR1-10) rides in crankcase bushing while steel sleeve (12–Fig. KR1-11) attached to camshaft (7) rides in crankcase bushing. Clearance between crankcase bushing and camshaft (7–Fig. KR1-10) journal or camshaft sleeve (12–Fig. KR1-11) should not exceed 0.20 mm. Renew tappet guide (2–Fig. KR1-9) if tappet bores are out-of-round more than 0.05 mm.

Reassembly is reverse of disassembly. When installing camshaft assembly in crankcase, rotate crankshaft so piston is at top dead center then insert camshaft so "I" mark on gear is aligned with mark in tappet guide opening of crankcase as shown in Fig. KR1-12.

GOVERNOR

R&R AND OVERHAUL. To remove governor, remove breather on top of crankcase then reach through opening and disconnect governor link (4–Fig. KR1-13) from injection pump. Detach speed control lever (21), spring retainer (18) and spring (17) from shaft (10). Remove end cover (E–Fig. KR1-14). Unscrew and remove stud (11–Fig. KR1-13) from shaft. Detach "E" ring (15) and withdraw governor shaft (10) from side of crankcase while removing governor fork (8) assembly through end of crankcase. The governor flyweight assembly (2) may be removed by turning stud (T) after removing pin (1).

Governor flyweight assembly (2) is designed according to engine governed speed and direction of crankshaft rotation. Governed speed may be 1500, 2000, 2500 or 3000 rpm. Flyweight assembly is available only as a unit assembly. When installing a new governor, be sure correct flyweight assembly is installed.

Reverse disassembly procedure to install governor components. Long end of governor spring (6) must engage notch in crankcase while short end of spring is against back side of governor arm (8) so spring tension will force fork arm towards end of crankcase. Refer to Fig. KR1-15 when installing spring (17–Fig. KR1-13) and spring retainer (18). Short end of spring (17) on constant speed engines should engage slot (C–Fig. KR1-15) of spring retainer (18) while short spring end on variable speed engines should engage slot (V). Long end of spring on all engines must engage lug on side of crankcase so lever (21–Fig. KR1-13) is tensioned upwards. After governor installation refer to ENGINE SPEED ADJUSTMENT section.

OIL PUMP

R&R AND OVERHAUL. To remove oil pump, remove end cover (E–Fig. KR1-14), then unscrew three Allen screws securing oil pump and remove oil pump. If oil pump is difficult to remove due to binding or a close fit, it will be necessary to remove crankshaft so pump may be tapped loose from inside crankcase.

To disassemble oil pump, detach snap ring (8–Fig. KR1-16) and remove gear (5). Unscrew oil pump housing screws, then tap gently on shaft to dislodge oil pump components. Oil pump is available only as a unit assembly and should be renewed if components are damaged or excessively worn. Gear backlash should not exceed 0.12 mm. Two different oil pumps are used according to crankshaft rotation. Be sure new pump matches crankshaft rotation.

Reverse disassembly procedure for assembly.

CRANKSHAFT

R&R AND OVERHAUL. To remove

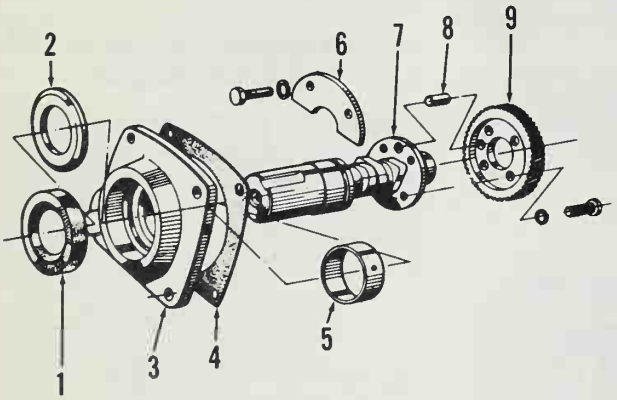


Fig. KR1-10–Exploded view of bushing-supported camshaft used on some engines.
1. Seal
2. Oil deflector
3. Bearing housing
4. Gasket
5. Bushing
6. Thrust plate
7. Camshaft
8. Dowel
9. Gear

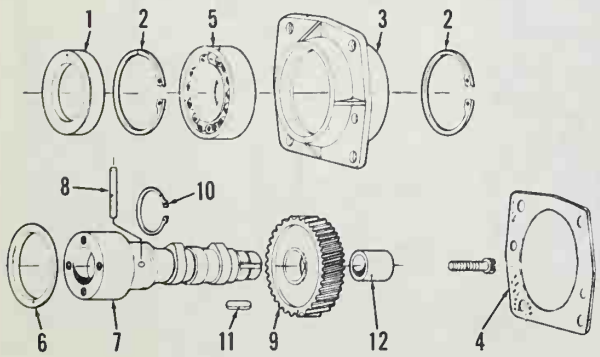


Fig. KR1-11–Exploded view of bearing-supported camshaft used on some models.
1. Seal
2. Snap ring
3. Bearing housing
4. Gasket
5. Bearing
6. Oil deflector
7. Camshaft
8. Starter pin
9. Gear
10. Snap ring
11. Key
12. Sleeve

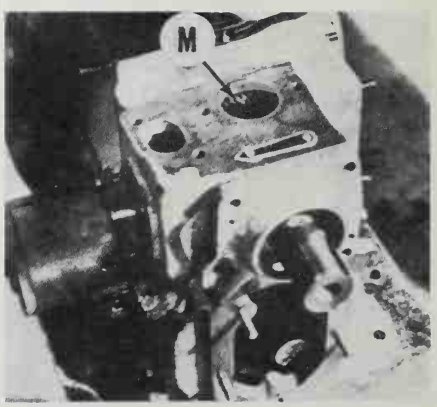


Fig. KR1-12–Align "I" mark on camshaft gear with mark (M) on crankcase. Piston must be at TDC. Refer to text.

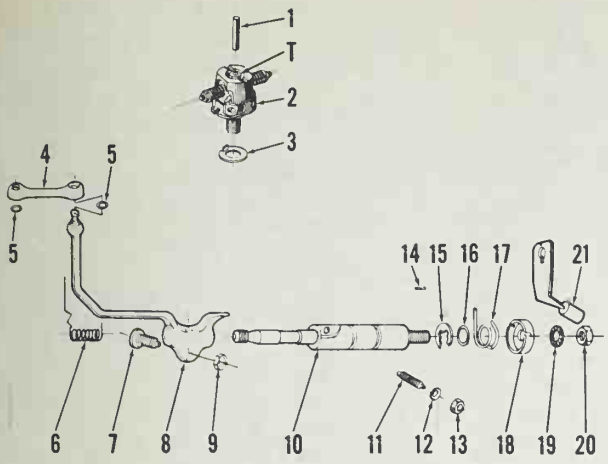


Fig. KR1-13 – Exploded view of governor mechanism.

1. Pin
2. Flyweight assy.
3. Tab washer
4. Link
5. Clips
6. Governor spring
7. Screw
8. Governor arm
9. Nut
10. Shaft
11. Idle speed screw
12. Lockwasher
13. Nut
14. Pin
15. "E" ring
16. "O" ring
17. Spring
18. Spring retainer
19. Lockwasher
20. Nut
21. Lever

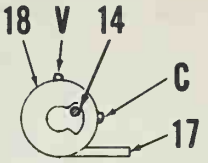


Fig. KR1-15 – Position short end of spring (17) in slot (V) of spring retainer on variable speed engines or in slot (C) on constant speed engines.

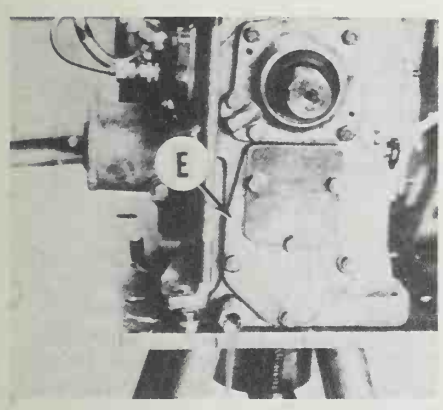


Fig. KR1-14 – Remove end cover (E) for access to governor and oil pump.

crankshaft, unscrew flywheel nut and using a suitable puller remove flywheel.

NOTE: On engines with clockwise crankshaft rotation, the flywheel nut has left-hand threads. Remove connecting rod and governor as outlined in previous sections. At flywheel end, unscrew bearing support retaining nuts and install jack screws in holes provided in bearing support. Loosen, then remove bearing support. Withdraw crankshaft from crankcase.

Crankshafts are designed for clockwise or counter-clockwise rotation. Be sure correct crankshaft is installed if renewal is required.

Use a suitable puller to remove crankshaft gear. Heat gear prior to assembly to ease installation.

Main bearing clearance is 0.053-0.093 mm. Standard crankpin journal diameter is 39.975-39.991 mm and rod bearing clearance is 0.031-0.083 mm. Undersize main and rod bearings are available.

Crankshaft end play should be 0.15-0.30 mm and is controlled by thrust washers (10 – Fig. KR1-7). Thrust washer thickness is 2.31-2.36 mm.

Install crankshaft by reversing removal procedure. Tighten main bearing support nuts to 24.5 N·m.

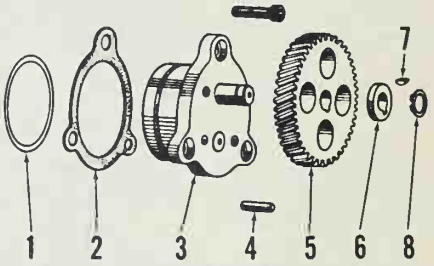


Fig. KR1-16 – View of oil pump. Dowel pins (4) are inserted through pump end plates and body.

1. "O" ring
2. Gasket
3. Oil pump
4. Dowel pins (2)
5. Gear
6. Spacer
7. Key
8. Snap ring

KUBOTA

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Model	No. Cyls.	Bore (mm)	Stroke (mm)	Displ. (cc)
EA400-N	1	78	84	401
EA400-NB	1	78	84	401
EA450-N	1	84	84	465
EA450-NB	1	84	84	465
EA500-N	1	86	90	522
EA500-NB	1	86	90	522
EA600-N	1	92	90	598
EA600-NB	1	92	90	598

All Kubota engines in this section are liquid-cooled, single-cylinder, four-stroke diesel engines.

MAINTENANCE

LUBRICATION

Recommended crankcase oil is SAE 10W-40 with API classification CB or CC. Crankcase capacity is 1.9 liters for Models EA400-N, EA400-NB, EA450-N and EA450-NB or 2.3 liters for all other models.

All models are equipped with a pressure lubrication system. The oil drain plug (D–Fig. K1-2) also serves as oil pickup and a screen filter is attached to end of drain bolt. The drain bolt should be removed and filter cleaned after first twenty hours of operation and after every 100 hours thereafter.

Refer to OIL PUMP section for pump service.

FUEL SYSTEM

FUEL PRIMER. All models are equipped with a fuel primer to aid starting. To operate fuel primer, open fuel valve (1–Fig. K1-1), push primer pump (3) button, then close fuel valve. The primer pump button should be depressed 5 to 6 times for smaller engines and 8 to 9 times for larger engines. Use of primer pump will depend on ambient temperature.

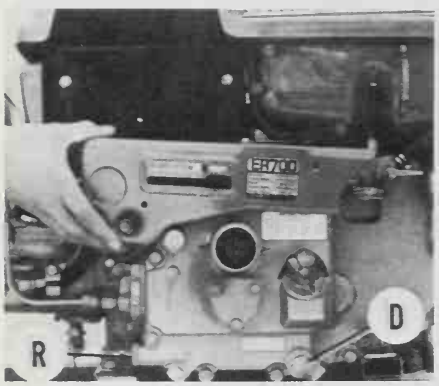


Fig. K1-2 – View showing location of oil drain plug (D) and oil pressure relief valve (R).

FUEL FILTER. A renewable fuel filter is located below fuel valve as shown in Fig. K1-3. Unscrew nut (11), detach cannister (10) and remove filter (9). Manufacturer recommends renewing fuel filter after every 100 hours of operation.

BLEED FUEL SYSTEM. Refer to Fig. K1-3 for view of fuel system. To bleed system, loosen fuel line (3) fitting at injection pump, open fuel valve and retighten fitting when fuel appears. Disconnect high pressure fuel line (2) from injector (1). Rotate engine to operate injection pump then reconnect fuel line when air-free fuel flows from fuel line.

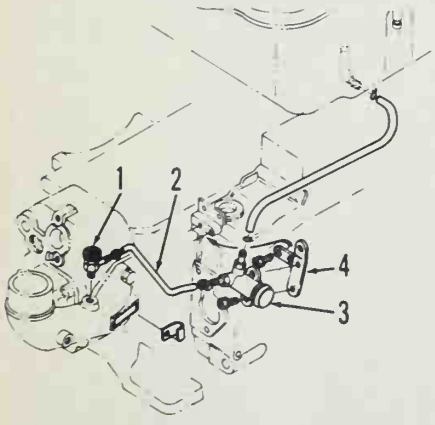
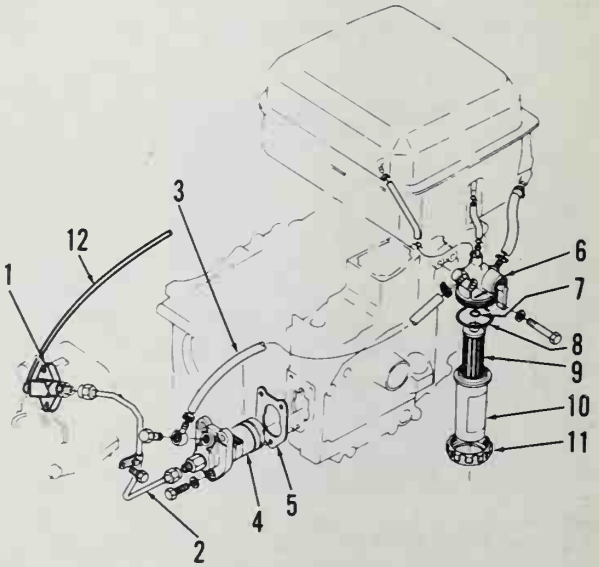


Fig. K1-1 – View of fuel primer circuit.
1. Fuel jet valve
2. Fuel line
3. Primer pump
4. Bracket

Fig. K1-3 – Exploded view of fuel system. Refer to Fig. K1-1 for fuel primer circuit.
1. Injector
2. High pressure fuel line
3. Inlet fuel line
4. Injection pump
5. Shim gasket
6. Fuel valve
7. "O" ring
8. "O" ring
9. Filter
10. Filter cannister
11. Nut
12. Fuel return line



INJECTION PUMP TIMING. Injection pump timing is adjusted using shims (5–Fig. K1-3). To check injection pump timing proceed as follows: Disconnect high pressure line from injection pump then unscrew delivery valve holder (1–Fig. K1-4) and remove valve spring (3) and delivery valve assembly (5). Reinstall delivery valve holder (1) and connect a suitable spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full open position. Rotate engine flywheel slowly in counterclockwise direction until fuel just stops flowing from spill pipe. Mark (M–Fig. K1-5) on fan cover should be aligned with "F" mark on flywheel which should provide injection timing of 19-21 degrees BTDC. If injection timing is incorrect, remove injection pump and remove or install shims (5–Fig. K1-3) as required. Adding shims will retard injection timing while removing shims advances injection timing. Each shim alters injection timing approximately 1½ degrees. Tighten injection pump mounting screws to 23.5-27.4 N·m. Reinstall delivery valve and spring and tighten delivery valve holder to 44.1 N·m.

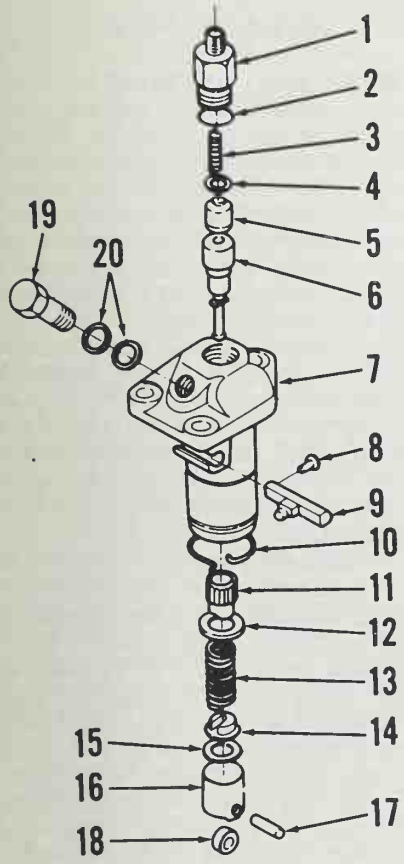


Fig. K1-4–Exploded view of injection pump.

1. Delivery valve holder
2. "O" ring
3. Spring
4. Gasket
5. Delivery valve
6. Plunger
7. Pump body
8. Pin
9. Control rack
10. Clip
11. Control sleeve
12. Washer
13. Spring
14. Spring retainer
15. Shim
16. Tappet
17. Pin
18. Roller

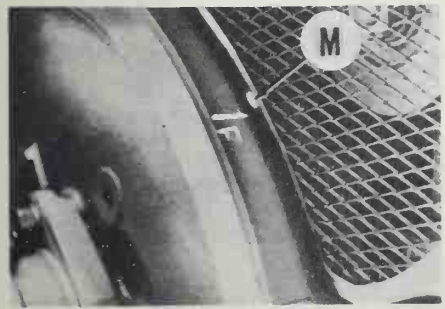


Fig. K1-5–View showing location of timing mark (M) on fan cover.

GOVERNOR

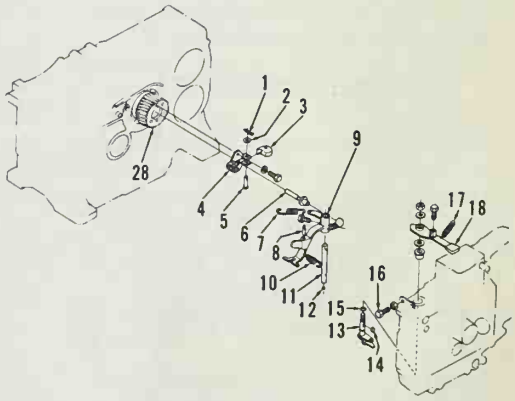
All models are equipped with a flyweight type governor attached to the crankshaft gear. Refer to Fig. K1-6 for an exploded view of governor mechanism.

Maximum no-load governed speed should be 2540-2580 rpm while low idle speed should be less than 1000 rpm.

Fuel limiting device (components 9 through 17–Fig. K1-6A) should be adjusted by loosening nut (14) then turning spring housing (10) so excessive smoke

Fig. K1-6–Exploded view of governor mechanism. Spring (10) connects to pin (7–K1-6A).

1. Pin
2. Washer
3. Flyweight
4. Weight carrier
5. Pin
6. Pushrod
7. Spring
8. Pin
9. Lever
10. Spring
11. Shaft
12. Ball
13. Throttle shaft
14. Key
15. "O" ring
16. Idle speed screw
17. Spring
18. Throttle lever



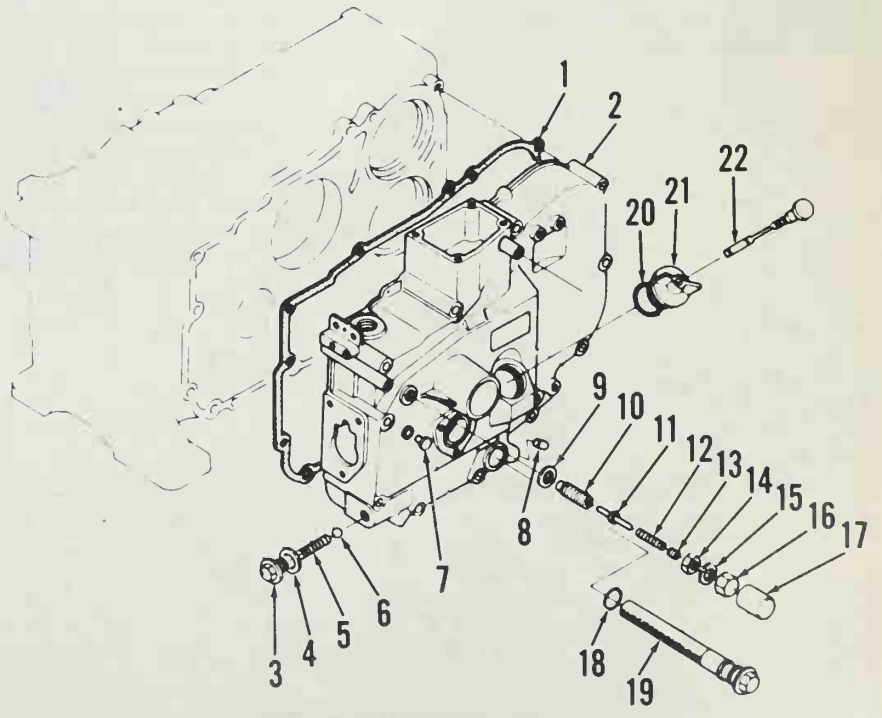


Fig. K1-6A–Exploded view of gearcase components.

1. Gasket
2. Gearcase
3. Plug
4. Gasket
5. Oil pressure relief spring
6. Oil pressure relief ball
7. Pin
8. Plug
9. Gasket
10. Fuel limiter spring housing
11. Pin
12. Spring
13. Screw
14. Nut
15. Gasket
16. Cap nut
17. Cap
18. "O" ring
19. Filter & drain plug
20. "O" ring
21. Fill plug
22. Dipstick

is not produced when engine is slightly overloaded.

COMPRESSION RELEASE

All models are equipped with a compression release which holds the exhaust valve open slightly when compression release lever (19–Fig. K1-7) is rotated. To adjust compression release, rotate engine crankshaft so piston is at top dead center on compression. Remove cover (1), loosen locknut (15–Fig. K1-8) and back off adjusting screw (16). Rotate compression release lever to engaged position. Turn adjusting screw (16) in until it contacts exhaust rocker arm (13), then turn screw 1½ additional turns. Tighten locknut and check operation of compression release.

COOLING SYSTEM

All models are equipped with a liquid type cooling system. A radiator is mounted above the engine and an engine driven fan circulates air through the radiator. Coolant is circulated by thermo-siphon. On "NB" models, alternator coils are mounted behind the fan and the fan also functions as the alternator rotor.

A coolant drain valve is located on underside of the cylinder head. Cooling system capacity is 1.6 liters for Models EA400-N, EA400-NB, EA450-N and EA450-NB or 2.1 liters for all other models. Recommended pressure rating for radiator cap is 88.25 kPa (13 psi).

Fan belt tension should be 5-10 mm using finger pressure against belt at midpoint between fan pulley and tension pulley. Relocate tension pulley to adjust belt tension.

AIR FILTER

All models are equipped with a dry type renewable air filter. Manufacturer recommends blowing out filter after every 100 to 200 hours of operation and renewing filter after six cleanings or one year.

REPAIRS

TIGHTENING TORQUES

Refer to following table for tightening torques. All values are in newton meters.

Connecting rod	
EA400-N, EA400-NB, EA450-N, EA450-NB	29.4-34.3
All other models	49.0-53.9
Crankcase cover	8.8-9.8
Cylinder head	
EA400-N, EA400-NB, EA450-N, EA450-NB	98.1-117.7
All other models	137.3-156.9
Flywheel	294-392
Gearcase cover	23.5-27.4
Injection pump	23.5-27.4
Injection pump delivery valve holder	44.1
Injector	23.5-27.4
Injector nozzle nut	78.4-98.1
Main bearing carrier	23.5-27.4
Rocker arm stand	39.2-45.1

COMPRESSION PRESSURE

Compression pressure should be 2530 kPa for Models EA400-N and EA400-NB, 2431 kPa for Models EA450-N and EA450-NB or 2235 kPa for all other models.

CYLINDER HEAD

R&R AND OVERHAUL. Drain coolant, remove muffler and disconnect fuel return line from injector. Disconnect both ends of high pressure fuel line. Remove air cleaner and intake pipe. Remove rocker cover (3–Fig. K1-7) then unscrew rocker stand retaining nut and remove rocker arm assembly. Unscrew cylinder head retaining nuts and remove cylinder head.

Check flatness of head surface using a straight edge placed along sides and across mating surface. If a feeler gage of 0.05 mm thickness will pass under straight edge, then head must be resurfaced. If head is resurfaced, check valve-to-piston clearance as outlined in following paragraph.

To check valve-to-piston clearance, install head and gasket with valves and spring installed but with injector removed. Tighten head retaining nuts to specified torque using a crossing pattern. Using a suitable measuring gage such as soft solder or Plastigage, insert gage between each valve and piston crown while rotating crankshaft through top dead center. Minimum allowable valve-to-piston clearance is 0.65 mm. Note that crush thickness of head gasket should be 1.25-1.45 mm for Models EA400-N, EA400-NB, EA450-N and EA450-NB or 1.35-1.55 mm for all other models.

Reverse removal procedure to reinstall cylinder head. Tighten cylinder

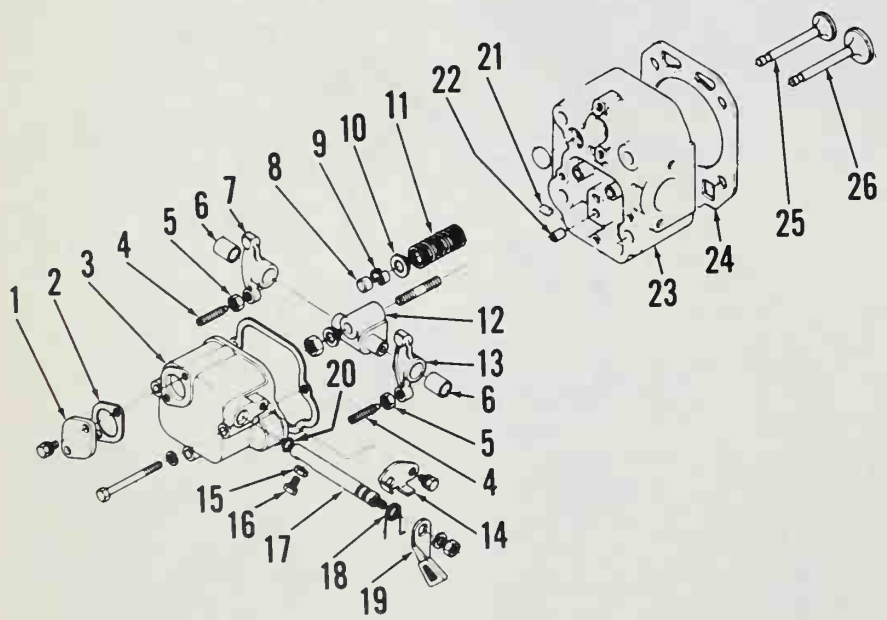


Fig. K1-7—Exploded view of cylinder head.

1. Cover
2. Gasket
3. Rocker cover
4. Adjusting screw
5. Locknut
6. Bushing
7. Rocker arm, ex.
8. Cap
9. Retainer keys
10. Spring retainer
11. Valve spring
12. Rocker stand
13. Rocker arm, int.
14. Bracket
15. Locknut
16. Screw
17. Shaft
18. Spring
19. Compression release lever
20. "O" ring
21. Plug
22. Pin
23. Head
24. Gasket
25. Exhaust valve
26. Intake valve

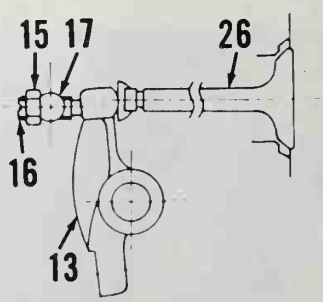


Fig. K1-8—Loosen locknut (15) and turn adjusting screw (16) to adjust compression release. See text.

head nuts to specified torque using a crossing pattern. Tighten rocker arm stand nut to specified torque. Adjust valve tappet gap as outlined in following section and compression release as outlined in a previous section.

VALVE TAPPET GAP

Valve tappet gap should be adjusted with engine cold and piston at top dead center on compression. Remove rocker cover and turn adjusting screws in rocker arms so valve gap for both valves is 0.16-0.20 mm for Models EA400-N, EA400-NB, EA450-N and EA450-NB or 0.195-0.235 mm for all other models.

VALVE SYSTEM

Both valves ride directly in cylinder head. Maximum allowable clearance between valve stem and valve guide is 0.1 mm. Valve guide diameter should be 7.010-7.025 mm on EA400-N, EA400-NB, EA450-N and EA450-NB or 8.015-8.030 mm for all other models. Valve stem diameter should be 6.960-6.975 mm on EA400-N, EA400-NB, EA450-N and EA450-NB or 7.960-7.975 mm for all other models.

Valves seat directly in head. Valve seat and face angles are 45 degrees. Valve seat width should be 1.4 mm. When depth of valve head from cylinder head surface exceeds 1.5 mm, then head surface should be machined.

Valve springs are interchangeable. Valve spring free length should be 38.5 mm while installed height is 33 mm. Valve spring pressure at installed height should be 66.7 Newtons with a minimum allowable pressure of 56.9 Newtons.

Rocker arm bushings (6–Fig. K1-7) are renewable. Bushing ID should be 14.002-14.050 mm. Diameter of rocker stand (12) shafts should be 13.973-13.984 mm. Maximum clearance between shaft and bushing is 0.15 mm.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE AND REINSTALL. Before removing an injector or loosening injector lines, thoroughly clean injector, lines and surrounding area using compressed air and a suitable solvent.

To remove injector unit, first remove high pressure line leading from pump to injector. Disconnect bleed line by removing banjo bolt or by pulling line from banjo nipple fitting (8–Fig. K1-9). Remove two stud nuts securing ears of injector body to left side of cylinder head and withdraw injector unit.

When installing injector, make sure machined seating surface in cylinder head bore is completely clean and free from carbon build-up. Use a new copper washer underneath injector nozzle. Turn retaining stud nuts both finger tight, then tighten alternately and evenly one-sixth turn at a time to a torque of 23.5-27.4 N·m. Start and run engine, listening for pressure leaks around nozzle seating washer. Correct pressure leaks by checking to be sure stud nuts are tightened evenly and injector unit is not cocked.

TESTING. A complete job of testing and adjusting the injector requires use of special test equipment. Only clean, approved testing oil should be used in tester tank. Nozzle should be tested for opening pressure, seat leakage, back leagage and spray pattern. When tested, nozzle should open with a high-pitched buzzing sound, and cut off quickly at end of injection with a minimum of seat leakage and a controlled amount of back leakage.

Before conducting test, operate tester lever until fuel flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, and that possibilities are good that injector can be returned to service without disassembly.

OPENING PRESSURE. Open valve to tester gage and operate tester lever slowly while observing gage reading. Opening pressure should be 11.76-12.26 MPa (1704-1775 psi).

Opening pressure is adjusted by adding or removing shims in shim pack (6–Fig. K1-9). Adding or removing one 0.1 mm (0.004 inch) thickness shim will change opening pressure approximately 980 kPa (140 psi).

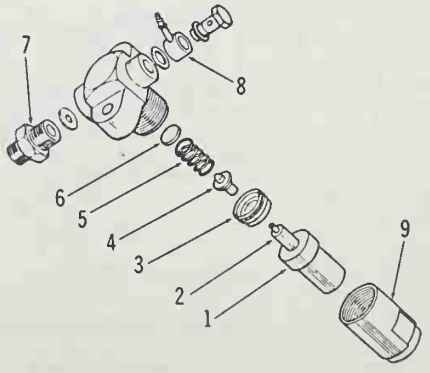


Fig. K1-9–Exploded view of injector.

1. Nozzle body
2. Nozzle valve
3. Spacer
4. Pressure pin
5. Spring
6. Shim
7. Pressure fitting
8. Return fitting
9. Nozzle nut

SEAT LEAKAGE. Nozzle tip should not leak at a pressure less than 10.7 MPa (1562 psi.). To check for leakage, actuate tester lever slowly and as gage needle approaches suggested test pressure, observe nozzle tip. Hold pressure for 10 seconds; if drops appear or nozzle tip becomes wet, valve is not seating, and injector must be disassembled and overhauled as later outlined.

BACK LEAKAGE. If nozzle seat was satisfactory as previously tested, check injector and connections for wetness which would indicate external leakage. If no leaks are found, bring gage pressure up to 10.7 MPa (1562 psi.), release lever and observe the time required for gage needle to drop to 3799 kPa (550 psi.). For a nozzle in good condition, this time should not be less than six seconds. A faster drop would indicate a worn or scored nozzle valve piston or body, and nozzle valve should be renewed.

NOTE: Leakage of tester check valve or connections will cause a false reading, showing up in this test as fast leakback. If a series of injectors fail to pass this test, the tester rather than injector units should be suspected.

SPRAY PATTERN. Spray pattern should be well atomized and slightly conical, emerging in a straight axis from nozzle tip. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder assembly. Refer to Fig. K1-9 for exploded view and proceed as follows:

Secure nozzle in a soft jawed vise or holding fixture and remove cap nut (9). Place all parts in clean calibrating oil or diesel fuel as they are removed, using a compartmented pan and using extra care to keep parts from each injector together and separate from other units which are disassembled at the time.

Clean exterior surfaces with a brass wire brush, soaking in an approved carbon solvent if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces.

Clean nozzle spray hole from inside using a pointed hardwood stick or wood

splinter as shown in Fig. K1-10. Scrape carbon from pressure chamber using hooked scraper as shown in Fig. K1-11. Clean valve seat using brass scraper as shown in Fig. K1-12, then polish seat using wood polishing stick and mutton tallow as in Fig. K1-13.

Back flush nozzle using reverse flusher adapter. Reclean all parts by rinsing thoroughly in clean diesel fuel or calibrating oil and assemble while parts are immersed in cleaning fluid. Make sure adjusting shim pack is intact. Tighten nozzle retaining nut (9–Fig. K1-9) to a torque of 78.4-98.1 N·m. Do not overtighten, distortion may cause valve to stick and no amount of overtightening can stop a leak caused by scratches or dirt. Retest assembled injector as previously outlined.

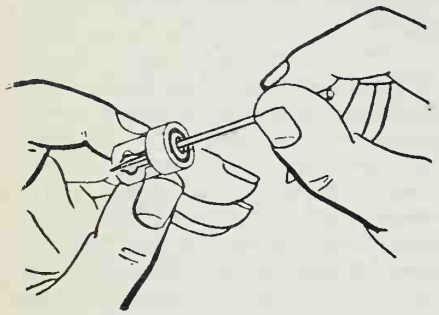


Fig. K1-10—Use a pointed hardwood stick to clean spray hole as shown.

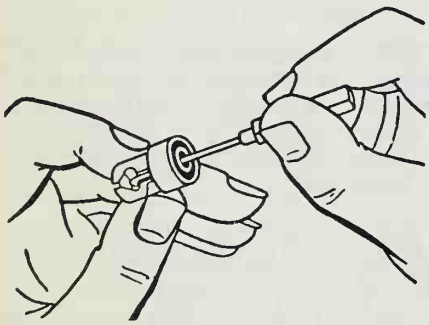


Fig. K1-11—Use a hooked scraper to clean carbon from pressure chamber.

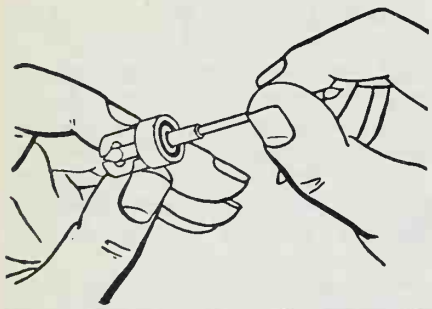


Fig. K1-12—Clean valve seat using brass scraper as shown.

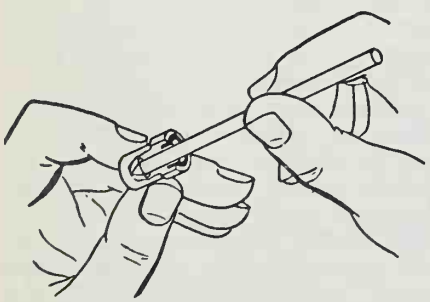


Fig. K1-13—Polish seat using polishing stick and mutton tallow.

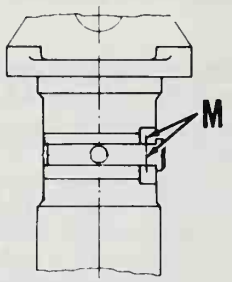


Fig. K1-14—Marks (M) on injection pump body and rack should align.

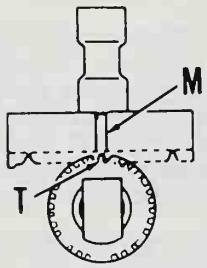


Fig. K1-15—Mark (M) on rack should align with control sleeve master tooth (T).

INJECTION PUMP

All models are equipped with the injection pump shown in Fig. K1-4. The injection pump should be tested and overhauled by a shop qualified for diesel injection pump repair.

If rack (9) is removed and must be reinstalled, align marks (M–Fig. K1-14) on pump body and rack and master tooth (T–Fig. K1-15) must align with mark (M) on rack.

The injection pump tappet is actuated by cam (9–Fig. K1-16) which is attached to camshaft (3). Inspect cam each time injection pump is removed.

Tighten injection pump screws to 23.5-27.4 N·m and refer to INJECTION PUMP TIMING section.

OIL PUMP

R&R AND OVERHAUL. Oil pump (23–Fig. K1-16) is housed in gearcase (31) and driven by a slot in the end of camshaft (3). To remove pump, unscrew cover (25) and extract pump assembly from cover.

The pump is available as a unit assembly only. Note the following measurements to detect pump wear. Inner rotor to outer rotor clearance (Fig. K1-17) should not exceed 0.2 mm. Outer rotor to gear cover clearance (Fig. K1-18) should not exceed 0.24 mm. With a straightedge placed across oil pump as shown in Fig. K1-19, gap between either rotor and gear cover should not exceed 0.25 mm.

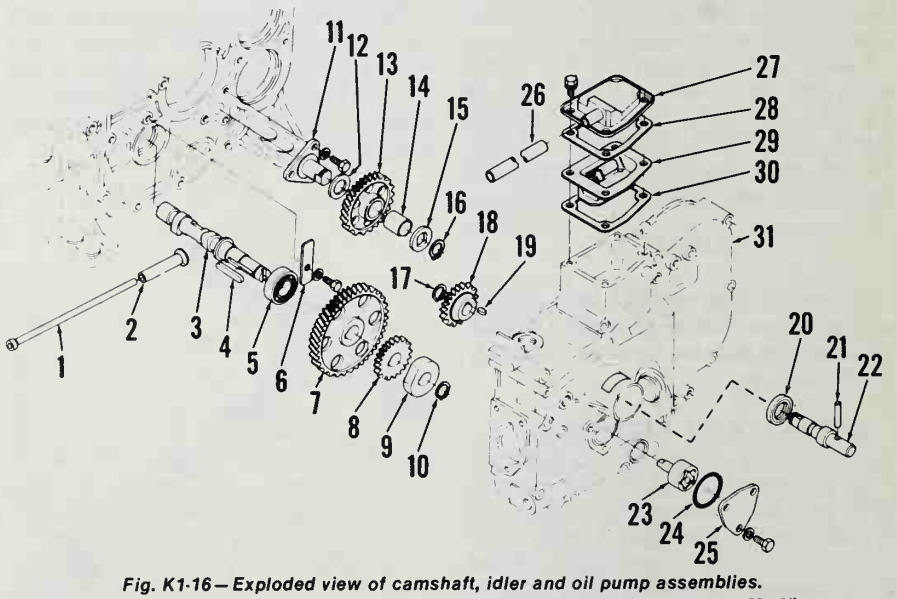


Fig. K1-16—Exploded view of camshaft, idler and oil pump assemblies.

1. Pushrod
2. Tappet
3. Camshaft
4. Key
5. Bearing
6. Bearing retainer
7. Gear
8. Gear
9. Injection pump cam
10. Snap ring
11. Idler shaft
12. Washer
13. Idler gear
14. Bushing
15. Slotted washer
16. Snap ring
17. Snap ring
18. Starter gear
19. Key
20. Bearing
21. Pin
22. Starter shaft
23. Oil pump
24. "O" ring
25. Pump cover
26. Hose
27. Breather cover
28. Gasket
29. Breather assy.
30. Gasket

The oil pressure relief valve ball (6–Fig. K1-6A) and spring (5) are located in gear cover. Oil pressure is not adjustable.

GOVERNOR

All models are equipped with a flyweight type governor as shown in Fig. K1-6. The flyweight assembly is attached to crankshaft gear (28) and actuates governor lever (9) which controls the position of fuel injection pump rack (9–Fig. K1-4).

Governor components are accessible after removing gearcase. Inspect components and renew any which are excessively worn or damaged.

GEAR TRAIN

Should the camshaft gear, crankshaft gear, idler gear or either balancer gear be removed, refer to Fig. K1-21 and align timing marks on gears as shown. Note that timing dots are found on camshaft and crankshaft gears while numbers are used on balancer gears. Timing dots and a number are stamped on the idler gear.

BALANCER SHAFTS

R&R AND OVERHAUL. The balancer shafts are accessible after removing gearcase. Remove idler gear (13–Fig. K1-16), then unscrew bearing retainer (14–Fig. K1-22) and extract balancer shafts (9). Inspect shafts, gears and bearings and renew if damaged. When reinstalling balancer assemblies, refer to GEAR TRAIN section for proper timing of balancer gears.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod are removed as a unit after removing cylinder head, crankcase cover (41–Fig. K1-23) and balancer shafts (9–Fig. K1-22). Unscrew rod cap retaining screws, detach rod cap and extract piston and rod from head end of engine.

When assembling piston and rod, arrow on original equipment piston crown should be on same side as rod and cap alignment marks as shown in Fig. K1-25. Install piston and rod in engine so piston arrow (A) points towards engine top. Replacement piston does not have arrow on crown and may be installed in either direction. Install rod cap so marks (M) on rod and cap are aligned and tighten rod screws to 29.4-34.3 N·m on EA400-N, EA400-NB, EA450-N and EA450-NB, or to 49.0-53.9 N·m on all other models.

PISTON AND RINGS

All models are equipped with three

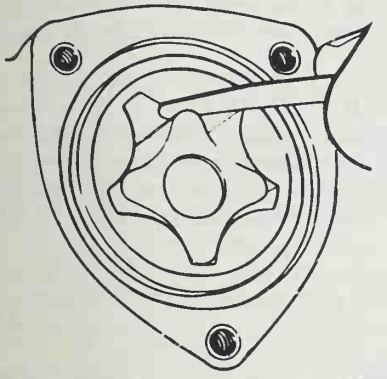


Fig. K1-17—Inner rotor to outer rotor clearance should not exceed 0.2 mm. Measure as shown.

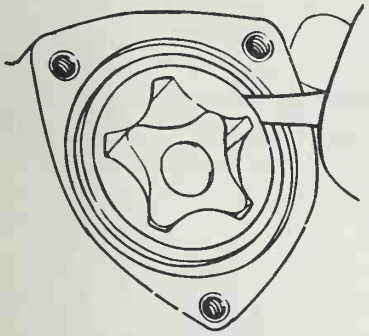


Fig. K1-18—Outer rotor to oil pump housing clearance should not exceed 0.24 mm. Measure as shown.

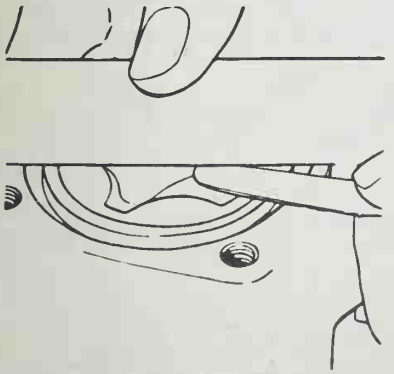


Fig. K1-19—Place a straightedge on oil pump housing and measure between rotor faces and housing. Gap must not exceed 0.25 mm.

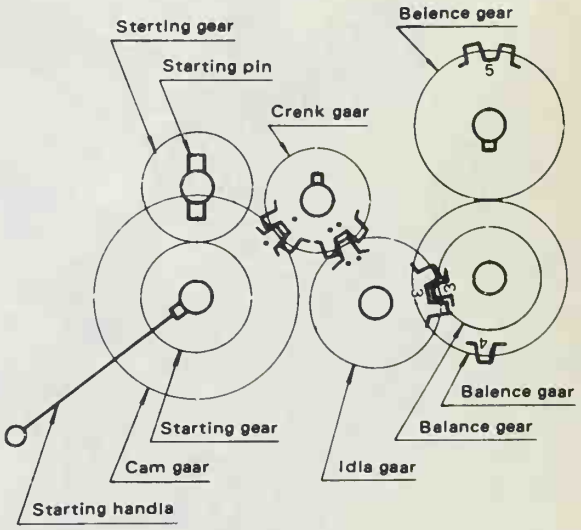


Fig. K1-21—Diagram of gear train showing timing marks.

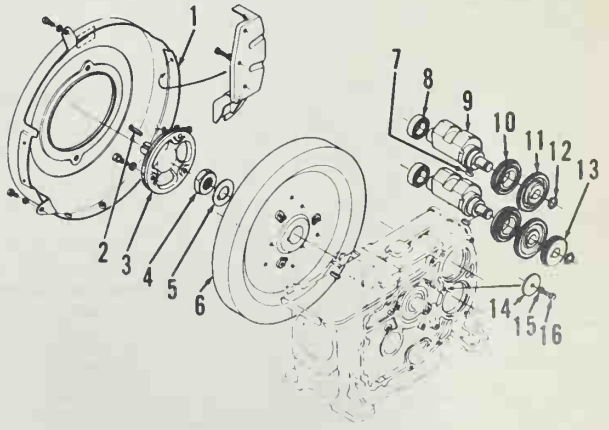


Fig. K1-22—Exploded view of balancer gears and flywheel. On electric start models, a ring gear surrounds flywheel.

1. Cover
2. Pin
3. Rope pulley
4. Nut
5. Lockwasher
6. Flywheel
7. Key
8. Bearing
9. Balancer
10. Bearing
11. Gear
12. Snap ring
13. Gear
14. Bearing retainer
15. Lockwasher
16. Screw

compression rings and an oil control ring surrounding an aluminum piston. Piston and rings are available in standard size only.

Piston diameter is measured perpendicular to piston pin and 12 mm from bottom of skirt on Models EA400-N, EA400-NB, EA450-N and EA450-NB or 11.5 mm from bottom of skirt on all other models. Piston diameter should be 77.885-77.915 mm on Models EA400-N and EA400-NB, 83.885-84.915 mm on Models EA450-N and EA450-NB, 85.875-85.905 mm on Models EA500-N and EA500-NB, and 91.865-91.895 mm on Models EA600-N and EA600-NB. Piston clearance should be 0.085-0.134 mm for Models EA400-N and EA400-NB, 0.085-0.137 mm for Models EA450-N and EA450-NB, 0.095-0.147 mm for Models EA500-N and EA500-NB, and 0.105-0.157 mm for Models EA600-N and EA600-NB.

Piston pin boss inner diameter should be 25.000-25.020 mm for Models EA400-N, EA400-NB, EA450-N and EA450-NB or 27.000-27.021 mm for all other models.

Note location and shape of piston rings in Fig. K1-26. Ring end gap should be 0.2-0.4 mm for all rings. Ring side clearance should be 0.04-0.07 mm for the top compression ring and 0.02-0.05 mm for all other rings.

PISTON PIN

A full floating piston pin is used on all models. Clearance between pin and piston bosses should be 0.002 mm interference to 0.010 mm loose. Clearance between pin and connecting rod bushing should be 0.014-0.038 mm.

CONNECTING ROD AND BEARINGS

The connecting rod is equipped with a renewable bushing in the small end and insert type bearings in the big end. Inner diameter of standard size big end bearing should be 44.010-44.056 mm for Models EA400-N, EA400-NB, EA450-N and EA450-NB, or 48.010-48.056 mm for all other models. Clearance between bearing and crankpin should be 0.035-0.097 mm. Bearings are available in 0.25 and 0.50 mm undersizes.

Inner diameter of small end bushing is 25.025-25.040 mm for Models EA400-N, EA400-NB, EA450-N and EA450-NB, or 27.025-27.040 mm for all other models. Clearance between bushing and piston pin should be 0.014-0.038 mm for all models.

CAMSHAFT

The camshaft is supported by a ball bearing at the gear end while the opposite end rides directly in the cylinder block.

R&R AND OVERHAUL. To remove camshaft, remove cylinder head and push rods. Remove gearcase (31–Fig. K1-16) then unscrew bearing retainer (6). Rotate camshaft one turn to force

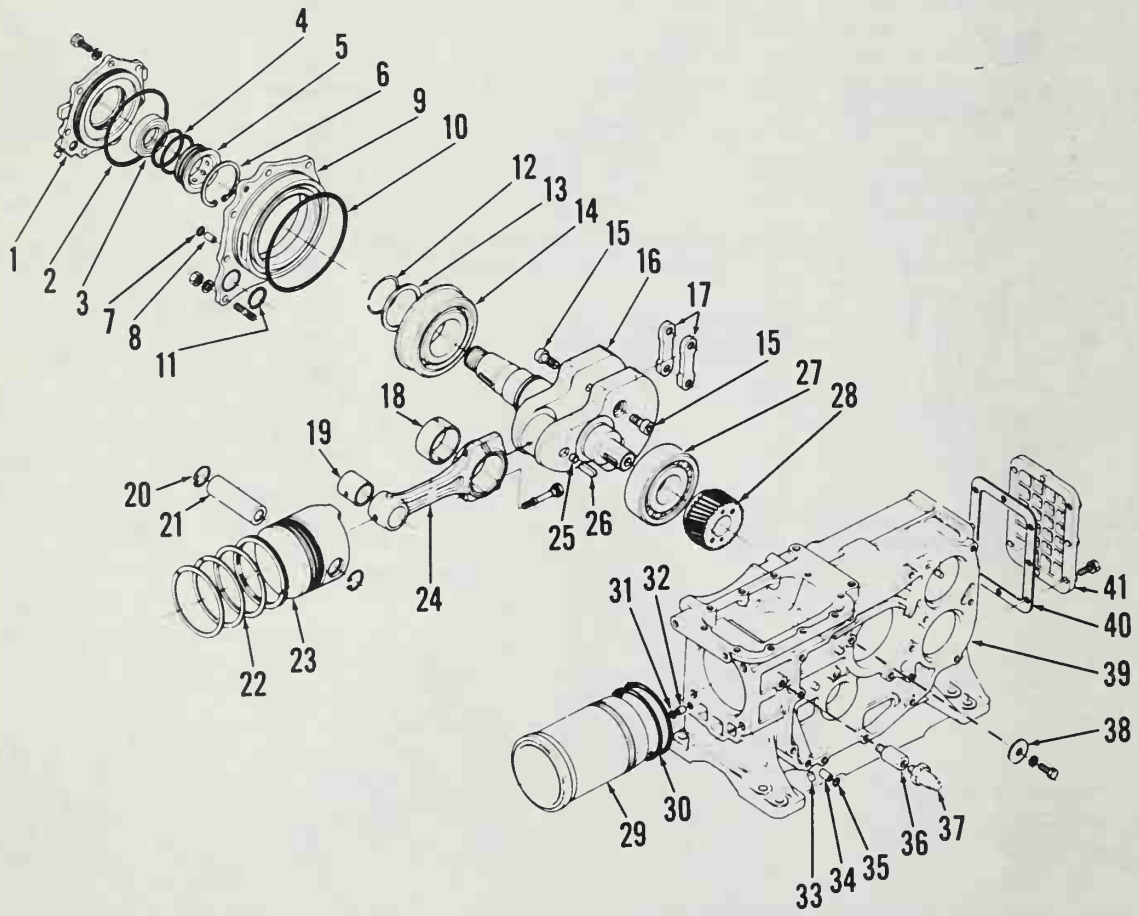


Fig. K1-23—Exploded view of crankshaft, piston, rod and block assemblies.

1. Seal housing
2. "O" ring
3. Bearing
4. "O" rings
5. Oil sleeve
6. Snap ring
7. "O" ring
8. Hollow dowel
9. Bearing carrier
10. "O" ring
11. "O" ring
12. Snap ring
13. Washer
14. Bearing
15. Screw
16. Crankshaft
17. Weights
18. Bearing
19. Bushing
20. Retainer
21. Piston pin
22. Piston rings
23. Piston
24. Connecting rod
25. Plug
26. Key
27. Bearing
28. Gear
29. Sleeve
30. "O" rings
31. "O" ring
32. Hollow dowel
33. Plug
34. Hollow dowel
35. "O" ring
36. Coupler
37. Oil pressure light
38. Bearing retainer
39. Cylinder block
40. Gasket
41. Cover

tappets away from lobes and withdraw camshaft while being careful not to dislodge tappets.

Camshaft lobe height for intake and exhaust lobes is 27 mm with a wear limit of 26.5 mm for Models EA400-N, EA400-NB, EA450-N and EA450-NB, or 33.5 mm with a wear limit of 33 mm for all other models.

Diameter of plain bearing end of camshaft is 21.967-21.980 mm while bearing bore in crankcase is 22.000-22.021 mm.

Refer to GEAR TRAIN section when installing camshaft for proper alignment of gear timing marks. Check backlash between camshaft and crankshaft gears. Backlash should be 0.048-0.14 mm for all models. Gear must be renewed if backlash is excessive.

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove flywheel, balancer shafts and piston with rod as previously outlined. Remove seal housing (1 – Fig. K1-23) and unscrew bearing carrier (9) retaining nuts, then withdraw crankshaft and bearing assembly from crankcase. Disassemble as required.

When inspecting components, be sure oil sleeve (5) is clean and serviceable as pressurized oil is directed through sleeve from oil passage in seal housing (1) to crankshaft for rod bearing lubrication. Inner diameter of sleeve should be 48.000-48.025 mm while corresponding diameter of crankshaft should be 47.959-47.975 mm. Be sure "O" rings (4) seal effectively or low pressure may result.

Note balancer weights (17) attached to crankshaft on Models EA400-N, EA400-NB, EA450-N and EA450-NB.

Crankshaft crankpin diameter is 43.959-43.975 mm for Models EA400-N, EA400-NB, EA450-N and EA450-NB, or 47.959-47.975 mm for all other models. Rod bearings which are 0.25 and 0.50 mm undersize are available.

Crankshaft end play should be 0.05-0.46 mm and is not adjustable. Be sure bearing is seated against bearing retainer when measuring end play. Refer to GEAR TRAIN section for proper timing of crankshaft gear.

ALTERNATOR

Models EA400-NB, EA450-NB, EA500-NB and EA600-NB are equipped with an alternator mounted behind the fan. The fan serves as the alternator rotor. Alternator output should be 8 volts with 3.1 amperes current at alternator speed of 6800 rpm.

ELECTRIC STARTER

Models EA400-NB, EA450-NB, EA500-NB and EA600-NB are equipped with an electric starter as shown in Fig. K1-30. Minimum brush length is 10 mm while wear limit of commutator is 29 mm diameter. With no load imposed on starter and using an 11.5 volt source, the starter shaft should rotate at 3500 rpm or more while drawing less than 90 amperes current.

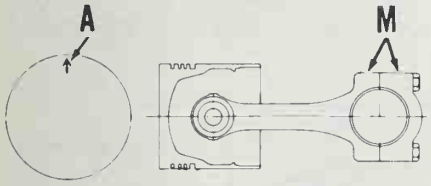


Fig. K1-25 – Assemble rod, cap and piston so marks (M) on rod and cap are on same side as piston arrow (A). Install in engine so marks (M) and arrow (A) are up.

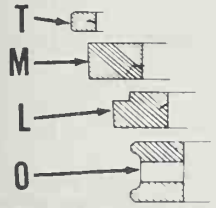


Fig. K1-26 – View of ring configuration for top compression ring (T), middle compression ring (M), lower compression ring (L) and oil control ring (O).

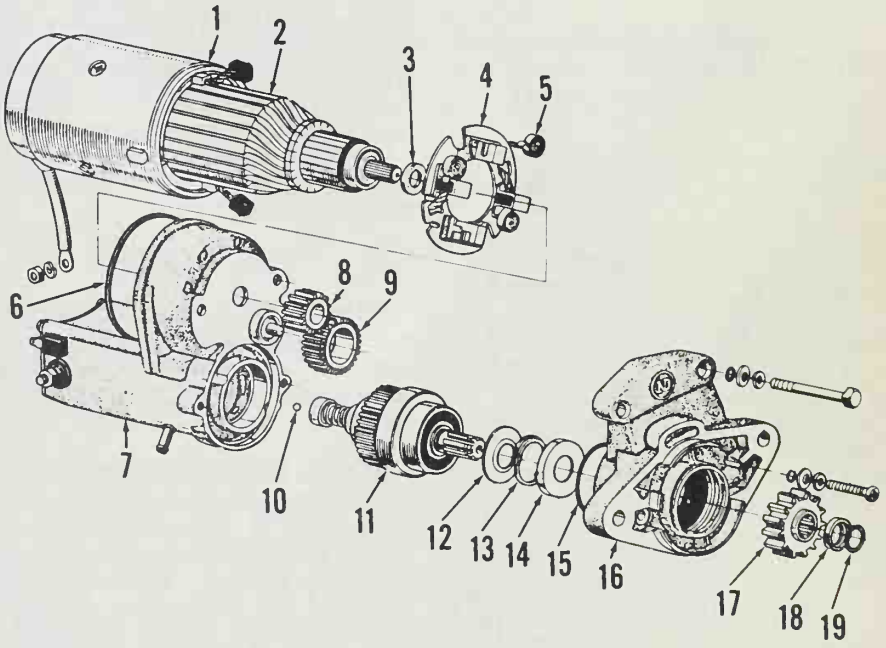


Fig. K1-30 – Exploded view of electric starter.

1. Frame
2. Armature
3. Felt washer
4. Brush assy.
5. Brush spring
6. Gasket
7. Switch hsg. assy.
8. Gear
9. Gear
10. Ball
11. Drive assy.
12. Thrust washer
13. Spring
14. Spring holder
15. "O" ring
16. End frame
17. Gear
18. Collar
19. Retainer

KUBOTA

Model	No. Cyls.	Bore (mm)	Stroke (mm)	Displ. (cc)
D650-B	3	64	70	675
D750-B	3	68	70	762
D850-B	3	72	70	855
D850-BC	3	72	70	855
Z500-B	2	68	70	508
Z600-B	2	72	70	570
ZB500C-B	2	68	70	508
ZB600C-B	2	72	70	570

All Kubota engines in this section are liquid-cooled, four-stroke diesel engines.

Number 1 cylinder is nearest cylinder to crankshaft pulley. Firing order is 1-2-3 for three cylinder engines.

MAINTENANCE

LUBRICATION

Recommended crankcase oil is SAE 10W-40 with API classification CB or CC. Crankcase capacity is 4.6 liters on Models D650-B, D750-B, D850-B and D850-BC, 2.6 liters on Models Z500-B and Z600-B, and 3.1 liters on Models ZB500C-B and ZB600C-B.

All models are equipped with a pressure lubrication system. Oil is directed from the oil pump to the oil pressure relief valve and oil filter. Oil is routed through an oil passage in the cylinder block to the main bearings, then through crankshaft oil passages to the crankpins. The cylinder block oil passage also routes oil to the cylinder head to lubricate the valve train.

Normal oil pressure is 294.2-441.3 kPa at operating speed. Refer to OIL PUMP section for pump service.

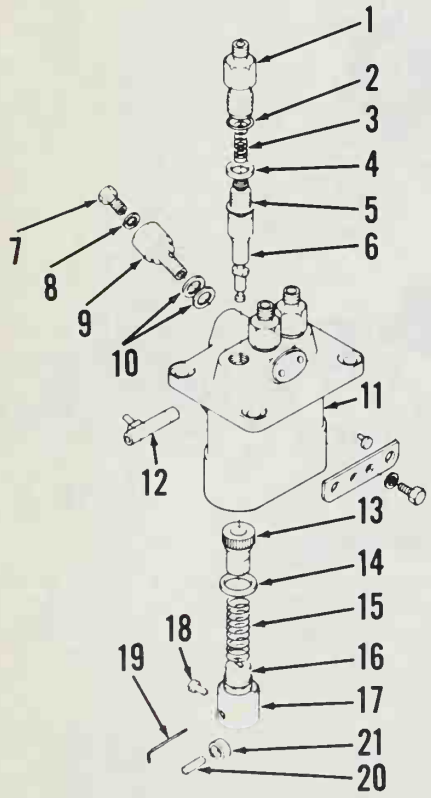


Fig. K2-1 – Exploded view of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Spring
4. Shim
5. Delivery valve assy.
6. Plunger
7. Air bleed screw
8. Gasket
9. Adapter
10. Gaskets
11. Pump body
12. Control rack
13. Control sleeve
14. Washer
15. Spring
16. Spring seat
17. Tappet
18. Guide pin
19. Pin
20. Pin
21. Roller

FUEL SYSTEM

FUEL FILTER. A combination fuel valve and filter assembly is attached to engine. Filter is renewable and should be discarded after every 400 hours of operation.

BLEED FUEL SYSTEM. To bleed fuel system, unscrew injection pump bleed screw (7 – Fig. K2-1), open fuel valve then install bleed screw when air-free fuel appears. Disconnect high pressure fuel lines from injectors. Rotate engine to operate fuel injection pump, then reconnect fuel lines when air-free fuel flows from fuel lines.

INJECTION PUMP TIMING. Injection pump timing is adjusted using shims (16 – Fig. K2-2). To check injection pump timing proceed as follows: Disconnect high pressure line for number 1 cylinder from injection pump, then unscrew delivery valve holder (1 – Fig. K2-1) and remove valve spring (3) and delivery valve assembly (5). Reinstall delivery valve holder (1) and connect a suitable spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full open position. Rotate engine flywheel slowly in counter-clockwise direction until fuel just stops flowing from spill pipe. On

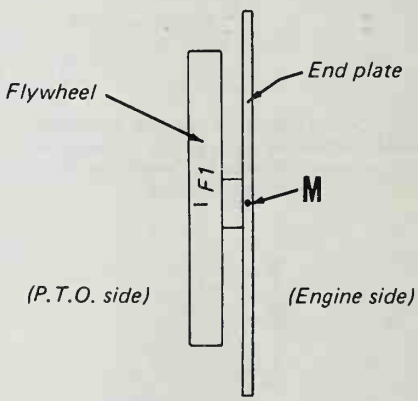
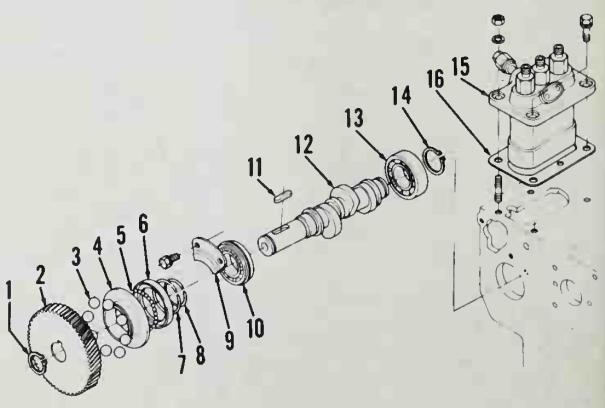


Fig. K2-3 – View of "F1" injection timing mark on flywheel and timing mark (M) on end plate of models so equipped. See text.

Fig. K2-2 – Exploded view of injection pump camshaft and governor components.

1. Snap ring
2. Gear
3. Large governor balls (8)
4. Sleeve
5. Small governor balls (30)
6. Governor case
7. Retainer ring
8. Retainer ring
9. Bearing retainer
10. Bearing
11. Key
12. Injection pump camshaft
13. Bearing
14. Snap ring
15. Injection pump
16. Shim gasket



models equipped with a flywheel housing, remove timing cover. Flywheel mark "F1" should be aligned with timing mark (M – Fig. K2-3) on cylinder block rear plate or flywheel housing. To adjust ignition timing, remove injection pump and add or delete shims (16 – Fig. K2-2). Each shim alters timing approximately 1½ crankshaft degrees. Add shims to retard timing or delete shims to advance timing. Be sure pump control rack pin properly engages operating fork when installing pump. Tighten pump retaining nuts or screws to 23.5-27.4 N·m. Reinstall delivery valve and spring and tighten delivery valve holder to 39.2-49.0 N·m.

GOVERNOR

All models are equipped with a flyball type governor mounted on front end of fuel injection pump camshaft. Refer to Fig. K2-2 and K2-4 for an exploded view of governor mechanism.

Slow idle speed for all models is 800 rpm and is adjusted by turning idle speed screw (37 – Fig. K2-4). High idle speed and maximum fuel limiting stop screws are sealed and should be adjusted by qualified personnel only. High idle speed should be 3500 rpm for Models Z600-B, ZB500C-B and ZB600C-B or 3200 rpm for all other models. Turn high idle speed screw (40) for adjustment.

Maximum fuel limiting stop should be set to prevent excessive smoke level at slight overload. To make adjustment, remove seal cap, loosen jam nut and turn spring housing (19) in to lower smoke level or out to raise smoke level.

COMPRESSION RELEASE

All models are equipped with a compression release which holds exhaust valves open slightly when compression release lever (9 – Fig. K2-5) is rotated. To adjust compression release, rotate engine crankshaft so piston in cylinder being adjusted is at top dead center on compression. Remove cover (3), loosen locknut (6) and back out adjusting screw (7). Rotate compression release lever to engaged position. Turn adjusting screw (7) in until it contacts exhaust rocker arm, then turn screw an additional 1½ turns. Tighten locknut and adjust remaining cylinders. Check operation of compression release being sure exhaust valves do not contact pistons.

COOLING SYSTEM

All engines are liquid cooled using a thermo-siphon type cooling system. Note that cooling fan is mounted on alternator. Recommended pressure rating for radiator cap is 88.25 kPa (13 psi).

Fan belt tension is correct if finger pressure applied against belt at mid-point between fan pulley and tension pulley deflects belt 7-9 mm. Relocate tension pulley to obtain desired belt tension.

AIR FILTER

All models are equipped with a dry type renewable air filter. Manufacturer recommends blowing out filter after every 100 to 200 hours of operation and renewing filter after six cleanings or one year.

REPAIRS

TIGHTENING TORQUES

Refer to following table for tightening torques. All values are in newton meters.

Connecting rod	26.5-30.4
Crankshaft nut	137.3-156.9
Crankshaft seal carrier	9.8-11.8
Cylinder head	
D650-B, D750-B, Z500-B, ZB500C-B	42.2-47.1
D850-B, D850-BC, Z600-B, ZB600C-B	58.8-63.7
Flywheel	53.9-58.8
Injection pump	23.5-27.4
Injector nozzle nut	29.4-49.0
Main bearing retainer screw	29.4-34.3

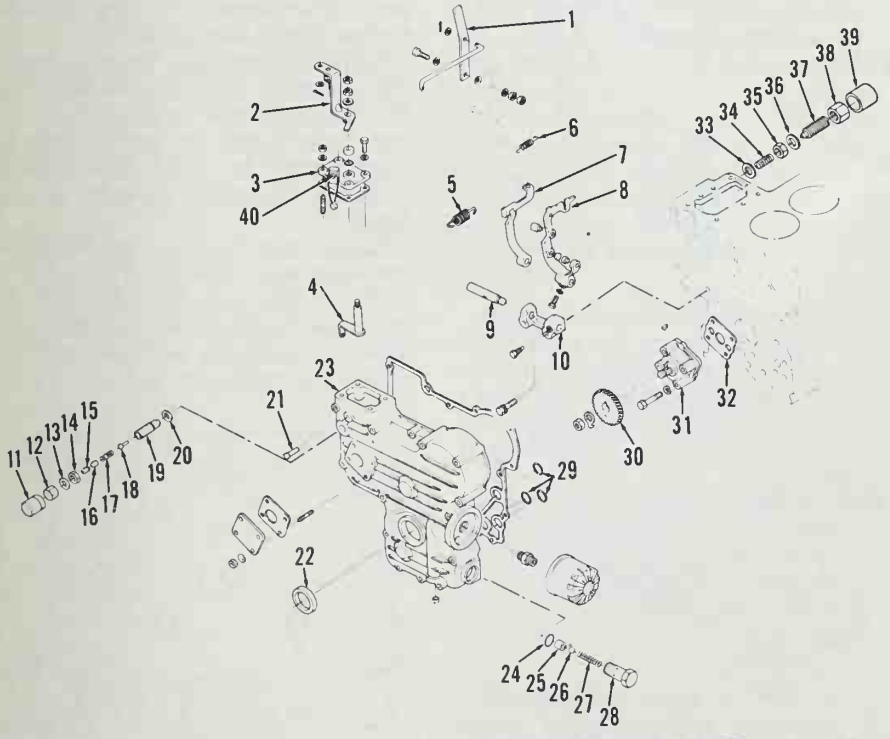


Fig. K2-4 – Exploded view of timing gear cover and associated components. Be sure "O" rings (29) are in place when installing cover (23).

1. Speed control
2. Control lever
3. Plate
4. Control arm
5. Governor spring
6. Start spring
7. Governor arm
8. Pump control arm
9. Pivot pin
10. Pivot block
11. Cap
12. Cap nut
13. Gasket
14. Locknut
15. Maximum fuel limiting screw
16. Spacer
17. Spring
18. Pin
19. Maximum fuel limiting body
20. Gasket
21. Start spring pin
22. Seal
23. Timing gear cover
24. "O" ring
25. Oil pressure relief valve seat
26. Relief valve ball
27. Spring
28. Valve body
29. "O" rings
30. Pump gear
31. Oil pump
32. Gasket
33. Gasket
34. Spring
35. Locknut
36. Gasket
37. Low idle speed screw
38. Cap nut
39. Cap
40. High idle speed screw

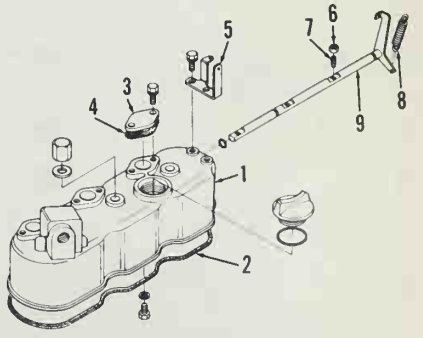


Fig. K2-5 – View of valve cover and compression release components.

1. Valve cover
2. Gasket
3. Cover
4. Gasket
5. Bracket
6. Locknut
7. Compression release screw
8. Spring
9. Compression release shaft

Main bearing screws
No. 1 ..... 19.6-23.5
Nos. 2 & 3 ..... 29.4-34.3
Oil pump 9.8-11.8
Rocker arm stand 16.7-20.6
Timing gear cover 9.8-11.3

COMPRESSION PRESSURE

Compression pressure should be 3138 kPa for Models D650-B, D750-B, Z500-B and ZB500C-B or 3236 kPa for all other models.

VALVE TAPPET GAP

Valve tappet gap should be adjusted with engine cold and piston at top dead center on compression. Remove rocker cover and turn rocker arm adjusting screws so valve gap for both valves is 0.145-0.185 mm.

CYLINDER HEAD

R&R AND OVERHAUL. Drain coolant, detach radiator hose then remove inlet and exhaust assemblies. Remove fan belt and disconnect injection lines. Remove rocker arm cover and rocker arm assembly. Unscrew cylinder head retaining screws and remove head.

Check flatness of head surface using a straight edge placed along sides and across mating surface. If a feeler gage of 0.03 mm thickness will pass under straight edge, then head must be resurfaced. If head is resurfaced, check valve-to-piston clearance as outlined in following paragraph.

To check valve-to-piston clearance, install head and gasket with valves and springs installed but with injectors removed. Tighten head fasteners to specified torque following sequence in Fig. K2-6A. Using a suitable measuring gage such as soft solder or Plastigage, insert gage between each valve and piston crown while rotating crankshaft through top dead center. Minimum allowable valve-to-piston clearance is 0.6 mm. Clearance may be increased by installing a shim gasket (20–Fig. K2-6) between cylinder head and head gasket. Shim gasket thickness is 0.2 mm.

Reverse removal procedure to reinstall cylinder head. Refer to Fig. K2-6A for cylinder head tightening sequence. Tighten cylinder head and rocker arm stand fasteners to specified torques. Adjust valve tappet gap and compression release as outlined in following and preceding sections.

VALVE SYSTEM

Both valves ride directly in cylinder head. Maximum allowable clearance between valve stem and valve guide is 0.1 mm. Valve guide diameter should be 7.010-7.025 mm while valve stem diameter should be 6.960-6.975 mm.

Valves seat directly in head. Valve seat and face angles are 45 degrees. Valve seat width should be 2.1 mm. When depth of valve head from cylinder head surface exceeds 1.1 mm, then head surface should be machined.

Valve springs are interchangeable. Valve spring free length should be 35.1-35.6 mm while installed height is 31 mm. Valve spring pressure at installed height should be 73.5 Newtons with a minimum allowable pressure of 64.7 Newtons.

Rocker arm bushings (6–Fig. K2-6) are renewable. Bushing ID should be 10.997-11.038 mm. Rocker shaft OD should be 10.973-10.984 mm. Maximum allowable clearance between shaft and rocker arm bushing is 0.15 mm.

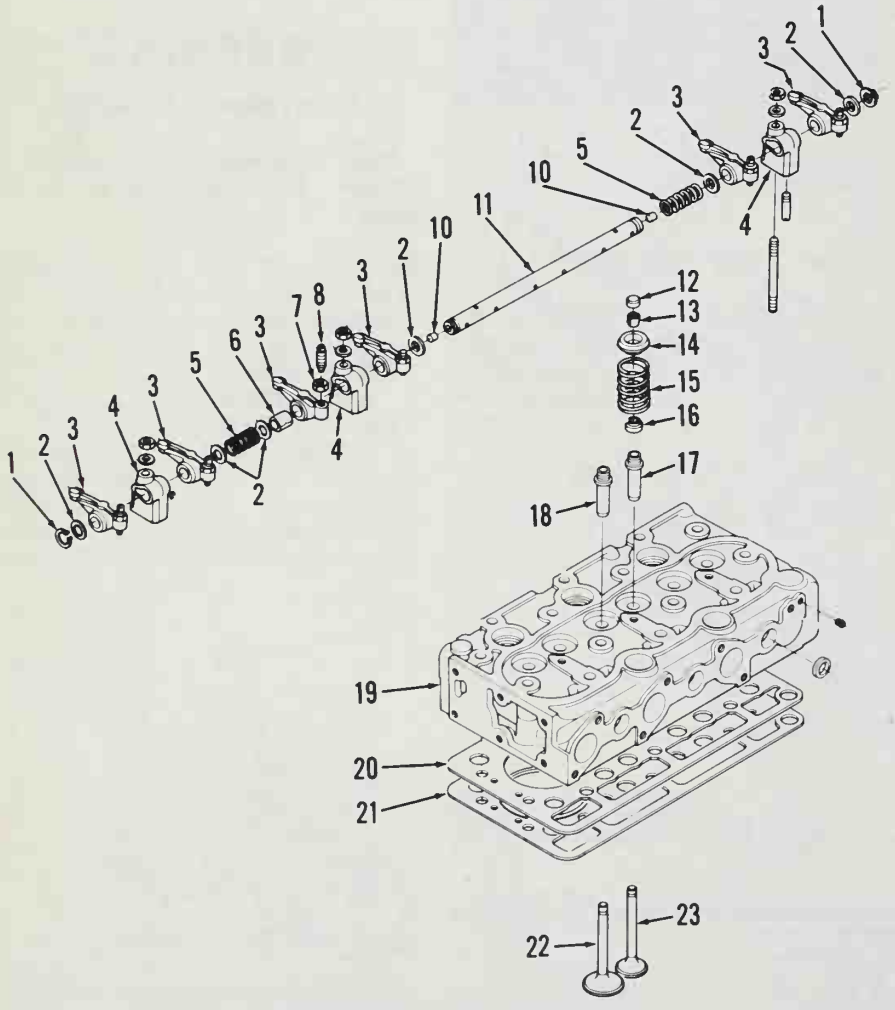


Fig. K2-6—Exploded view of valve train.

1. Snap ring
2. Washer
3. Rocker arm
4. Shaft stand
5. Spring
6. Bushing
7. Locknut
8. Adjusting screw
10. Set screw
11. Rocker shaft
12. Valve cap
13. Retainer keys
14. Retainer
15. Spring
16. Seal
17. Exhaust valve guide
18. Intake valve guide
19. Cylinder head
20. Shim
21. Gasket
22. Intake valve
23. Exhaust valve

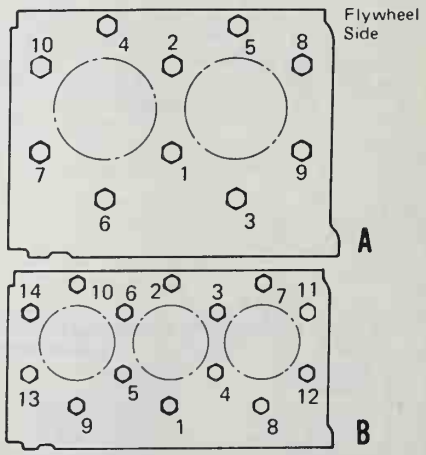


Fig. K2-6A—Follow sequence in diagram A when tightening cylinder head fasteners on two-cylinder models or diagram B on three-cylinder models.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE AND REINSTALL. Before removing an injector, or loosening injector lines, thoroughly clean injector, lines and surrounding area using compressed air and a suitable solvent.

To remove injector unit, first remove high pressure line leading from injection pump to injector. Disconnect bleed line by removing nut and banjo fitting, or by pulling line(s) from banjo nipple fitting (2–Fig. K2-7). With pressure and bleedback lines removed, unscrew injector from its mounting position on cylinder head.

When installing injector, make sure that machined seating surface in cylinder head is completely clean and free from carbon build-up. Use a new copper washer underneath injector nozzle and tighten injector carefully to 29.4-49.0 N·m.

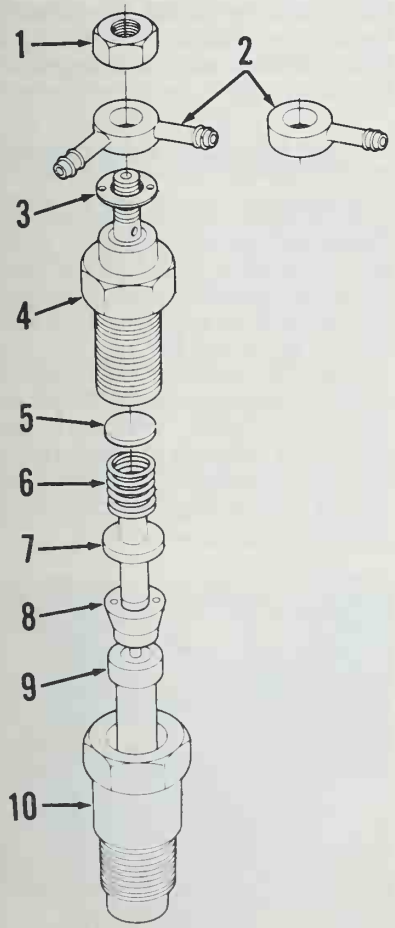


Fig. K2-7—Exploded view of injector.

1. Nut
2. By-pass fitting
3. Washer
4. Pressure fitting
5. Shim
6. Spring
7. Pressure pin
8. Spacer
9. Nozzle & valve
10. Nozzle nut

TESTING. A complete job of testing and adjusting the injector requires use of special test equipment. Only clean, approved testing oil should be used in tester tank. Nozzle should be tested for opening pressure, seat leakage and spray pattern. When tested, nozzle should open with a high-pitched buzzing sound, and cut off quickly at end of injection with a minimum of seat leakage and a controlled amount of back leakage.

Before conducting test, operate tester lever until fuel flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, and that possibilities are good that injector can be returned to service without disassembly.

OPENING PRESSURE. Open valve to tester gage and operate tester lever slowly while observing gage reading. Opening pressure should be 13.7 MPa (1990 psi).

Opening pressure is adjusted by adding or removing shims in shim pack (5–Fig. K2-7). Adding or removing one 0.1 mm thickness shim will change opening pressure approximately 980 kPa (140 psi).

SEAT LEAKAGE. Nozzle tip should not leak at a pressure less than 12.7 MPa (1846 psi). To check for leakage, actuate tester lever slowly and as gage needle approaches suggested test pressure, observe nozzle tip. Hold pressure for 10 seconds; if drops appear or nozzle tip becomes wet, valve is not seating, and injector must be disassembled and overhauled as later outlined.

NOTE: Leakage of tester check valve or connections will cause a false reading, showing up in this test as fast leakback. If a series of injectors fail to pass this test, the tester rather than injector units should be suspected.

SPRAY PATTERN. Spray pattern should be well atomized and slightly conical, emerging in a straight axis from nozzle tip. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder assembly. Refer to Fig. K2-7 for exploded view and proceed as follows:

Secure pressure fitting (4) in a soft jawed vise or holding fixture and remove nozzle nut (10). Place all parts in clean calibrating oil or diesel fuel as they are removed, using a compartmented pan and using extra care to keep parts from each injector together and separate from other units.

Clean exterior surfaces with a brass wire brush, soaking in an approved carbon solvent if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces.

Clean nozzle spray hole from inside using a pointed hardwood stick or wood splinter as shown in Fig. K2-8. Scrape carbon from pressure chamber using hooked scraper as shown in Fig. K2-9. Clean valve seat using brass scraper as shown in Fig. K2-10, then polish seat us-

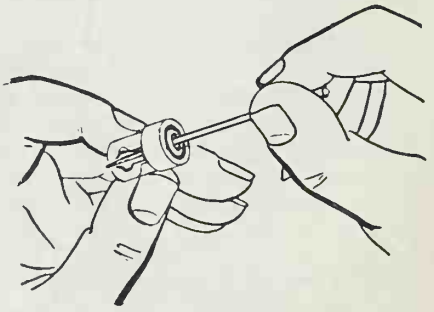


Fig. K2-8—Use a pointed hardwood stick to clean spray hole as shown.

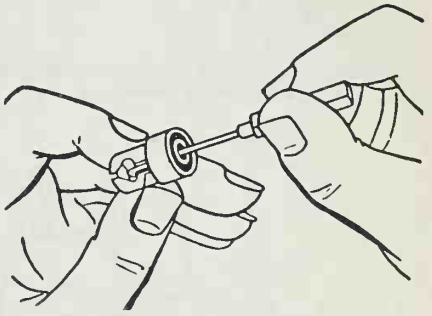


Fig. K2-9—Use hooked scraper to clean carbon from pressure chamber.

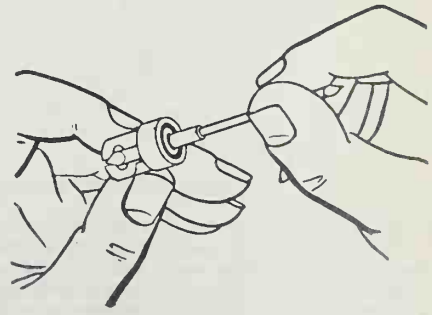


Fig. K2-10—Clean valve seat using brass scraper as shown.

ing wood polishing stick and mutton tallow as in Fig. K2-11.

Back flush nozzle using reverse flusher adapter. Reclean all parts by rinsing thoroughly in clean diesel fuel or calibrating oil and assemble while parts are immersed in cleaning fluid. Make sure adjusting shim pack is intact. Tighten nozzle retaining nut (10–Fig. K2-7) to a torque of 58.8-78.4 N·m. Do not overtighten, distortion may cause valve to stick and no amount of overtightening can stop a leak caused by scratches or dirt. Retest assembled injector as previously outlined.

GLOW PLUGS

Glow plugs are parallel connected with each individual glow plug grounding through mounting threads like a spark plug. Indicator light will glow after about 30 seconds if unit is operating satisfactorily and will fail to glow if circuit is open.

Glow plugs are rated at 10.5 volt, 7 ampere capacity. If indicator light fails to glow when start switch is held in "Heat" position an appropriate length of time, check for loose connections at switch, indicator lamp, glow plug connections and ground. Using an ohmmeter, check resistance of each glow plug in turn. Resistance between glow plug terminal and cylinder head should be approximately 1.6 ohms.

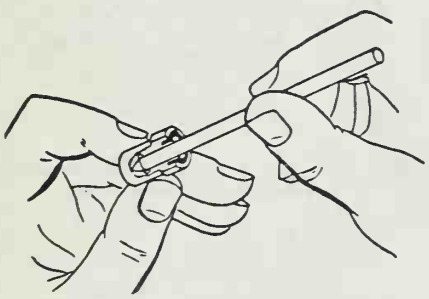


Fig. K2-11–Polish seat using polishing stick and mutton tallow.

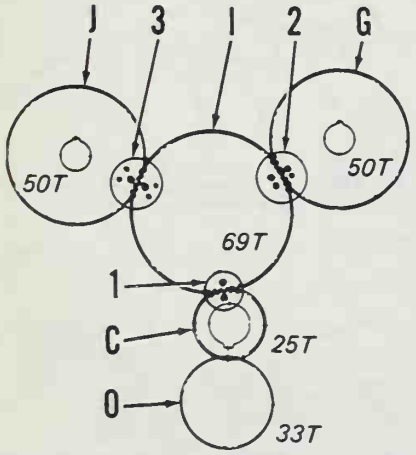


Fig. K2-12–Diagram of drive gears showing proper alignment of timing marks. Note three marks (3) on injection pump gear (J) and idler gear (I); two marks (2) on camshaft gear (G) and idler gear (I); single marks on crankshaft gear (C) and idler gear (I). No marks are used on oil pump gear (O).

INJECTION PUMP

All models are equipped with an injection pump similar to type shown in Fig. K2-1. The injection pump should be tested and overhauled by a shop qualified in diesel injection pump repair.

The injection pump tappets are actuated by lobes on injection pump camshaft (12–Fig. K2-2). Inspect camshaft each time injection pump is removed.

Tighten pump retaining nuts to 23.5-27.4 N·m and refer to INJECTION PUMP TIMING section.

TIMING GEARS AND COVER

REMOVE AND REINSTALL. To remove timing gear cover, remove cover just below injection pump and detach governor spring (5–Fig. K2-4) from governor arm (7). Detach control linkage to control lever (2). If radiator obstructs crankshaft pulley removal, then drain coolant and relocate radiator. Remove fan belt and fan, then unscrew crankshaft pulley nut and using a suitable puller, remove crankshaft pulley. Unscrew and remove timing gear cover.

Refer to Fig. K2-12 for proper alignment of timing marks on crankshaft, idler, camshaft and injection pump camshaft gears. Backlash between any two gears should be 0.04-0.11 mm. Refer to appropriate sections for gear service.

When installing timing gear cover, be sure three "O" rings (29–Fig. K2-4) are in place. Tighten timing cover screws to 9.8-11.3 N·m.

OIL PUMP

R&R AND OVERHAUL. To remove oil pump, first remove timing gear cover as previously outlined then unscrew and remove pump.

Clearance between inner and outer rotor measured as shown in Fig. K2-13 is 0.11-0.15 mm with an allowable limit of 0.2 mm. Clearance between outer rotor and pump body measured as shown in Fig. K2-14 is 0.07-0.15 mm with an allowable limit of 0.25 mm. Individual pump components are not available; pump must be serviced as a unit assembly.

Oil pressure relief ball (26–Fig. K2-4) and spring (27) are located in timing gear cover. Oil pressure should be 441 kPa and is not adjustable.

GOVERNOR

All models are equipped with a flyball type governor as shown in Fig. K2-2. Ball movement against governor sleeve (4) actuates governor lever (8–Fig. K2-4) which is connected to fuel injection control rack. Flyball movement is balanced by governor spring (5).

Governor components are accessible after removing timing gear cover. Inspect components and renew any which are excessively worn or damaged.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod are removed as a unit after removing oil pan, oil pickup and cylinder head. Unscrew rod cap retaining screws, detach rod cap and extract piston and rod.

Note that numbers are stamped on sides of rod and cap and should be on same side when assembled. Install piston and rod units so numbers on rod and cap are toward fuel injection pump side of engine. Tighten rod screws to 26.5-30.4 N·m.

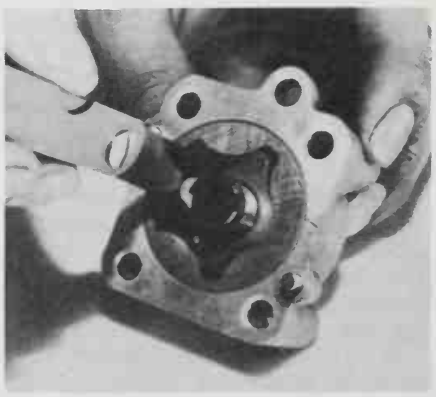


Fig. K2-13–Measure clearance between inner and outer oil pump rotors as shown. Desired clearance is 0.11-0.15 mm.

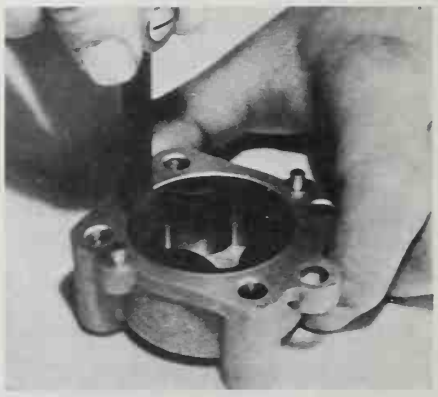


Fig. K2-14–Measure clearance between outer rotor and oil pump body as shown. Desired clearance is 0.07-0.15 mm.

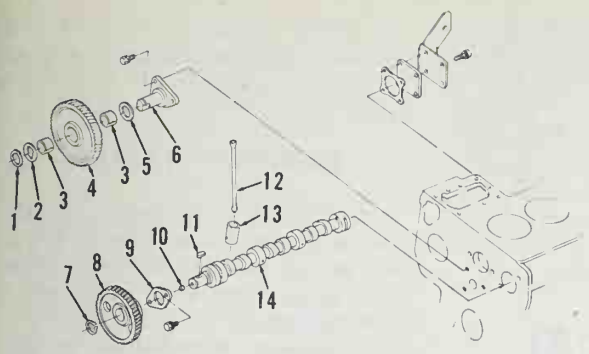


Fig. K2-16—Exploded view of camshaft and idler gear assemblies.

1. Snap ring
2. Slotted washer
3. Bushing
4. Idler gear
5. Washer
6. Idler shaft
7. Snap ring
8. Gear
9. Retainer
10. Plug
11. Key
12. Push rod
13. Tappet
14. Camshaft

CAMSHAFT

R&R AND OVERHAUL. To remove camshaft, remove cylinder head and timing gear cover as previously outlined, then remove tappets. Unscrew camshaft retainer plate (9—Fig. K2-16) and withdraw camshaft from cylinder block. If necessary, press camshaft gear (8) off camshaft.

Camshaft lobe height should be 26.88 mm with a wear limit of 26.83 mm. Camshaft bearing journal diameter should be 32.934-32.950 mm while inner diameter of renewable camshaft bearings is 33.000-33.025 mm. Maximum allowable clearance between camshaft journal and bearing is 0.15 mm. With camshaft supported in V-blocks at outer bearing journals, maximum allowable runout measured at either center bearing journal is 0.02 mm.

When installing camshaft gear on camshaft, first install retainer (9—Fig. K2-16). Heat camshaft gear to approximately 80° C (176° F) and push gear onto camshaft until there is 0.07-0.22 mm clearance between retainer and side of camshaft journal as shown in Fig. K2-17. Refer to TIMING GEARS AND COVER section to properly align camshaft gear timing marks during installation.

PISTON AND RINGS

All models are equipped with two compression rings and an oil control ring surrounding an aluminum, cam-ground piston. Piston and rings are available in 0.5 mm oversize.

Standard piston diameter measured at skirt perpendicular to piston pin is 64.000-64.019 mm for Model D650-B, 68.000-68.019 mm for Models D750-B, Z500-B and ZB500C-B, or 72.000-72.019 mm for all other models. Piston to cylinder clearance should be 0.11-0.149 mm for Model D650-B or 0.115-0.154 mm for all other models.

Piston pin boss inner diameter should be 20.000-20.013 mm for all models with a wear limit of 20.03 mm.

Piston ring end gap is 0.25-0.40 mm for compression rings and 0.20-0.40 mm for oil ring on all models. Maximum wear limit for any ring is 1.25 mm. The top compression ring is a keystone type and side clearance is not measured. Side clearance for second compression ring should be 0.085-0.112 mm and for oil ring should be 0.020-0.052 mm.

PISTON PIN

A full floating piston pin is used on all models. Clearance between pin and piston bosses should be 0.002 mm interference to 0.010 mm loose. Clearance between pin and connecting rod bushing is 0.014-0.038 mm.

CONNECTING ROD AND BEARINGS

Connecting rods are equipped with a renewable bushing in the small end and insert type bearings in the big end. Inner diameter of big end bearing should be 37.004-37.050 mm while clearance between bearing and crankpin should be 0.029-0.091 mm. Bearings are available in 0.20 and 0.40 mm undersizes.

Small end bushing inner diameter is 20.025-20.040 mm. Clearance between piston pin and bushing is 0.014-0.038 mm.

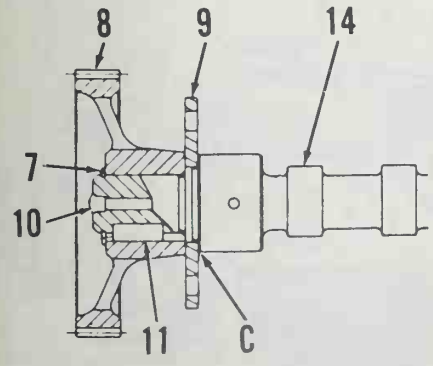


Fig. K2-17—Install gear (8) on camshaft (14) so there is 0.07-0.22 mm clearance (C) between retainer (9) and side of front camshaft journal.

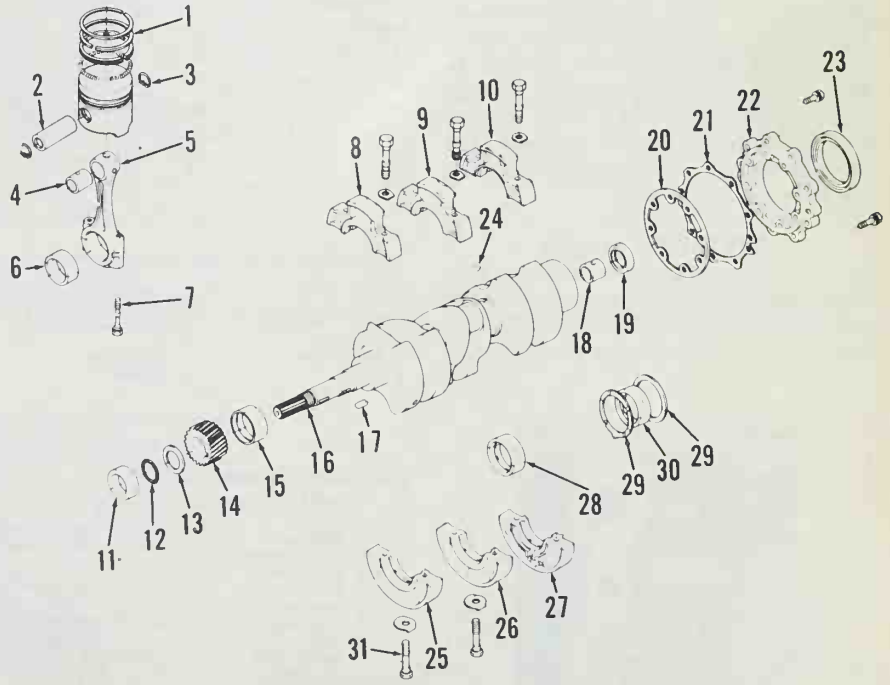


Fig. K2-18—Exploded view of piston, rod and crankshaft assembly.

1. Piston rings
2. Piston pin
3. Retainer
4. Bushing
5. Connecting rod
6. Bearing
7. Screw
8. Upper bearing carrier half, front
9. Upper bearing carrier half, middle
10. Upper bearing carrier half, rear
11. Spacer
12. "O" ring
13. Oil slinger
14. Gear
15. Bearing
16. Crankshaft
17. Key
18. Bushing
19. Seal
20. Gasket
21. Gasket
22. Seal carrier
23. Seal
24. Plug
25. Lower bearing carrier half, front
26. Lower bearing carrier half, middle
27. Lower bearing carrier half, rear
28. Main bearing
29. Thrust washers
30. Rear main bearing
31. Locator screw

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove pistons and rods, timing gear cover, crankshaft gear, flywheel and seal carrier (22 – Fig. K2-18). Free bearing carriers (25, 26 and 27) by unscrewing locating screws (31 – Fig. K2-18 or K2-19). Carefully withdraw crankshaft and bearing carrier assembly out rear of cylinder block. Note that bearing carriers are a tight fit in cylinder block to prevent oil loss between oil passages in block and bearing carriers. Remove screws securing bearing carrier halves and separate halves from crankshaft. Note that main bearing carriers are not interchangeable.

Standard main journal diameter is 43.934-43.950 mm. Main bearing clearance for front bearing (15 – Fig. K2-18) should be 0.034-0.106 mm while clearance for all other bearings should be 0.034-0.092 mm. Main bearings are available in standard sizes only.

Crankshaft end play should be 0.15-0.31 mm and is controlled by thrust washers (29) which are available in standard thickness only. Install thrust washers so grooved side is away from bearing carrier.

Standard size of crankpin journals is 36.959-36.975 mm. Rod bearings are offered in 0.20 and 0.40 mm undersizes.

To reinstall crankshaft, reverse removal procedure. Tighten rear bearing carrier screws to 19.6-23.5 N·m and screws of center bearing carriers to 29.4-34.3 N·m. Tighten carrier locating screws (31) to 29.4-34.3 N·m. Install seal carrier so top mark is towards head surface and tighten screws in a diagonal pattern to 9.8-11.8 N·m.

CYLINDER LINER

All models are equipped with dry type cylinder liners. Use suitable removal and installation tools to renew defective liners. Install cylinder liner so distance from top of liner to cylinder block head surface is plus or minus 0.025 mm.

Standard inner diameter of cylinder liner is 64.000-64.019 mm for Model D650-B, 68.000-68.019 mm for Models D750-B, Z500-B and ZB500C-B and 72.000-72.019 mm for all other models. The cylinder liner may be bored for 0.5 mm oversize piston installation.

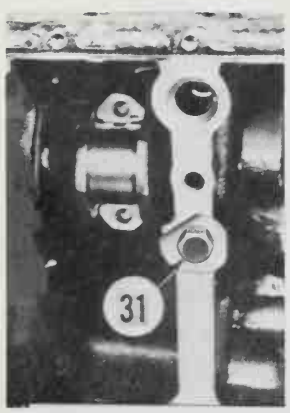


Fig. K2-19 – View showing location of locating screw (31) which secures bearing carrier to block.

ELECTRICAL SYSTEM

ALTERNATOR

Alternator (2 – Fig. K2-20) is mounted on water outlet (3) and drives fan (1). The alternator is available only as a unit assembly.

Alternator should produce 14 volts maximum with a minimum charging current of 8½ amperes at alternator speed of 4250 rpm.

ELECTRIC STARTER

Refer to Fig. K2-21 for an exploded view of Nippon Denso electric starter used on all models. Minimum brush length is 10.7 mm while wear limit of commutator is 30.7 mm diameter. With no load imposed on starter and using an 11 volt source, the starter shaft should rotate at 5000 rpm or more while drawing less than 50 amperes current.

Pinion engagement depth is adjusted by turning hook (H – Fig. K2-21). With starter pinion in engaged position, distance between collar (8) and pinion should be 0.1-0.4 mm. Turn hook (H) so pinion engagement depth is correct.

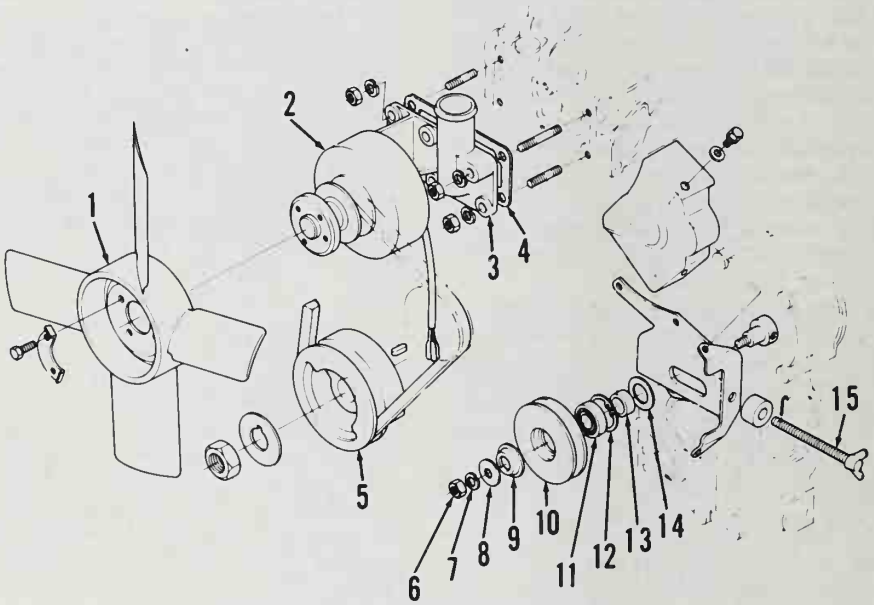


Fig. K2-20 – View of alternator and tensioner pulley.

1. Fan
2. Alternator
3. Water outlet
4. Gasket
5. Crankshaft pulley
6. Nut
7. Lockwasher
8. Washer
9. Collar
10. Tensioner pulley
11. Bearing
13. Sleeve
14. Washer
15. Belt tension adjusting screw

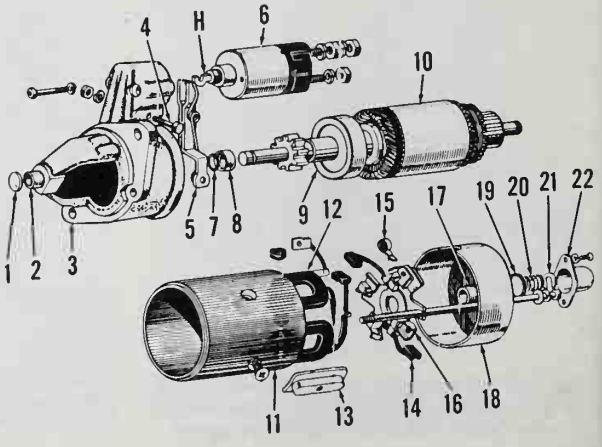


Fig. K2-21 – Exploded view of electric starter.

1. Cap
2. Bushing
3. Drive housing
4. Pivot bolt
5. Fork
6. Solenoid
7. Snap ring
8. Collar
9. Starter drive
10. Armature
11. Frame
12. Field coils
13. Field magnets
14. Brush
15. Brush spring
16. Brush plate
17. Bushing
18. End frame
19. Packing
20. Spring
21. Spring retainer
22. Cap

KUBOTA

Model	No. Cyls.	Bore (mm)	Stroke (mm)	Displ. (cc)
D1102-B	3	76	82	1115
D1102-BC	3	76	82	1115
D1302-B	3	82	82	1299
D1402-B	3	85	82	1395
S2200-B	6	76	82	2231
S2600-B	6	82	82	2598
V1502-B	4	76	82	1487
V1502-BC	4	76	82	1487
V1702-B	4	82	82	1732
V1902-B	4	85	82	1861
VT1502-B	4	76	82	1487
Z751-B	2	76	82	743
Z851-B	2	82	82	866

All Kubota engines in this section are liquid-cooled, four-stroke diesel engines having two, three, four or six cylinders.

MAINTENANCE

LUBRICATION

Recommended crankcase oil is SAE 10W-40 with API classification CB or CC. Crankcase capacity is 6.7 liters for Models D1102-B, D1102-BC, D1302-B and D1402-B; 12.7 liters for Models S2200-B and S2600-B; 9 liters for Models V1502-B, V1502-BC, V1702-B, V1902-B and VT1502-B; 3.7 liters for Models Z751-B and Z851-B.

All models are equipped with a pressure lubrication system. Oil is directed from the oil pump to the oil pressure relief valve and oil filter. Oil is routed through an oil passage in the cylinder block to the main bearings then through crankshaft oil passages to the crankpins. The cylinder block oil passage also routes oil to the cylinder head to lubricate the valve train.

Normal oil pressure is 294.2-441.3 kPa for Models S2200-B, Z751-B and Z851-B or 294.2-392.2 kPa for all other models.

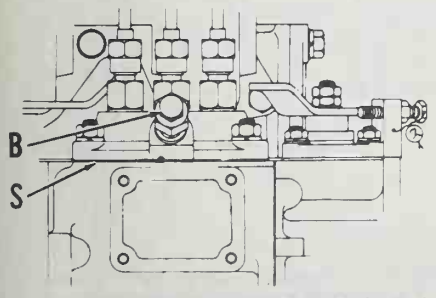


Fig. K3-1 – Injection timing is adjusted by adding or deleting shims (S) between pump and engine block. A jet-start cock (5 – Fig. K3-12) is installed in place of bleed screw (B) on some models.

Refer to OIL PUMP section for pump service.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter is mounted on side of engine. Filter element should be renewed after every 400 hours of engine operation.

BLEED FUEL SYSTEM. To bleed fuel system, remove bleed screw on fuel filter bracket, then open fuel valve. Reinstall bleed screw when air-free fuel flows. Unscrew injection pump bleed screw (B – Fig. K3-1), open fuel valve, then reinstall bleed screw when air-free fuel appears. Disconnect high pressure fuel lines from injectors. Rotate engine to operate fuel injection pump, then reconnect fuel lines when air-free fuel flows from fuel lines.

INJECTION PUMP TIMING. Injection pump timing is adjusted using shims (S – Fig. K3-1). To check injection pump timing proceed as follows: Disconnect high pressure line for number 1 cylinder from injection pump then unscrew delivery valve holder (1 – Fig. K3-2) and remove valve spring (2) and delivery valve assembly (4). Reinstall delivery valve holder (1) and connect a suitable

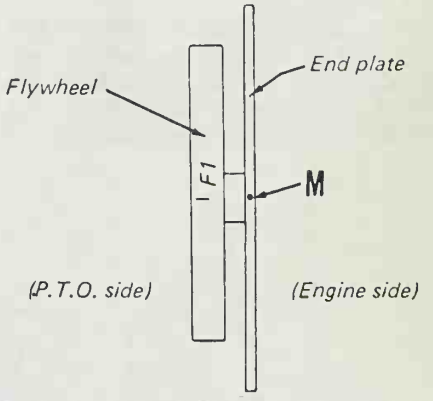
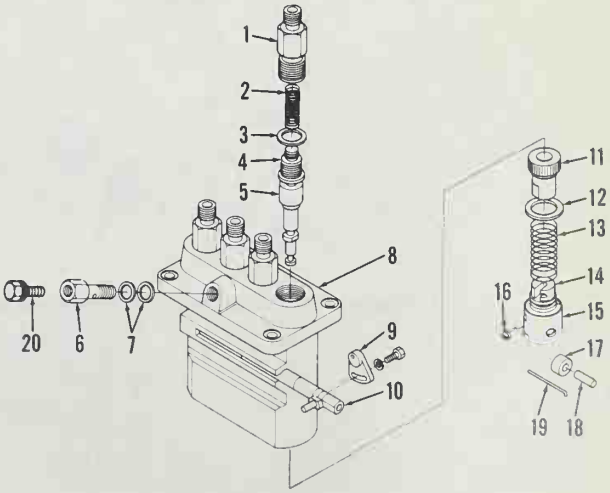


Fig. K3-3 – View of "F1" injection timing mark on flywheel of all models and timing mark (M) on end plate of models so equipped. See text.

Fig. K3-2 – Exploded view of injection pump used on four-cylinder engines. Other models are similar. A jet-start cock is installed in place of bleed screw (20) on some models.

1. Delivery valve holder
2. Spring
3. Shim
4. Deliver valve assy.
5. Plunger
6. Inlet fuel fitting
7. Gaskets
8. Pump body
9. Plate
10. Control rack
11. Control sleeve
12. Washer
13. Spring
14. Spring seat
15. Tappet
16. Guide pin
17. Roller
18. Pin
19. Pin



spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full open position. Rotate engine flywheel slowly in counter-clockwise direction until fuel just stops flowing from spill pipe. On models equipped with a flywheel housing, remove timing cover. Flywheel mark "F1" should be aligned with timing mark (M – Fig. K3-3) on cylinder block rear plate or timing pointer on flywheel housing. To adjust injection timing, remove injection pump and add or delete shims (S – Fig. K3-1). Each shim alters timing approximately 1½ crankshaft degrees. Add shims to retard timing or delete shims to advance timing. Be sure pump control rack pin properly engages operating fork when installing pump. Tighten pump retaining nuts or screws to 23.5-27.4 N·m. Reinstall delivery valve and spring and tighten delivery valve holder to 39.2-49.0 N·m.

GOVERNOR

All models are equipped with a flyball type governor mounted on front end of fuel injection pump camshaft. Refer to Fig. K3-4 for an exploded view of governor linkage.

Slow idle speed for all models is 800 rpm and is adjusted by turning idle speed screw (30 – Fig. K3-4). High idle speed and maximum fuel limiting stop screws are sealed and should be adjusted by qualified personnel only. High idle speed should be 2800 rpm for Model S2200-B or 3000 rpm for all other models. Turn high idle speed screw (3) for adjustment.

Maximum fuel limiting stop should be set to prevent excessive smoke level at slight overload. To make adjustment, remove seal cap, loosen jam nut and turn spring housing (21) in to lower smoke level or out to raise smoke level.

Some models are equipped with a "torque rise" adjustment screw (12). Position of screw is set at factory and manufacturer does not recommend further adjustment.

COMPRESSION RELEASE

All models are equipped with a compression release which holds exhaust valves open slightly when compression release lever (1 – Fig. K3-5) is rotated. To adjust compression release, rotate engine crankshaft so piston in cylinder being adjusted is at top dead center on compression. Remove cover (8), loosen locknut (3) and back out adjusting screw (2). Rotate compression release lever to engaged position. Turn adjusting screw (2) in until it contacts exhaust rocker arm, then turn screw an additional 1½ turns. Tighten locknut and adjust remaining cylinders. Check operation of compression release being sure exhaust valves do not contact pistons.

COOLING SYSTEM

All engines are liquid cooled with Models Z751-B and Z851-B using thermo-siphon circulation while all other models are equipped with a water pump.

Recommended pressure rating for radiator cap is 88.25 kPa (13 psi). On all models except Z751-B and Z851-B, thermostat opening temperature is 80.5-83.5° C. Fan belt tension is correct if finger pressure applied to belt at midpoint between alternator pulley and crankshaft pulley deflects belt 7-9 mm.

AIR FILTER

All models are equipped with a dry type renewable air filter. Manufacturer recommends blowing out filter after every 100 to 200 hours of operation and renewing filter after six cleanings or one year.

REPAIRS

TIGHTENING TORQUES

Refer to following table for tightening torques. All values are in newton meters.

Connecting rod	36.3-41.2
Crankshaft nut	
S2200-B, S2600-B	196-215
All other models	137-156
Crankshaft seal carrier	23.5-27.4
Cylinder head	
S2200-B, S2600-B	73.5-83.4
All other models	73.5-78.4
Flywheel	98.1-107.9
Injection pump	23.5-27.4
Injector nozzle nut	29.4-49.0
Main bearing retainer screw	63.7-68.6

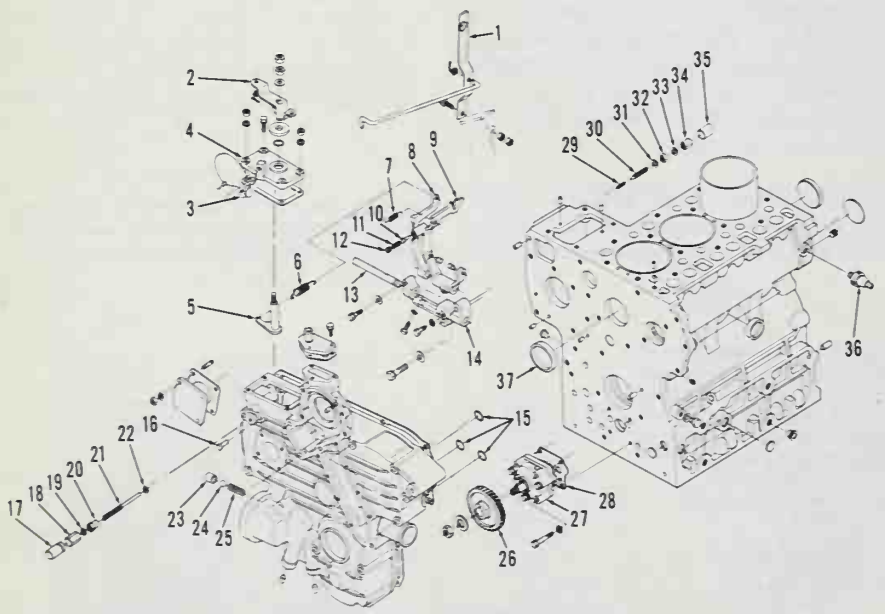


Fig. K3-4 – Exploded view of timing gear cover and associated components.

1. Speed control
2. Control lever
3. High idle adjusting screw
4. Plate
5. Control arm
6. Governor spring
7. Start spring
8. Governor arm
9. Governor lever
10. Plunger
11. Spring
12. Set screw
13. Pivot pin
14. Pivot block
15. "O" rings
16. Pin
17. Cap
18. Cap nut
19. Gasket
20. Locknut
21. Maximum fuel limiting screw
22. Gasket
23. Valve seat
24. Relief valve ball
25. Spring
26. Gear
27. Oil pump
28. Gasket
29. Spring
30. Low idle adjusting screw
31. Gasket
32. Locknut
33. Gasket
34. Cap nut
35. Cap
36. Oil pressure sender

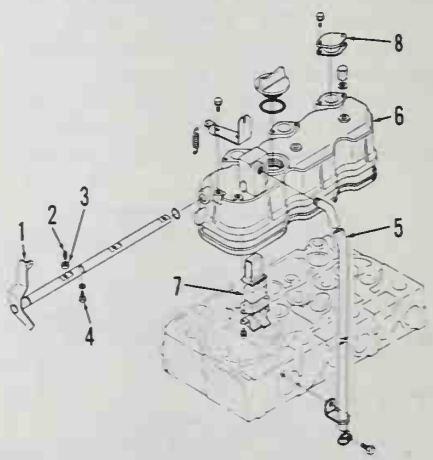


Fig. K3-5 – Exploded view of valve cover and compression release components.

1. Compression release shaft
2. Compression release screw
3. Locknut
4. Screw
5. Vent tube
6. Valve cover
7. Breather
8. Cover

Main bearing screws	29.4-34.3
Oil pump	9.8-11.8
Rocker arm stand	17.4-20.3
Timing gear cover	23.5-27.4

WATER PUMP

All Models Except Z751-B And Z851-B

R&R AND OVERHAUL. To remove water pump, drain coolant and if necessary, relocate radiator for access to pump. Remove fan belt, fan, spacer and pulley then unbolt and remove pump from timing gear cover.

Using a suitable puller, pull flange (2–Fig. K3-8) off shaft. Disengage circlip (3), then push shaft and bearing assembly (4) out front of housing. Disassemble as required.

Shaft and bearings (4) are available only as a unit assembly.

COMPRESSION PRESSURE

Compression pressure should be 3334 kPa for Models D1302-B, V1702-B and Z851-B or 3236 kPa for all other models. Compression pressure readings should not vary more than 10 per cent.

CYLINDER HEAD

R&R AND OVERHAUL. Drain coolant, detach by-pass hose then remove alternator, inlet and exhaust manifolds. Disconnect fuel injection lines and remove rocker arm cover and rocker arm assembly. Unscrew cylinder head retaining screws and remove head.

Check flatness of head surface using a straight edge placed along sides and across mating surface. If a 0.03 mm feeler gage will pass under straight edge, then head must be resurfaced. If head is resurfaced, check valve-to-piston clearance as outlined in following paragraph.

To check valve-to-piston clearance, install head and gasket with valves and springs installed but with injectors removed. Tighten head fasteners to specified torque following sequence in Fig. K3-9. Using a suitable measuring gage such as soft solder or Plastigage, insert gage between each valve and piston crown while rotating crankshaft through top dead center. Minimum allowable valve-to-piston clearance is 0.9 mm. Clearance may be increased by installing a shim gasket (20–Fig. K3-10) between cylinder head and head gasket. Shim gasket thickness is 0.15 mm.

Reverse removal procedure to reinstall cylinder head. Refer to Fig. K3-9 for cylinder head tightening sequence. Tighten cylinder head and rocker arm fasteners to specified torques. Adjust valve tappet gap and compression release as outlined in following and preceding sections.

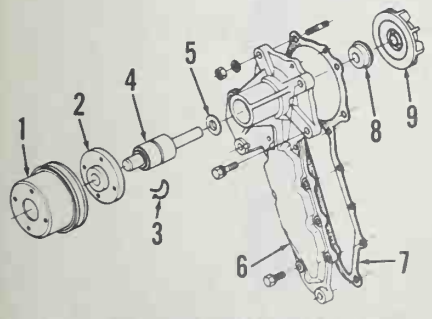


Fig. K3-8 – Exploded view of water pump.

1. Pulley
2. Flange
3. Circlip
4. Shaft & bearing assy.
5. Slinger
6. Pump body
7. Gasket
8. Seal
9. Impeller

VALVE TAPPET GAP

Valve tappet gap should be adjusted with engine cold and piston at top dead center on compression. Remove rocker cover and turn rocker arm adjusting screws so valve gap for both valves is 0.18-0.22 mm.

VALVE SYSTEM

Both valves ride directly in cylinder head. Maximum allowable clearance between valve stem and valve guide is 0.1 mm. Valve guide diameter is 8.015-8.030 mm while valve stem diameter is 7.950-7.975 mm.

Valves seat directly in head. Valve seat and face angles are 45 degrees. Valve seat width should be 2.1 mm. When depth of valve head from cylinder head surface exceeds 1.3 mm, then head surface should be machined.

Valve springs are interchangeable. Valve spring free length should be 41.7-42.2 mm while installed height is 35.15 mm. Valve spring pressure at installed height should be 117.7 Newtons with a minimum allowable pressure of 100.0 Newtons.

Rocker arm bushings (6–Fig. K3-10) are renewable. Bushing ID is 14.002-14.043 mm while rocker shaft OD is 13.973-13.984 mm. Maximum allowable clearance between shaft and rocker arm bushing is 0.15 mm.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE AND REINSTALL. Before removing an injector, or loosening injector lines, thoroughly clean injector, lines and surrounding area using com-

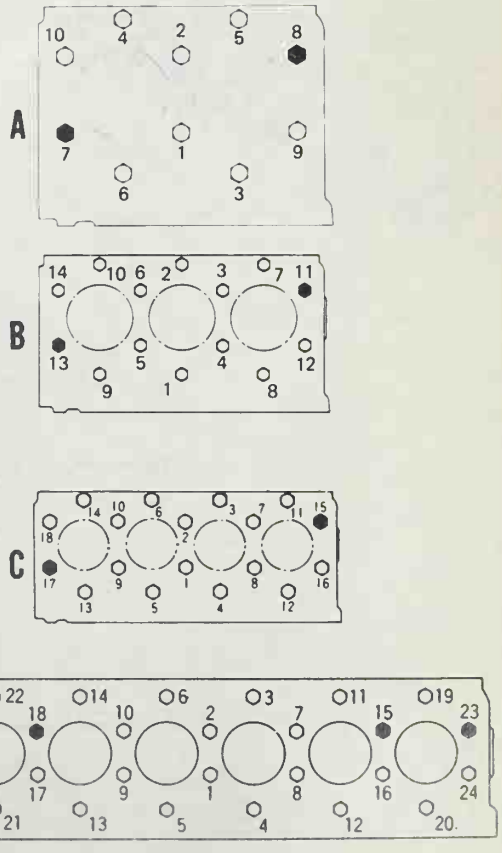


Fig. K3-9 – When tightening cylinder head fasteners, follow sequence in drawing (A) for two-cylinder engines; drawing (B) for three-cylinder engines; drawing (C) for four-cylinder engines; drawing (D) for six-cylinder engines.

pressed air and a suitable solvent.

To remove injector unit, first remove high pressure line leading from injection pump to injector. Disconnect bleed line by removing nut and banjo fitting, or by pulling line(s) from banjo nipple fitting (2–Fig. K3-11). With pressure and bleed-back lines removed, unscrew injector from its mounting position on cylinder head.

When installing injector, make sure that machined seating surface in cylinder head is completely clean and free from carbon build-up. Use a new copper washer underneath injector nozzle and tighten injector carefully to 29.4-49.0 N·m.

TESTING. A complete job of testing and adjusting the injector requires use of special test equipment. Only clean, approved testing oil should be used in tester tank. Nozzle should be tested for opening pressure, seat leakage, back leakage and spray pattern. When tested, nozzle should open with a high-pitched buzzing sound, and cut off quickly at end of injection with a minimum of seat leakage and a controlled amount of back leakage.

Before conducting test, operate tester lever until fuel flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, and that possibilities are good that injector can be returned to service without disassembly.

OPENING PRESSURE. Open valve to tester gage and operate tester lever slowly while observing gage reading. Opening pressure should be 13.7 MPa (1990 psi).

Opening pressure is adjusted by adding or removing shims in shim pack (5–Fig. K3-11). Adding or removing one 0.1 mm thickness shim will change opening pressure approximately 980 kPa (140 psi).

SEAT LEAKAGE. Nozzle tip should not leak at a pressure less than 12.7 MPa (1846 psi). To check for leakage, actuate tester lever slowly and as gage needle approaches suggested test pressure, observe nozzle tip. Hold pressure for 10 seconds; if drops appear or nozzle tip becomes wet, valve is not seating, and injector must be disassembled and overhauled as later outlined.

NOTE: Leakage of tester check valve or connections will cause a false reading, showing up in this test as fast leakback. If a series of injectors fail to pass this test, the tester rather than injector units should be suspected.

SPRAY PATTERN. Spray pattern should be well atomized and slightly conical, emerging in a straight axis from nozzle tip. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder assembly. Refer to Fig. K3-11 for exploded view and proceed as follows:

Secure nozzle in a soft jawed vise or holding fixture and remove cap nut (10). Place all parts in clean calibrating oil or

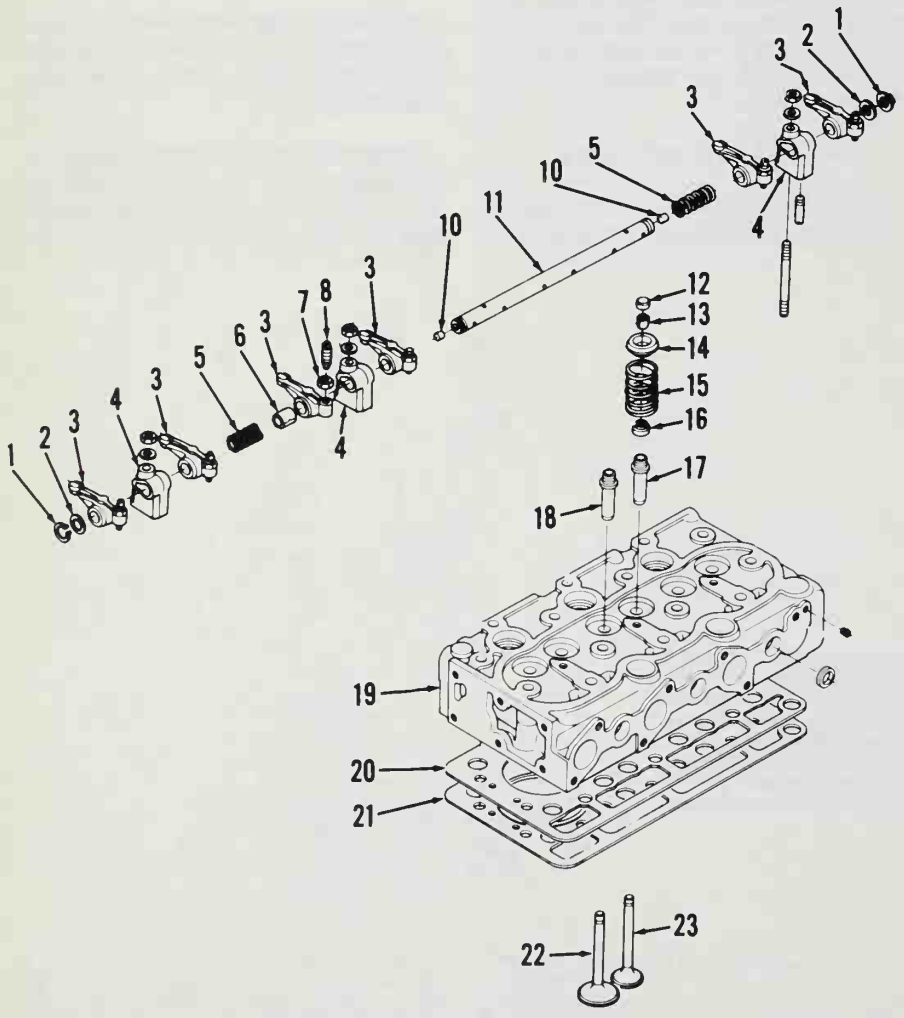


Fig. K3-10—Exploded view of valve train.

1. Snap ring
2. Washer
3. Rocker arm
4. Shaft stand
5. Spring
6. Bushing
7. Locknut
8. Adjusting screw
10. Set screw
11. Rocker shaft
12. Valve cap
13. Retainer keys
14. Retainer
15. Spring
16. Seal
17. Exhaust valve guide
18. Intake valve guide
19. Cylinder head
20. Shim
21. Gasket
22. Intake valve
23. Exhaust valve

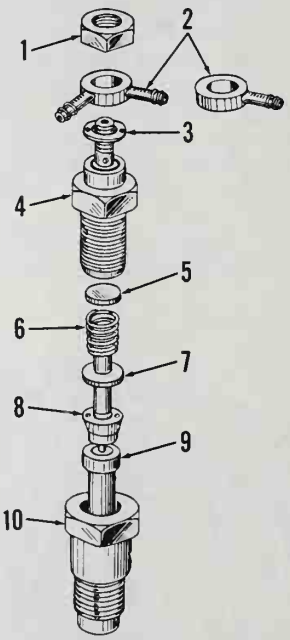


Fig. K3-11—Exploded view of injector.

1. Nut
2. By-pass fitting
3. Washer
4. Pressure fitting
5. Shim
6. Spring
7. Pressure pin
8. Spacer
9. Nozzle & valve
10. Nozzle nut

diesel fuel as they are removed, using a compartmented pan and using extra care to keep parts from each injector together and separate from other units which are disassembled at the time.

Clean exterior surfaces with a brass wire brush, soaking in an approved carbon solvent if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces.

Clean nozzle spray hole from inside using a pointed hardwood stick or wood splinter as shown in Fig. K3-15. Scrape carbon from pressure chamber using hooked scraper as shown in Fig. K3-16. Clean valve seat using brass scraper as shown in Fig. K3-17, then polish seat using wood polishing stick and mutton tallow as in Fig. K3-18.

Back flush nozzle using reverse flusher adapter. Reclean all parts by rinsing thoroughly in clean diesel fuel or calibrating oil and assemble while parts are immersed in cleaning fluid. Make sure adjusting shim pack is intact. Tighten nozzle retaining nut (10–Fig. K3-11) to a torque of 58.8-78.4 N·m. Do not overtighten, distortion may cause valve to stick and no amount of overtightening can stop a leak caused by scratches or dirt. Retest assembled injector as previously outlined.

GLOW PLUGS

Glow plugs are parallel connected with each individual glow plug grounding through mounting threads like a spark plug. Indicator light will glow after about 30 seconds if unit is operating satisfactorily and will fail to glow if circuit is open.

Glow plugs are rated at 10.5 volt, 7 ampere capacity. If indicator light fails to glow when start switch is held in "Heat" position an appropriate length of time, check for loose connections at switch, indicator lamp, glow plug connections and ground. Using an ohmmeter, check resistance of each glow plug in turn. Resistance between glow plug terminal and cylinder head should be approximately 1.6 ohms.

INJECTION PUMP

All models are equipped with an injection pump similar to type shown in Fig. K3-2. The injection pump should be tested and overhauled by a shop qualified in diesel injection pump repair.

The injection pump tappets are actuated by lobes on injection pump camshaft (14–Fig. K3-20). Inspect camshaft each time injection pump is removed.

Tighten pump retaining nuts to 23.5-27.4 N·m and refer to INJECTION PUMP TIMING section.

TIMING GEARS AND COVER

REMOVE AND REINSTALL. To remove timing gear cover, drain coolant and relocate radiator. Remove cover just below injection pump and detach governor spring (6–Fig. K3-4) from governor arm (8). Detach control linkage to control lever (5). Remove fan belt and fan then unscrew crankshaft pulley nut and using a suitable puller remove crankshaft pulley. Unbolt and remove timing gear cover.

Refer to Fig. K3-21 for proper alignment of timing marks on crankshaft,

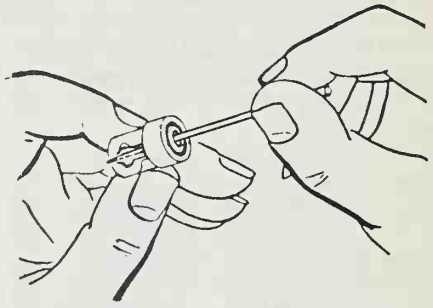


Fig. K3-15—Use a pointed hardwood stick to clean spray hole as shown.

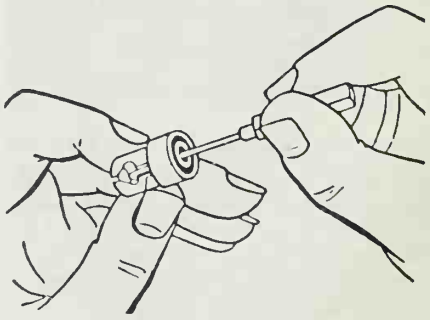


Fig. K3-16—Use a hooked scraper to clean carbon from pressure chamber.

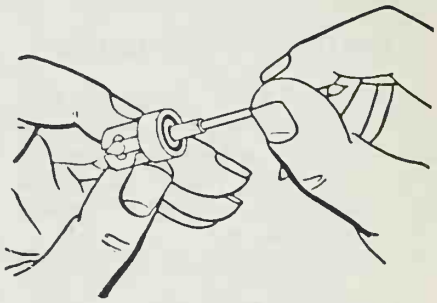


Fig. K3-17—Clean valve seat using brass scraper as shown.

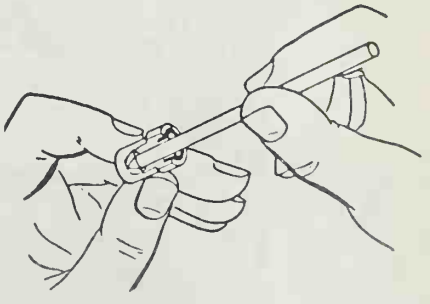


Fig. K3-18—Polish seat using polishing stick and mutton tallow.

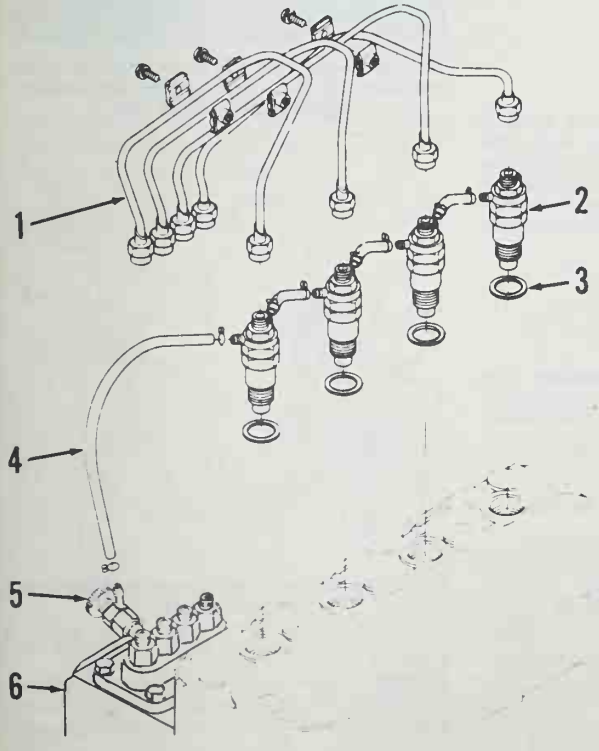


Fig. K3-12—View of fuel injection system using jet-start cock (5) on Model V1502-B. Other models are similar.

1. High pressure lines
2. Injector
3. Washer
4. Return line
5. Jet-start cock
6. Injection pump

idler, camshaft and injection pump camshaft gears. Backlash between any two gears should be 0.04-0.11 mm. Refer to appropriate sections for gear service.

When installing timing gear cover, be sure three "O" rings (15–Fig. K3-4) are in place. Tighten timing gear cover screws to 23.5-27.4 N·m.

OIL PUMP

R&R AND OVERHAUL. To remove oil pump, first remove timing gear cover as previously outlined then unbolt and remove pump.

Clearance between inner and outer rotor measured as shown in Fig. K3-22 is 0.11-0.16 mm with an allowable limit of 0.2 mm. Clearance between outer rotor and pump body measured as shown in Fig. K3-23 is 0.11-0.19 mm with an allowable limit of 0.25 mm. Individual pump components are not available; pump must be serviced as a unit assembly.

An oil pressure relief valve is located in the oil filter mounting pad.

GOVERNOR

All models are equipped with a flyball type governor as shown in Fig. K3-20. Ball movement against governor sleeve (6) actuates governor lever (9–Fig. K3-4) which is connected to fuel injection control rack. Flyball movement is balanced by governor spring (6).

Governor components are accessible after removing timing gear cover. Inspect components and renew any which are excessively worn or damaged.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod are removed as a unit after removing oil pan, oil pickup and cylinder head. Unscrew rod cap retaining screws, detach rod cap and extract piston and rod.

Note that numbers are stamped on sides of rod and cap and should be on same side when assembled. Install piston and rod units so numbers on rod and cap are toward fuel injection pump side of engine. Tighten rod screws to 36.3-41.2 N·m.

PISTON AND RINGS

All models are equipped with two compression rings and an oil control ring surrounding an aluminum, cam-ground piston. Piston and rings are available in 0.5 mm oversize.

Standard piston diameter measured at skirt perpendicular to piston pin is 84.915-84.935 mm for Models D1402-B and V1902-B, 81.915-81.935 mm for Models D1302-B, V1702-B, S2600-B and Z851-B, or 75.915-75.935 for all other models. Piston to cylinder clearance should be 0.065-0.104 mm at piston skirt for all models.

Piston pin boss inner diameter is 23.000-23.013 mm for all models with a wear limit of 23.04 mm.

Piston ring end gap is 0.3-0.45 mm for compression rings and 0.25-0.45 mm for oil ring on all models. Maximum ring end gap for any ring is 1.25 mm. The top compression ring is a keystone type and side clearance is not measured. Side clearance should be 0.093-0.120 mm for second compression ring and 0.02-0.052 mm for oil ring.

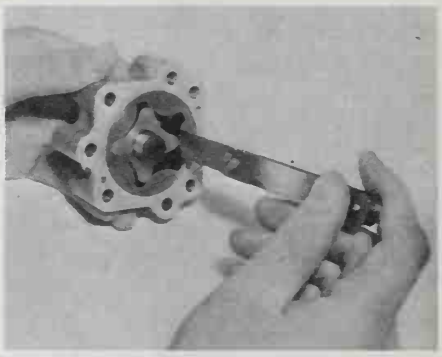


Fig. K3-22—Measure clearance between inner and outer oil pump rotors as shown. Desired clearance is 0.11-0.16 mm.

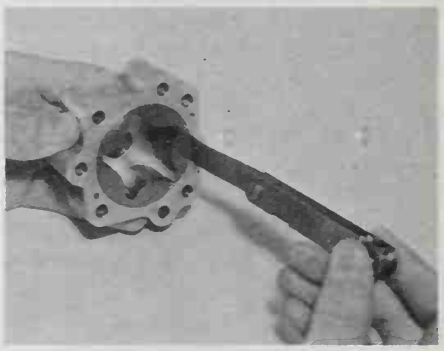


Fig. K3-23—Measure clearance between outer rotor and oil pump body as shown. Desired clearance is 0.11-0.19 mm.

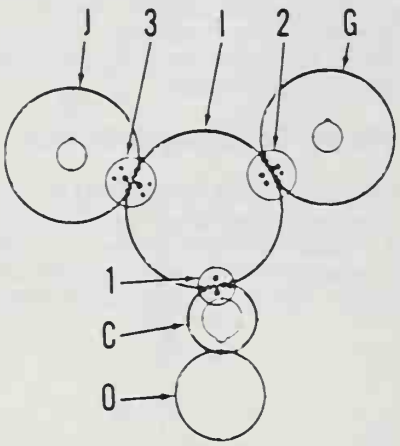


Fig. K3-21—Diagram of drive gears showing proper alignment of timing marks. Note three marks (3) on injection pump gear (J) and idler gear (I); two marks (2) on camshaft gear (G) and idler gear (I); single marks on crankshaft gear (C) and idler gear (I). No marks are used on oil pump gear (O).

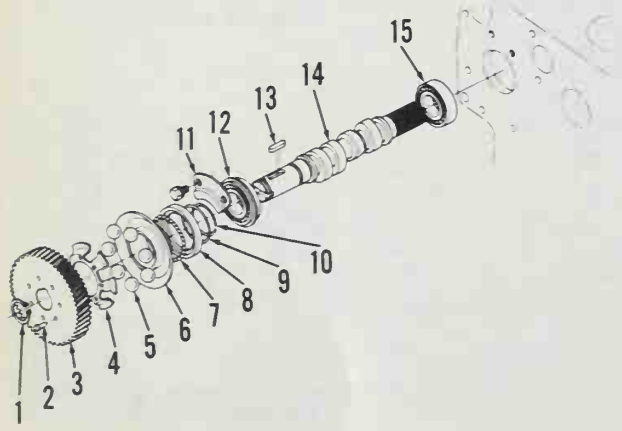


Fig. K3-20—Exploded view of injection pump camshaft and governor components.

1. Snap ring
2. Pin
3. Gear
4. Ball guide
5. Large governor balls
6. Sleeve
7. Small governor balls
8. Ball case
9. Retainer ring
10. Retainer ring
11. Bearing retainer
12. Bearing
13. Key
14. Injection pump camshaft
15. Bearing

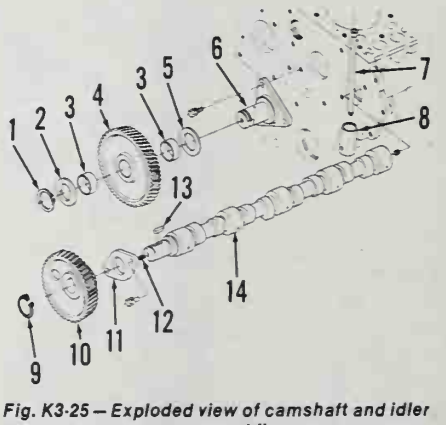


Fig. K3-25—Exploded view of camshaft and idler gear assemblies.

1. Snap ring
2. Slotted washer
3. Bushing
4. Idler gear
5. Washer
6. Idler shaft
7. Push rod
8. Tappet
9. Snap ring
10. Gear
11. Retainer
12. Plug
13. Key
14. Camshaft

PISTON PIN

A full floating piston pin is used on all models. Clearance between pin and piston bosses should be 0.011 mm interference to 0.011 mm loose. Clearance between pin and connecting rod bushing is 0.014-0.038 mm.

CONNECTING ROD AND BEARINGS

Connecting rods are equipped with a renewable bushing in the small end and insert type bearings in the big end. Inner diameter of standard big end bearing should be 44.010-44.052 mm while clearance between bearing and crankpin should be 0.035-0.097 mm. Bearings are available in 0.20 and 0.40 undersizes.

Small end bushing inner diameter is 23.025-23.040 mm. Clearance between piston pin and bushing is 0.014-0.038 mm.

CAMSHAFT

R&R AND OVERHAUL. To remove camshaft, remove cylinder head and timing gear cover as previously outlined then remove tappets. Unscrew camshaft retainer plate (11 – Fig. K3-25) and withdraw camshaft from cylinder block. If necessary, press camshaft gear (10) off camshaft.

Camshaft lobe height should be 33.36 mm with a wear limit of 33.31 mm. Camshaft bearing journal diameter should be 39.934-39.950 mm while inner diameter of renewable camshaft bearings is 40.000-40.025 mm. Maximum allowable clearance between camshaft journal and bearing is 0.15 mm. With camshaft supported in V-blocks at outer bearing journals, maximum allowable runout measured at either center bearing journal is 0.08 mm on Model S2200-B or 0.02 mm for all other models.

When installing camshaft gear on camshaft, first install retainer (11 – Fig. K3-25). Heat camshaft gear to approximately 80° C (176° F) and push gear onto camshaft until there is 0.07-0.22 mm clearance between retainer and side of camshaft journal as shown in Fig. K3-26. Refer to TIMING GEARS AND COVER section to properly align camshaft gear timing marks during installation.

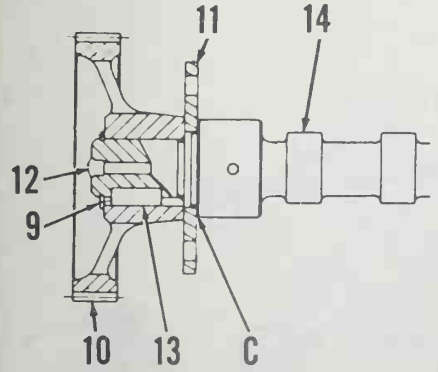


Fig. K3-26 – Install gear (10) on camshaft (14) so there is 0.007-0.22 mm clearance (C) between retainer (11) and side of front camshaft journal.

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove pistons and rods, timing gear cover, crankshaft gear, flywheel and seal carrier (23 – Fig. K3-27). Free bearing carriers (28) by unscrewing locating screws (30 – Fig. 3-28) in underside of block and also in side of block on Model S2200-B. Carefully withdraw crankshaft and bearing carrier assembly out rear of cylinder block. Note that bearing carriers are a tight fit in cylinder block to prevent oil loss between oil passages in block and bearing carriers. Remove screws securing bearing carrier halves and separate halves from crankshaft. Note that main bearing carriers are not interchangeable.

Standard main journal diameter is 51.921-51.940 mm. Main bearing clearance for front bearing (17 – Fig. K3-27) is 0.040-0.118 mm while clearance for all other main bearings is 0.040-0.104 mm. Main bearings are available in standard sizes only.

Crankshaft end play should be 0.15-0.31 mm and is controlled by thrust washers (27) which are available in standard thickness only. Install thrust washers so grooved side is away from bearing carrier.

Standard size of crankpin journal is 43.959-43.975 mm. Rod bearings are offered in 0.20 and 0.40 mm undersizes.

To reinstall crankshaft, reverse removal procedure. Tighten bearing carrier screws to 29.4-34.3 N·m. Tighten

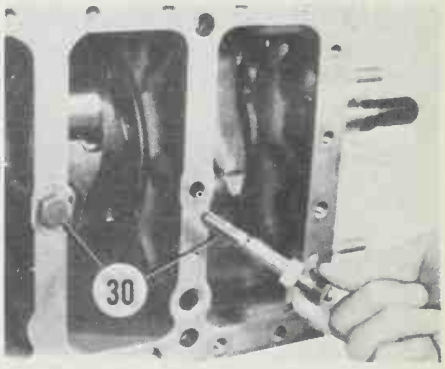


Fig. K3-28 – View showing location of locating screw (30) which secures bearing carrier to block. Model S2200-B is also equipped with screws in side of block that secure bearing carrier.

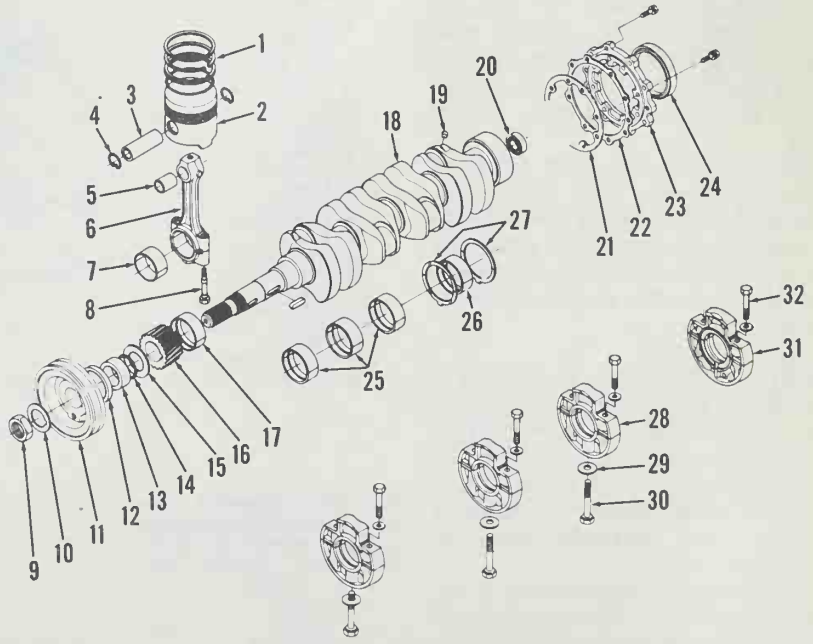


Fig. K3-27 – Exploded view of piston, rod and crankshaft assembly. Lower section of bearing carrier (28) on Model S2200-B are retained by side screws as well as screw (30).

1. Piston rings
2. Piston
3. Piston pin
4. Retainer
5. Bushing
6. Connecting rod
7. Bearing
8. Screw
9. Nut
10. Washer
11. Pulley
12. Oil seal
13. Spacer
14. "O" ring
15. Oil slinger
16. Gear
17. Bearing
18. Crankshaft
19. Plug
20. Ball bearing
21. Gasket
22. Gasket
23. Seal carrier
24. Oil seal
25. Bearings
26. Bearing
27. Thrust washers
28. Bearing carriers
29. Washer
30. Screw
31. Rear bearing carrier
32. Screw

carrier locating screws to 63.7-68.6 N·m. Install seal carrier (23).

CYLINDER LINER

All models are equipped with dry type cylinder liners. Use suitable removal and installation tools to renew defective liners. Install cylinder liner so distance from top of liner to cylinder block head surface is plus or minus 0.025 mm.

Standard cylinder liner inner diameter is 76.000-76.019 mm on Models D1102-B, D1102-BC, S2200-B, V1502-B, V1502-BC, VT1502-B and Z751-B; or 82.000-82.019 mm on Models D1302-B, S2600-B, V1702-B and Z851-B. The cylinder liner may be bored to accept a 0.5 mm oversize piston.

ELECTRICAL SYSTEM

ALTERNATOR AND REGULATOR

ALTERNATOR. An alternator rated at 20 amperes output is used on Models Z751-B, Z851-B, D1102-B and D1102-BC while all other models are equipped with a 25 amperes output alternator. Refer to Fig. K3-30 for an exploded view of alternator.

New brush length is 15.5 mm; renew brush if worn to 10 mm or less. To check stator assembly, use an ohmmeter and check continuity between "N" terminal and each stator lead. If continuity does not exist, renew stator. Check continuity between "N" terminal and stator frame. If continuity exists, renew stator.

Using an ohmmeter check diodes in rectifier assembly (14). Ohmmeter should read infinity during one test then continuity in other test with ohmmeter leads reversed. Individual diodes are not available and rectifier must be renewed as an assembly.

REGULATOR. Voltage regulator is available only as an assembly and adjustment is not normally required. Output voltage is controlled at 13.6-14.6 volts, with a rated output of 10 amperes.

With wiring disconnected or regulator removed, check alternator using an ohmmeter as follows:

Touch ohmmeter leads to IG & F terminals of regulator. Ohmmeter should read zero. If cover is removed and upper voltage control points manually opened, 11 ohms resistance should exist across resistor.

Touch ohmmeter leads to L & E terminals of regulator. Ohmmeter should read zero. If cover is removed and light relay points opened, 100 ohms resistance should exist across voltage regulator coil.

Touch ohmmeter leads to N & E terminals of regulator. Reading should be approximately 32 ohms.

Infinite resistance should exist between B terminal and any other terminal unless regulator cover is removed and light relay armature pushed down to connect lower set of points. With armature depressed, zero resistance should exist between L & B terminals and 100 ohms resistance should exist between E & B terminals.

STARTER. Refer to Fig. K3-31 or K3-32 for an exploded view of electric starter.

MODEL Z751-B. Minimum brush length is 10.7 mm while minimum commutator diameter is 32.5 mm. With no load imposed on starter and using an 11 volt source, the starter shaft should rotate at 5000 rpm or more while drawing less than 50 amperes current.

Pinion engagement depth is adjusted by turning hook (H – Fig. K3-31). With starter pinion in engaged position,

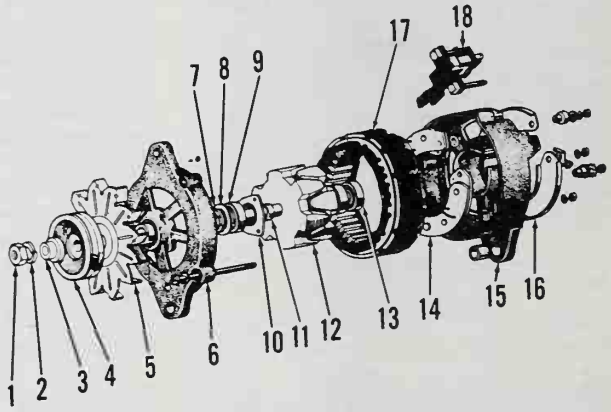


Fig. K3-30 – Exploded view of typical alternator.

1. Nut
2. Lockwasher
3. Spacer
4. Pulley
5. Fan
6. End frame
7. Oil felt
8. Cover
9. Bearing
10. Bearing retainer
11. Spacer
12. Rotor
13. Bearing
14. Rectifier
15. Housing
16. Cover
17. Stator
18. Brush assy.

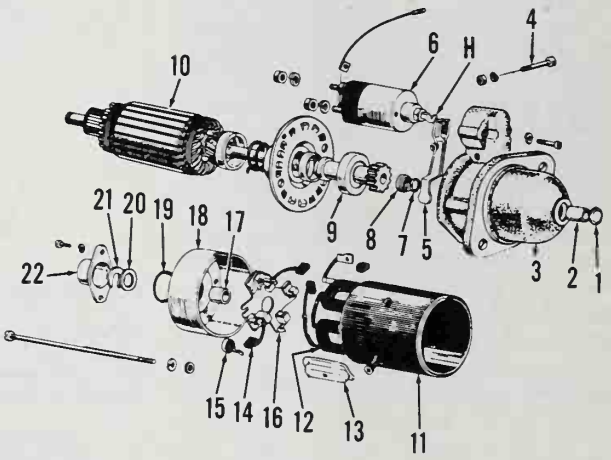


Fig. K3-31 – Exploded view of electric starter used on Models D1102-B, D1102-BC, Z751-B and Z851-B.

1. Cap
2. Bushing
3. Drive housing
4. Pivot bolt
5. Fork
6. Solenoid
7. Snap ring
8. Collar
9. Starter drive
10. Armature
11. Frame
12. Field coils
13. Field magnets
14. Brush
15. Brush spring
16. Brush plate
17. Bushing
18. End frame
19. Packing
20. Spring
21. Spring retainer
22. Cap

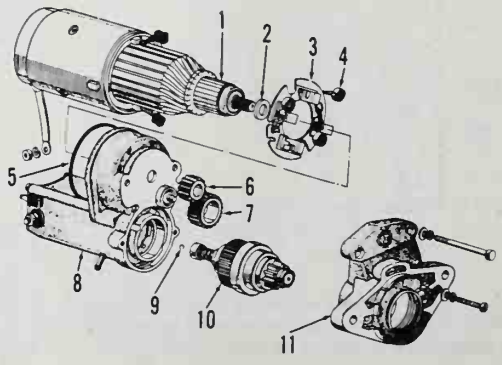


Fig. K3-32 – Exploded view of electric starter used on all models except D1102-B, D1102-BC, Z751-B and Z851-B.

1. Armature
2. Gasket
3. Brush plate
4. Brush spring
5. Gasket
6. Drive gear
7. Driven gear
8. Switch assy.
9. Ball
10. Clutch assy.
11. Gear housing

distance between collar (8) and pinion should be 0.1-0.4 mm. Turn hook (H) so pinion engagement depth is correct.

MODELS D1102-B, D1102-BC AND Z851-B. Minimum brush length is 12.7 mm while minimum commutator diameter is 32.5 mm. With no load imposed on starter and using an 11 volt source, the starter shaft should rotate at 6000 rpm or more while drawing less than 45 amperes current.

Pinion engagement depth is adjusted by turning hook (H – Fig. K3-31). With starter pinion in engaged position, distance between collar (8) and pinion should be 0.1-0.4 mm. Turn hook (H) so pinion engagement depth is correct.

ALL OTHER MODELS. Minimum brush length is 12.7 mm while minimum commutator diameter is 29 mm. With no load imposed on starter and using an 11.5 volt source, the starter shaft should rotate at 3500 rpm or more while drawing less than 90 amperes current.

LISTER

LISTER DIESEL INC.
555 East 56 Highway
Olathe, Kansas 66061

MODEL	No. Cyls.	Bore	Stroke	Displ.
LT1	1	82.55 mm	76.2 mm	0.408 liter

Lister diesel engine type can be identified by the last two digits of engine number found on plate (Fig. L1) attached to air shield or fan shroud.

Engines are four-stroke, vertical, single-cylinder with direct fuel injection. Standard crankshaft rotation is clockwise from flywheel end. Metric threads are used throughout engine.

MAINTENANCE

STARTING PROCEDURE

Normally engine will be manually started from camshaft, but in cases where final drive is from gear end, starting can be from flywheel end through geared-up starting. Refer to Accessory Section.

To start engine, refer to Fig. L2, pull stop lever outwards over middle catch and turn it clockwise to almost vertical position. If a variable speed control lever is used, move lever towards "FAST". Move compression release lever towards flywheel. Lightly oil end of starting shaft, install handle and crank engine. When sufficient speed is obtained, move compression release lever towards fuel tank and continue cranking until engine fires.

CAUTION: Do not allow handle to rotate on running shaft.

LUBRICATION

Engine must use H. D. Diesel lubricating oils. Oil specifications must equal or better API service classification CC. Engines, run with high load factor or if sulphur content of fuel exceeds 0.6%, should use API service CD grade lubricating oils.

Oil should be changed every 125 hours or more often if engine is operated under heavy load or dusty conditions. Recommended oil for temperatures below 5° C. is SAE 10W, between 5° C. and 30° C. is SAE 20/20W and above 30° C. is SAE 30. The oil sump capacity is 1.5 liters.

FUEL SYSTEM

No. 2 diesel fuel is recommended for most conditions. No. 1 diesel fuel should be used for light duty or cold weather operation. Fuel system is equipped with two bleeder valves. One valve is located on fuel filter mounting. Fuel pump is vented on top side (See Fig. L3).

FUEL PUMP. Bryce Berger fuel pump is located on side of engine between push rods. Split shims at base of pump are used to obtain accurate timing. If service becomes necessary, it is recommended that it be done by an accredited Service Department.

If pump is removed for service, check and adjust pump timing. Set control lever to "Start" position and turn flywheel to firing position (timing mark on flywheel opposite mark on fan shroud and both valves closed). Disconnect fuel injector pipe at pump and injector, remove delivery valve holder, delivery valve and spring (see Fig. L3A). If fuel flows from pump, turn crankshaft clockwise until flow ceases. Replace delivery valve holder and turn crankshaft counter-clockwise until fuel starts to flow. Then, slowly turn in clockwise rotation until flow stops. When flow stops, firing mark on flywheel should be in line with mark on fan shroud. If not, shims of 0.127 mm and 0.254 mm below pump body must be added or removed to adjust timing. Add shims to retard timing, subtract shims to advance timing. When timing is correct, torque pump bolts to 8.8 N·m.

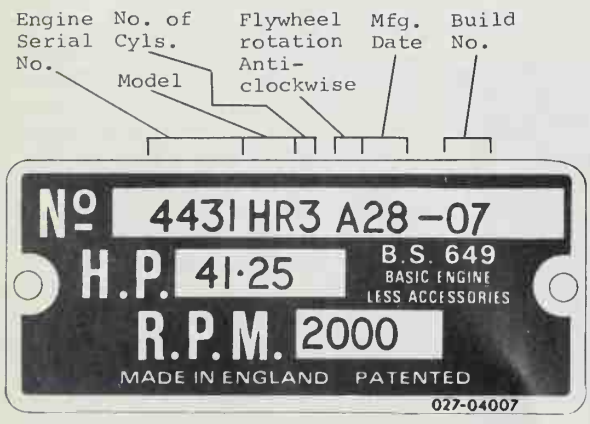


Fig. L1 – View of typical engine identification plate used. To insure use of proper parts and specifications, use complete number.

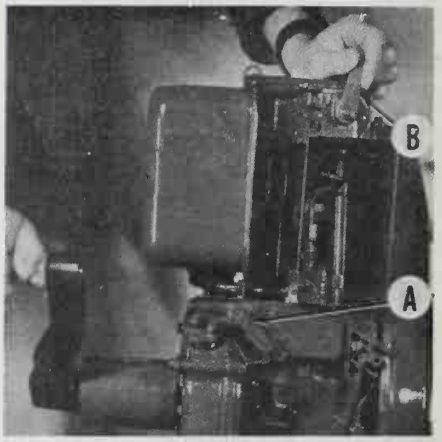


Fig. L2 – Pull stopping lever (A) out and turn it clockwise to a vertical position. Move compression release lever (B) towards flywheel. After engine fires, turn stopping lever to middle catch.

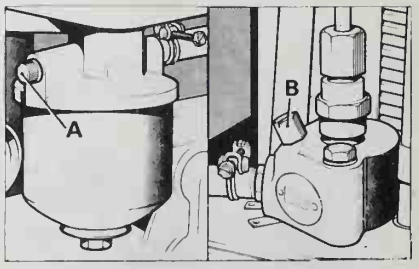


Fig. L3 – Air bleed valves on (A) fuel filter mounting bracket and (B) fuel pump.

Builds	Speed Ranges Rpm	Deg. BTDC
1,2,4	Up to 2500	24
3,5,6,7,8	2501 and over	27
10	Up to 1000	22
11	Up to 1500	26
9,12,13,14,15	1501 and over	30

FUEL INJECTOR

Two different type injector nozzles are used. The most reliable type nozzle is a single hole, pintle type injector. Pintle nozzles used are the delay type.

To check nozzle, connect injector to hand pump and apply 10132.5 kPa pressure to a dry nozzle. If nozzle is seating properly, no leakage should appear. The leak down rate is checked by applying 16212.0 kPa of pressure and noting the time it takes to drop from 15198.75 to 10132.5 kPa. Time must be between 10 seconds and 55 seconds.

To check the spray, connect injector externally to fuel pump. Set engine control to "RUN" position and crank engine at about 60 rpm.

CAUTION: Make certain injector spray is directed away from your person.

If spray seems to be denser in one direction, nozzle or pintle is dirty. Careful brushing with a special brass brush will sometimes remove dirt, but if uneven spray continues, complete disassembly and cleaning will be necessary. Such repair should be done by an authorized Service Department.

The second type injector has three 0.25 mm diameter spray holes. Seating pressure of the injector spring is 19251.75 kPa. Checking procedures are basically the same as the pintle type. If major repair is necessary, faulty injector should be sent to an authorized Service Department.

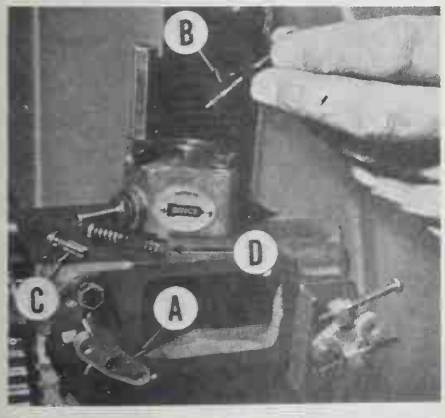


Fig. L3A – To time fuel pump, set control lever (A) to "START" position. Disconnect injector pipe and remove delivery valve holder (B), delivery valve (C) and spring (D). Refer to text for details.

GOVERNOR

To check or adjust governor settings, remove fuel pump inspection cover and end cover. Engine controls should be in "Start" position and camshaft gently tapped towards flywheel to take up any end play.

Clearance between thrust sleeve and step on camshaft is 5.0 mm (A – Fig. L6) with fuel pump calibration mark (B) lined up. Adjust by altering the length of governor link (C – Fig. L7).

Set engine controls to "Run" position, with fuel pump calibration marks lined up, set clearance (G – Fig. L6) to the value listed for the load requirement and engine build number.

APPLICATION	BUILD NUMBER	"G"-Fig. L6
*100% load	1,3,5	0.5mm
	11	0.6mm
	2,4	0.7mm
	9,10,12,15	1.0mm
90/100%	6,7	0.3mm
	13,14	0.8mm

*An engine set to 100% load will develop its rated H.P. continuously including 10% over-load for a period not exceeding one hour in any period of 12 hours consecutive running.

Engines may be equipped with either a constant speed or variable speed control. Speed adjustments are similar on both controls. To adjust idle speed (variable speed control), turn adjusting screw counter-clockwise until it no longer effects engine speed; governor will likely cause engine to "hunt". Turn screw clockwise until "hunting" stops or until desired speed is obtained and tighten locknut (Fig. L5).

Governor weights and springs are serviced separately. For proper part identification and adjustment, contact an authorized Service Department.

REPAIRS

TIGHTENING TORQUES

Recommended tightening torques are as follows. Values in newton meters.

Connecting rod	21.0
Cylinder head	40.6
Flywheel retaining screws	196
Fuel pump delivery valve holder	54.2
Injector clamp	21.0
Sump retaining screws	21.0
Main bearing housing	21.0
Upper manifold nuts	21.0
Lower manifold nuts	8.8
Injection pipe nuts	28.4
Injector top plug	27.1

CYLINDER HEAD

A two-piece cylinder is used. Top half is cast iron and holds the rocker arm assembly, valve springs, compression release lever and injector. Lower half is aluminum alloy and contains valve seats

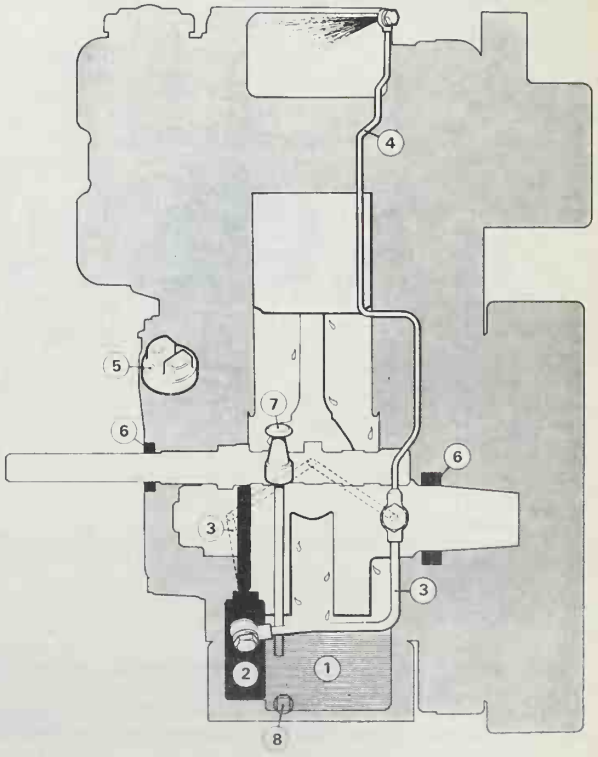


Fig. L4 – Cut-away view of lubricating system.
1. Sump
2. Plunger type pump
3. Main bearing oil supply
4. Rocker arm oil supply
5. Filler plug
6. Oil seals
7. Dipstick
8. Drain plug

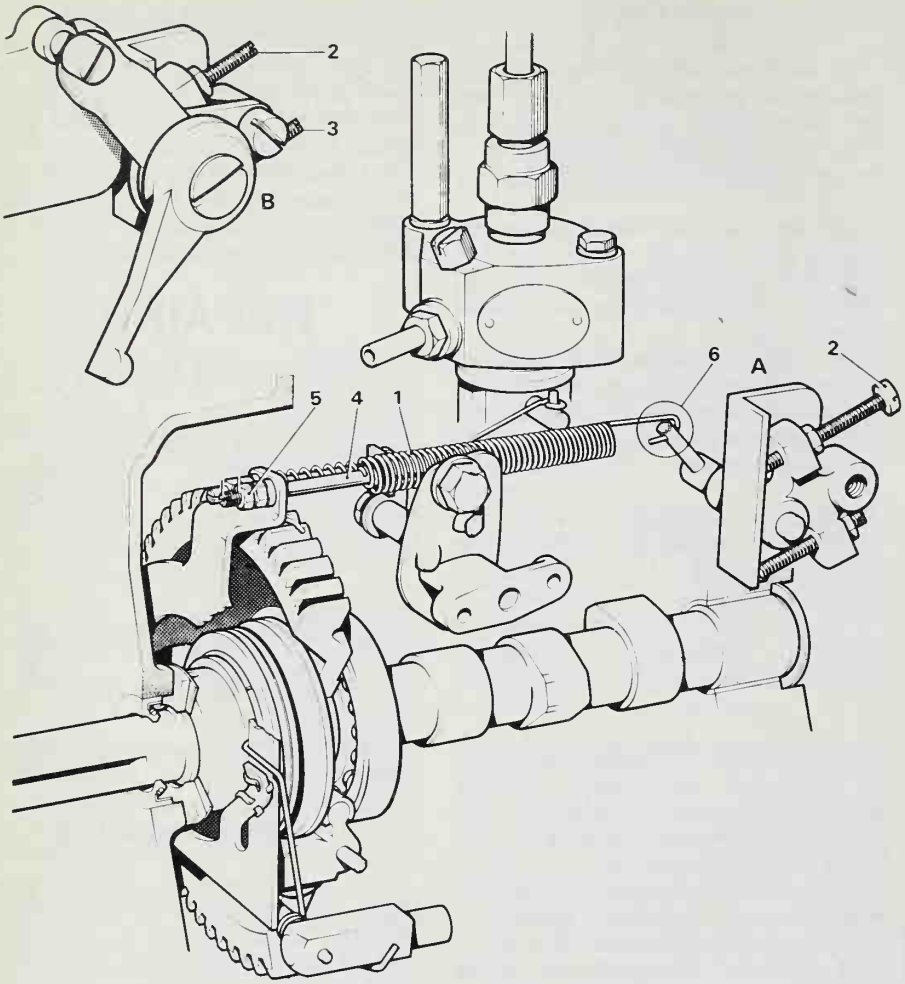


Fig. L5 — Two speed controls are used, constant speed (A) and variable speed (B). Speed adjustments are similar. Refer to text for details.

1. Speeder spring
2A. Speed adjusting screw (constant)
2B. Idle speed screw (variable)
3. Maximum speed screw (variable)
4. Governor link
5. Link locknuts
6. Speed control lever pin

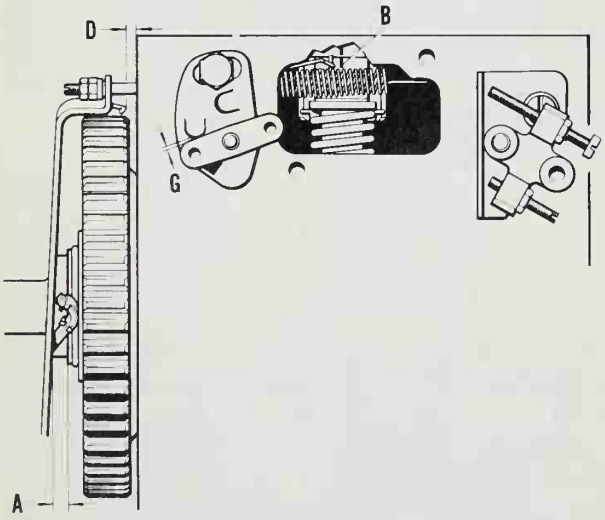


Fig. L6 — To check or adjust fuel pump and governor, remove fuel pump inspection door and gear cover. Set distance (A) to 5.0 mm and align calibration mark (B). Governor lever stop to crankcase clearance (D) is 6.0-8.0 mm. Refer to text for details and values of (G).

and a tapped hole in intake port for an oil priming cup used for cold starting. Valve guides are a press fit and hold head together.

To check cylinder head clearance, place two pieces of lead wire (1.2 mm) thick on cylinder head, as near as possible in line with piston pin. Tighten cylinder head to 40.6 N·m and turn piston past TDC twice. Remove head and measure lead wire. The lead wire should measure 0.71-0.79 mm. Clearance can be adjusted by (0.075 mm) shims (10 – Fig. L9) placed between cylinder head (9) and head gasket (13).

NOTE: No sealer is to be used on head gasket; however, a light coating of high melting point grease is recommended. Thread sealer is recommended for cylinder head studs and nuts.

VALVE SYSTEM

Exhaust valve guide is a press fit into both halves of head. Intake guide is a press fit into the lower half. An "O" ring and retaining plate is used on intake guide. When installing new guides, in-

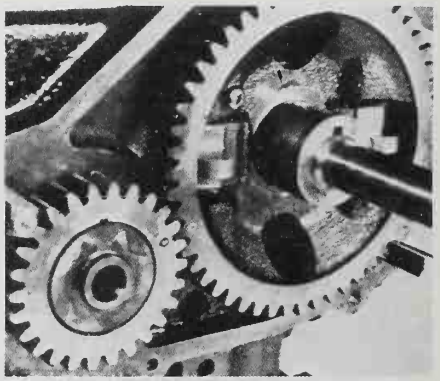


Fig. L8 — When installing camshaft or crankshaft gear, align "O" timing marks as shown.

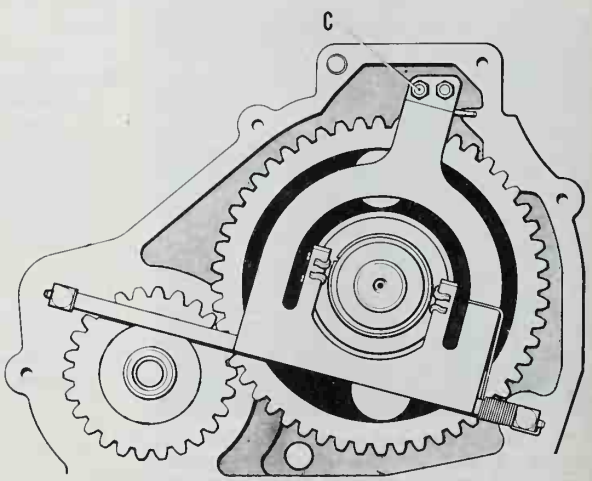


Fig. L7 — To align fuel pump calibration mark, adjust governor link at (C).

stall with lettering at the top and with 12.35-12.60 mm of guide projecting above casting. Running clearance for both guides is 0.06 mm with maximum wear clearance of 0.089 mm. A 7.899 mm gage must pass through exhaust guide after installation. If not, ream guide to 7.899-7.919 mm.

Valve seat angle is 45.5° with a seat width of 1.65-2.29 mm for intake and 1.00-1.15 mm on early models and 1.65-2.01 mm on late models for the exhaust. Valve face angle is 44.5-45°. Check valve seats and valves for nicks, cracks or pitting. Reface valves and regrind seats as necessary. If valves or seats are damaged beyond further service, renew valves and/or cylinder head.

Valve spring free length is 43.7-45.5 mm. Renew spring if free length is 42.5 mm or less.

To adjust valve clearance, turn piston to TDC on firing stroke (both valves closed). Loosen locknut and turn adjusting screw until 0.13 mm clearance (engine cold) is obtained. Tighten locknut and recheck clearance. Repeat procedure for both valves.

To adjust compression release lever, piston must be at TDC with both valves closed. Turn adjusting screw until rocker arm begins to depress valve and then turn screw one full turn clockwise.

PISTON, PISTON PIN AND RINGS

A low expansion aluminum alloy piston with recessed combustion chamber is used. Piston is 82.398-82.423 mm in diameter and has an initial clearance in cylinder bore of 0.127 mm with maximum wear clearance of 0.22 mm. The piston pin is a push fit. The pin rides in a copper faced steel backed bushing in small end of connecting rod. Piston pin diameter is 28.5674-28.5725 mm and has a running clearance of 0.0385-0.0556 mm with a maximum wear clearance of 0.064 mm.

Piston is fitted with four rings; a barrel face chrome firing ring, a taper faced compression ring, a spring expander scraper ring and a slotted scraper ring fitted below piston pin. Ring clearances are as follows:

Ring End Gaps	New	Maximum Wear
Firing ring	0.30-0.46mm	0.61mm
Compression ring	0.20-0.36mm	0.56mm
Expander Scraper	0.20-0.36mm	0.56mm
Slotted Scraper	0.20-0.36mm	0.56mm

Ring Side Clearance	New	Maximum Wear
Firing Ring*	0.00-0.06mm	0.10mm
Compression Ring	0.051-0.101mm	0.14mm
Expander Scraper	0.051-0.101mm	0.14mm
Slotted Scraper	0.051-0.101mm	0.14mm

*Special gage required.

CYLINDER BARREL AND CONNECTING ROD

Standard cylinder bore is 82.550-82.575 mm. If cylinder is scored or badly worn, it must be resized to 0.255, 0.51 or 1.22 mm oversize. When installing cylinder assembly, flat sided

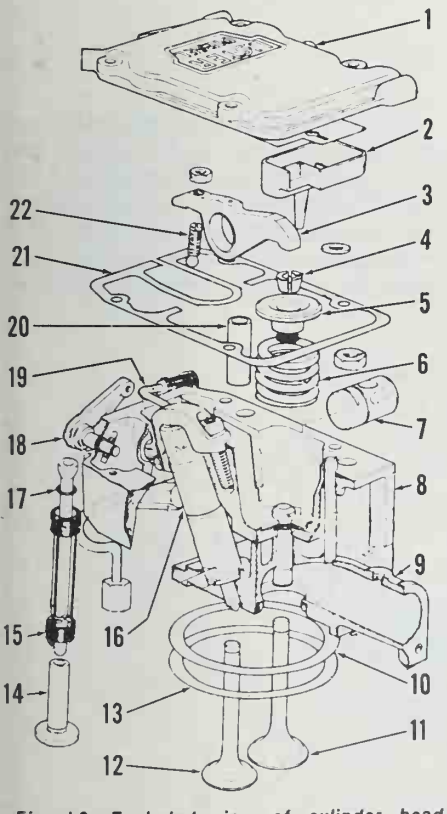


Fig. L9—Exploded view of cylinder head assembly.

1. Valve cover
2. Breather box
3. Rocker arm
4. Valve keepers
5. Spring retainer
6. Valve spring
7. Rocker arm stub shaft
8. Top plate
9. Cylinder head
10. Shim (0.075 mm)
11. Intake valve
12. Exhaust valve
13. Cylinder head gasket
14. Valve tappet
15. Push rod tube assembly
16. Injector
17. Push rod seal
18. Compression release lever assembly
19. Leak off pipe
20. Valve guide
21. Valve cover gasket
22. Rocker arm adjusting screw

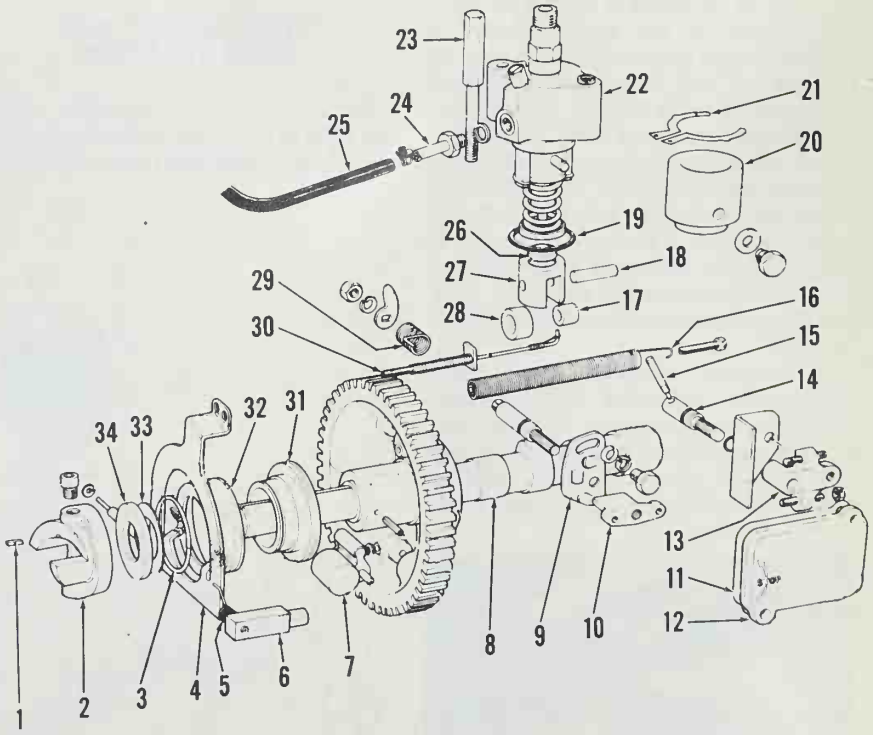


Fig. L10—Exploded view of camshaft, fuel pump and governor assemblies.

1. Key
2. Starting dog collar
3. Spring ring
4. Governor lever assembly
5. Return spring
6. Pivot block
7. Governor weight
8. Camshaft assembly
9. Control plate
10. Control knob
11. Inspection door gasket
12. Fuel pump inspection door
13. Speed control lever
14. Speed control spindle
15. Speed control lever pin
16. Speeder spring
17. Roller bushing
18. Roller pin
19. Fuel pump "O" ring
20. Fuel pump tappet guide
21. Shims (0.125 and 0.508 mm)
22. Fuel pump
23. Fuel pump bolt
24. Inlet connector
25. Fuel pipe
26. Insert
27. Fuel pump tappet
28. Roller
29. Control lever spring
30. Governor link assembly
31. Governor sleeve
32. Thrust washer and pad
33. Shim (0.13, 0.25 & 0.38 mm)
34. Thrust washer

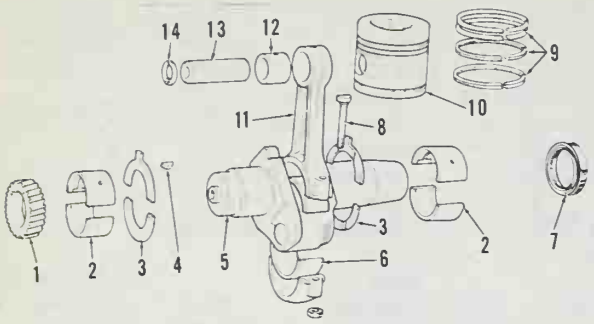


Fig. L11—Exploded view of crankshaft, connecting rod and piston.

1. Crankshaft gear
2. Main bearings
3. Thrust washers
4. Key
5. Crankshaft
6. Connecting rod bearings
7. Oil seal
8. Rod bolt
9. Piston rings (4 used)
10. Piston
11. Connecting rod
12. Piston pin bushing
13. Piston pin
14. Retaining ring

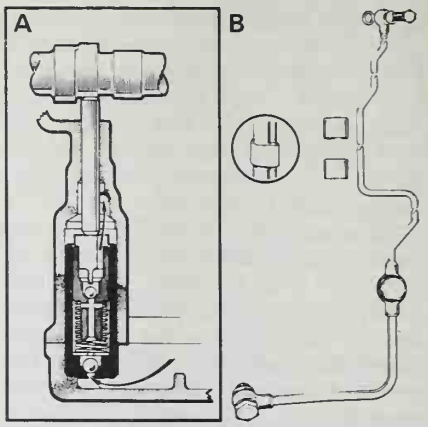


Fig. L14—A self regulating plunger-type oil pump is used. An external pipe (B) carries oil to flywheel end main bearing and cylinder head. Gears, governor camshaft and underside of piston are splash lubricated.

cylinder fins face the flywheel.

A forged steel connecting rod is used with a steel backed copper lead bearing which is precision finished. Rod bearing has a running clearance of 0.033-0.077 mm and maximum wear clearance of 0.100 mm. Rod bearings are available in undersizes of 0.255, 0.510 and 1.22 mm for use with reground crankshaft. Torque connecting rod nuts to 21 N·m.

Small end of rod is fitted with a copper faced bushing. New bushing to new piston pin clearance is 0.0385-0.0556 mm with a maximum wear clearance of 0.064 mm.

CAMSHAFT

The steel camshaft is supported by a ball bearing at the gear end and a bushing sealed by an expansion plug at the flywheel end. Renew ball bearing if it feels rough when rotated. Bushing has a running clearance of 0.051 mm with a maximum wear clearance of 0.090 mm. A metal shim (33—Fig. L10) fitted between thrust washer and gear hub adjusts end play. Camshaft end play is 0.13-0.255 mm. Shims of 0.13, 0.25 and 0.4 mm thicknesses are available. Only one shim of appropriate thickness must be used.

To remove camshaft, drain and remove fuel tank and cylinder head. Drain and remove sump, oil pump and plunger. Disconnect speeder spring and remove fuel pump. Remove locating screw for fuel pump tappet guide and remove tappet and guide. Disconnect oil feed pipe. Remove retaining clips from push rod guides and lift push rods and guides out (making sure push rod tube rubber seals are retained). Lift off governor lever, link and speeder spring. Slide thrust sleeve assembly off. Lift valve tappets and remove camshaft. Reinstall camshaft aligning timing marks as shown in Fig. L8.

To renew camshaft ball bearing, remove roll pin from hub of cam gear. Support camshaft assembly on hub of bearing race and push cam through gear and bearing. Press new bearing on camshaft and install key. When installing cam gear apply pressure to gear hub. Install new roll pin.

CRANKSHAFT AND MAIN BEARINGS

The crankshaft is a graphite casting and runs in two steel backed main bearings. A new crankshaft journal diameter is 53.955-53.967 mm. Running clearance for main bearings is 0.034-0.089 mm with maximum wear clearance of 0.120 mm. Main bearings are two-piece inserts and are not interchangeable. Top half of bearing has an oil groove and hole which must be properly located. Undersized

Fig. L12—To service oil pump, drain and carefully remove sump.

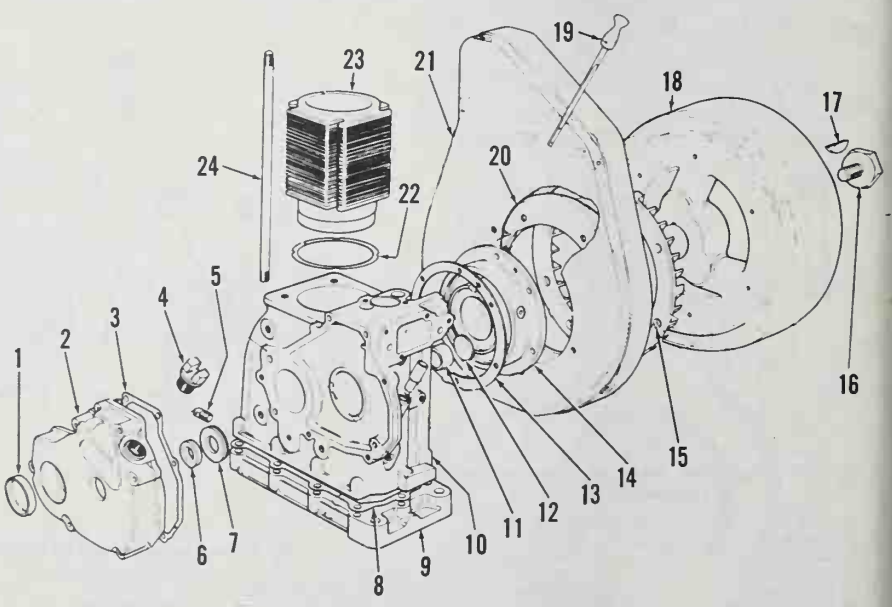


Fig. L13—Exploded view of cylinder block assembly.

1. Plug
2. End cover assembly
3. End cover gasket
4. Oil filler plug
5. Drain plug
6. Oil seal
7. Thrust washer
8. Sump gasket
9. Oil sump
10. Crankcase assembly
11. Camshaft bushing
12. Expansion plug
13. Shim (0.127 or 0.254 mm)
14. Main bearing housing
15. Fan
16. Flywheel screw
17. Key
18. Flywheel
19. Dipstick
20. Air seal
21. Fan shroud
22. Cylinder barrel gasket
23. Cylinder barrel
24. Stud

bearings of 0.255, 0.51 and 1.02 mm are available.

New crankpin diameter is 53.967-53.980 mm. Running clearance of new rod bearing on new crankpin is 0.033-0.077 mm with maximum wear clearance of 0.100 mm. Crankshaft end play is adjusted by steel backed copper based split thrust washers. Thrust washers are installed between crankshaft and main bearing housing and between crankshaft and crankcase. Crankshaft end play is 0.13-0.23 mm. End play is adjusted by installing 0.13 mm or 0.25 mm shims between main bearing housing and crankcase.

OIL PUMP

A self regulating plunger type pump is used (Fig. L14). Pump delivers 68.95 kPa at 1000 rpm. An external pipe, secured by swivel union plugs is used. Gears, governor, camshaft and underside of piston are splash lubricated.

LISTER

MODEL	No. Cyl.	Bore	Stroke	Displ.
ST1	1	3¾ in.	3½ in.	38.7 cu. in.
ST2	2	3¾ in.	3½ in.	77.4 cu. in.
ST3	3	3¾ in.	3½ in.	116.1 cu. in.

Engines in this section are four-stroke type with vertical cylinders and direct fuel injection. Engine type can be identified by last two digits of engine number found on plate attached to fuel pump housing door (Fig. L25). Crankshaft rotation may be either clockwise or counter-clockwise as viewed from flywheel end.

MAINTENANCE

STARTING PROCEDURES

Engines may be equipped with either a manual or electric start. In cases where final drive is from gear end, manual starting can be from flywheel end through geared-up starter. Refer to Accessory Section.

To start engine, pull control lever out and allow it to rotate counter-clockwise until it is against top stop in a vertical position and move compression release lever towards flywheel. Prime cylinders and oil system by turning engine slowly 3 to 20 turns. After priming, crank engine until maximum speed is obtained and release compression release lever.

CAUTION: Do not allow handle to continue to rotate on running shaft.

When engine reaches normal speed, turn control lever clockwise to horizontal position against the stop and reduce speed as required.

NOTE: If engine is equipped with electric starter, do not crank engine more than 10 seconds at a time.

LUBRICATION

Engines must use H.D. Diesel lubricating oils that equal or better API specifications for CC classification. If engines are operated under heavy loads or high temperatures, or if sulphur content in fuel exceeds 0.6%, API service classification CD/SE or CD/SD oils are recommended. Recommended oil change interval is every 250 hours operation with filter change at same time. **Check oil level daily.**

Crankcase capacities are:

ST1 .....3.5 pts.
ST2 .....9.5 pts.
ST3 .....13.5 pts.

If operating temperatures fall below 10° F., SAE 10W should be used. From 10° to 85° F. use SAE 20/20W. Above 85°, SAE 30 weight oil is called for.

All engines in this section are full pressure lubricated. Refer to Fig. L28 for cross-sectional view of lubrication system.

FUEL SYSTEM

No. 2 diesel fuel is recommended for most conditions. No. 1 diesel fuel should be used for light duty or cold weather operation.

The fuel filter should be renewed every 1500 hours. When filter element is serviced, air must be bled from system in the following manner:

Make sure fuel tank is full. Loosen each bleeder valve one at a time on filter body and outlet banjo fitting. Retighten valves when air free fuel flow is obtained. Loosen bleeder valve on each fuel pump (start nearest to fuel tank); tighten when air free flow is obtained (Fig. L26).

FUEL PUMP. A separate Bryce Berger fuel pump is fitted for each cylinder. It is recommended that all service of fuel pump(s), other than renewal, be carried out by an approved service department.

To check fuel pump timing, set control lever to "start" position and turn flywheel so "Z" mark on flywheel is opposite mark on fan shroud. Remove delivery valve holder, valve and spring. If fuel flows from pump, turn crankshaft in direction of normal engine rotation until flow ceases. Replace delivery valve holder and turn crankshaft backwards until fuel starts to flow, then turn in opposite direction until flow ceases. Blow fuel from top of holder to make sure flow has stopped. The firing mark on the flywheel should be opposite mark on the fan shroud. If not, shims of 0.005 and 0.010 inch thicknesses below pump body

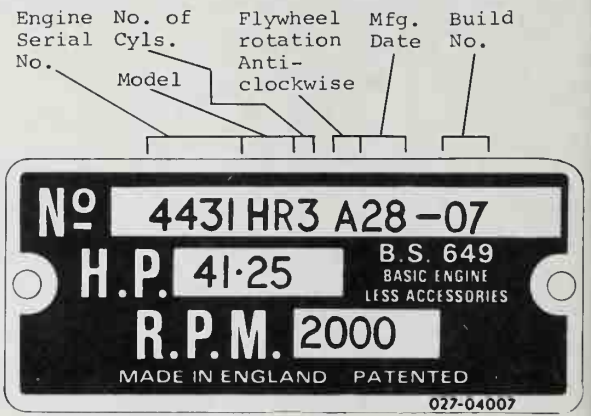


Fig. L25—View of typical engine identification plate used. To insure use of proper parts and specifications, use complete number.

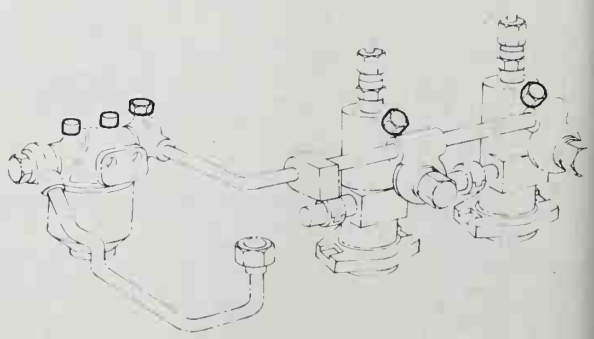


Fig. L26—When fuel filter is serviced, air must be bled from fuel system. Loosen each bleeder valve one at a time. Retighten valves when air free fuel flow is obtained.

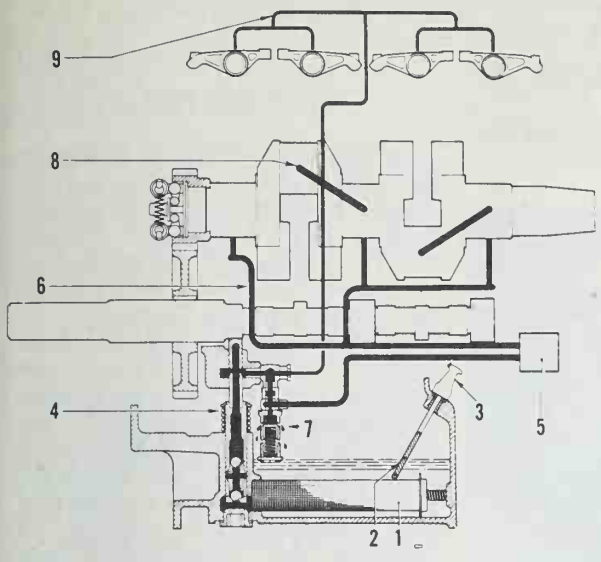


Fig. L28—Basic lubrication system on early model engines.

1. Screen
2. Oil level
3. Dipstick assy.
4. Oil pump assy.
5. Oil filter
6. Oil pipe to main bearings
7. Pressure relief valve
8. Oil passage to rod bearings
9. Oil pipe to rocker arms

measured with a hand pump and gage, must drop from 2205 to 1470 psi within 10 to 55 seconds.

To check injector spray, remove and reconnect injector externally to fuel pump. Crank engine about 60 rpm. Spray should be a very fine mist. All sprays should have the same appearance and length. If one hole is totally blocked or dribbles, injector must be renewed or be cleaned and rebuilt by an authorized Service Department.

GOVERNOR

Two types of flyweight governors are used; variable and constant speed. Governor assemblies are contained within the gear case. Governor weights and springs are serviced separately. To

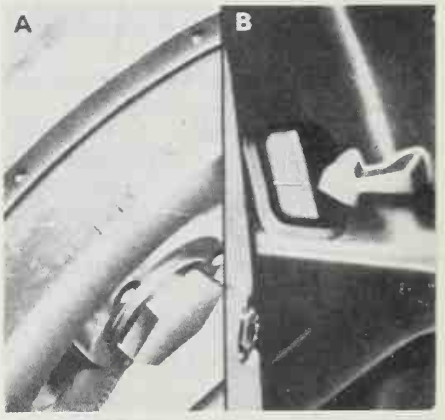


Fig. L31—To adjust fuel pump timing, set engine control to "Start". Set "Z" mark on flywheel opposite timing mark on fan shroud. Refer to text. View "A" is ST1 engine; view "B" is ST2 or ST3 engine.

must be added or removed to adjust pump timing. Approximately 0.035 inch thick shim pack is normally below the pump body. To advance timing, remove shims; to retard timing add shims. On multiple cylinder engines, time each additional pump using same procedure.

The correct timing is as follows:

Speed Ranges RPM	Degree BTDC
Up to 1999	19°
2000 to 2601	22°
Over 2601	25°

FUEL INJECTOR. All models are equipped with four hole (0.0098 in.) spray injectors. Injector pressure setting is 2940 psi. The leak down rate,

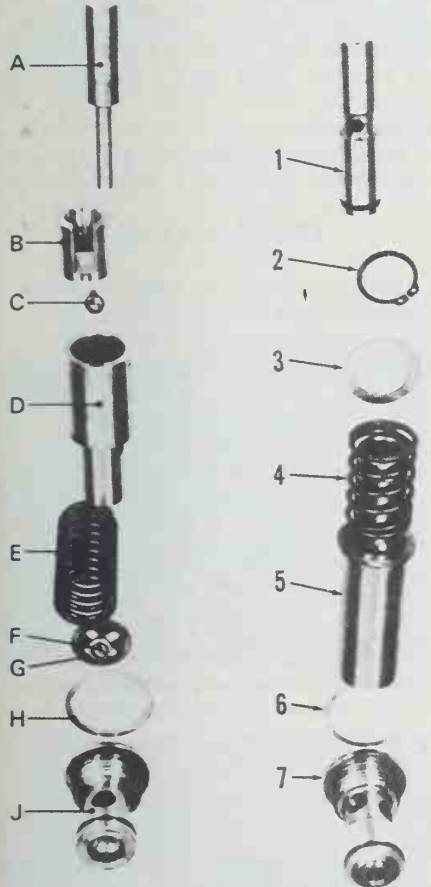


Fig. L29—A non-regulated oil pump (right) is used. The self regulating pump (left) was introduced May 1978. All current production ST engines are equipped with self regulating pumps.

A. Push rod
B. Plunger cap
C. Ball valve
D. Plunger
E. Spring
F. Ball
G. Retaining plate
H. Washer
J. Plug

1. Push rod
2. Snap ring
3. Washer
4. Spring
5. Oil plunger assy.
6. Washer
7. Suction valve

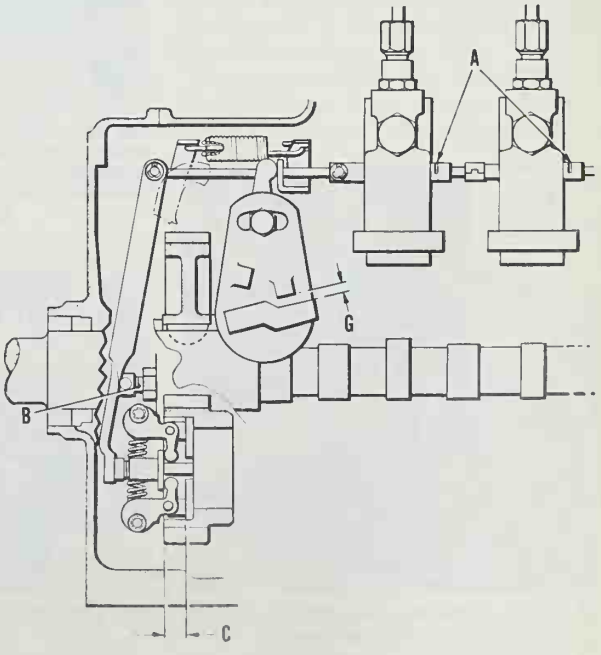


Fig. L30—To adjust fuel pump and governor setting, set engine control to "Run" position. Adjust linkage until calibration marks (A) coincide with sides of fuel pumps to within 0.005 inch. Adjust clearance (C) to ½-inch by turning governor lever fulcrum (B). Refer to text for details and values of (G).

install correct weights and springs and adjust properly, contact an authorized Service Department.

Governor lever (Fig. L32) operating the fuel pump(s) is carried in a fulcrum bearing in the crankcase. The bearing extends approximately 0.750 inch from face of crankcase and is adjusted as follows:

Set engine control to "RUN" position and adjust linkage until calibration marks (A – Fig. L30) line up with sides of fuel pump bodies within 0.005 inch. Pump racks must move freely after this adjustment. Adjust governor lever fulcrum (B) so that when calibration marks are in position, distance (C) is ½-inch.

To set clearance (G – Fig. L30), maintain correct clearance and rotate locating plate until calibration marks are in position. The full width of each mark must be visible. After making adjustments, pump racks and linkage must move freely.

The correct values of (G) are as follows:

Engine Speed Rpm	Clearance (G) inches	Movement of Rack corresponding to clearance inches
1200-2199	0.014-0.016	0.045-0.051
2200-2699	0.026-0.028	0.083-0.089
2700-3000	0.035-0.037	0.112-0.118

For engines driving fans, centrifugal pumps and marine engines, set as follows:

1200-2199	*0.003-0.005	0.009-0.015
2200-2699	0.006-0.008	0.020-0.026
2700-3000	0.015-0.017	0.048-0.054

*All Moisture Extraction Units should be set to this clearance.

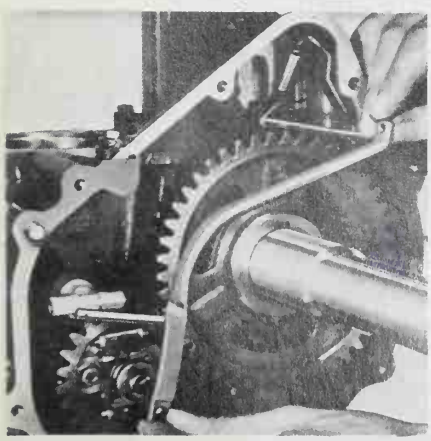


Fig. L32 – Governor lever is carried in a fulcrum bearing in the crankcase.

REPAIRS

TIGHTENING TORQUES

Recommended tightening torques are as follows. Values are in ft.-lbs.

Connecting rod nuts	32
Cylinder head nuts	50
Flywheel retaining screw	300
Injector cap nut & locknut	65
Delivery valve holder	40
Injector pipe nuts	21
Injector clamp nuts	15
Rocker adjusting screws	15
Flexible couplings	8
Balance weight setscrews	32

VALVE COVER AND COMPRESSION RELEASE LEVER

The valve cover carries the compression release lever. On multiple cylinder engines, adjust each compression release as follows:

Crank engine to TDC on firing stroke of cylinder to be adjusted. Remove oil filler cap and move lever towards flywheel. Loosen locknut and adjust screw until exhaust valve touches the piston. Turn screw back ½-turn and tighten locknut.

When no oil filler hole is provided, compression release should be adjusted so adjusting screw just touches valve rocker when cover is in place. Then, turn screw clockwise ¾-turn and lock in position.

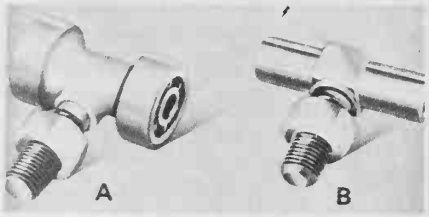


Fig. L33 – Fulcrum bearing is fitted so bearing center line is approximately 0.750 inch from crankcase surface. Bearing (A) is used on 3 cylinder engines; (B) is used on one and two cylinder engines.

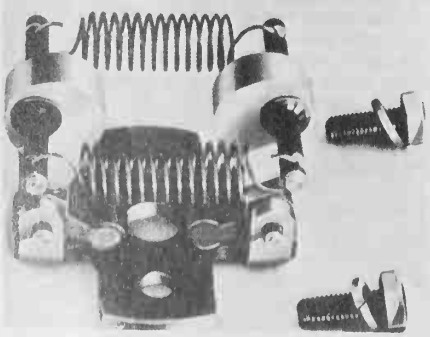


Fig. L34 – View of constant speed governor weight assembly.

CYLINDER HEAD

Cylinder head consists of two parts. Top half (top plate) is cast iron and contains the rocker arms, valve springs and breather tube. Lower half (cylinder head) is aluminum alloy and contains the valve seats. Valve guides are a press fit and hold the halves together.

To check piston to cylinder head clearance, place two pieces of lead wire 0.048 inch thick on head, clear of valve recesses and as near as possible in line with piston pin. Tighten head to correct torque and crank piston past TDC twice. Remove cylinder head and measure lead wire. The thickness should be 0.035-0.038 inch. Shims of 0.003 inch thickness, placed between cylinder head and head gasket, adjust clearance.

During final assembly, a high melting point grease should be used to hold gasket and shims in place. Lister recommends that a thread sealer be used on cylinder head nuts, washers and studs. On multi-cylinder engines, a straight edge or manifold must be used to insure proper alignment of all intake and exhaust ports.

VALVE SYSTEM

Valve seat width is 0.065-0.090 inch for intake and 0.053-0.070 inch for exhaust. Valve seat angle is 45.5°. If seats are nicked, cracked or pitted to a point that they cannot be reground, cylinder head must be renewed.

Valve guides are a press fit and are not interchangeable. A rubber seal is installed on intake guide and is held in place by retaining plate (1 – Fig. L40). When installing new guides, guide should extend 0.495-0.515 inch above surface of casting. A 0.3428 inch diameter gage must pass through exhaust guide. If not, ream to 0.3428-0.3436 inch. Running clearance of valve stem in guide is 0.003-0.004 inch with maximum wear clearance of 0.005 inch.

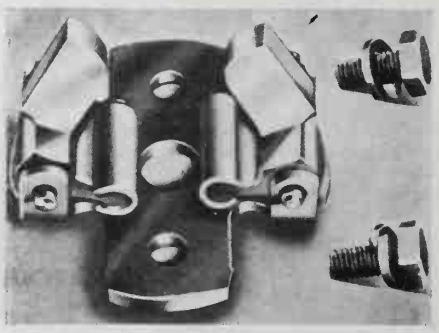


Fig. L35 – Variable speed governor weight assembly used on ST engines.

Valve face angle is 45-45.5°. Valve spring free length is 2.324 inches. Rocker arm bushing clearance is 0.003-0.004 inch with maximum wear clearance of 0.005 inch.

To adjust rocker arm clearance, turn piston to TDC on firing stroke (both valves closed). Loosen locknut and turn adjusting screw until both valves have 0.006 inch clearance (cold). Tighten locknut and recheck clearance.

PISTON, PISTON PIN AND RINGS

Piston diameter is 3.7427 inches. Normal running clearance is 0.008-0.010 inch with maximum wear clearance of 0.014 inch. Pistons and rings in oversizes of 0.010, 0.020 and 0.040 inch are available. Piston pins are 1.3123-1.3125 inches in diameter.

Each piston is fitted with five rings: one barrel faced chrome firing ring; two taper faced compression rings; one conformable type (with spring expander) scraper ring and a slotted scraper ring installed below piston pin. Ring specifications are as follows:

Ring End Gap	New Clearance	Maximum Wear Clearance
Firing Ring	0.017-0.024 in.	0.035 in.
Compression Rings	0.011-0.018 in.	0.030 in.
Scraper Rings	0.015-0.022 in.	0.030 in.

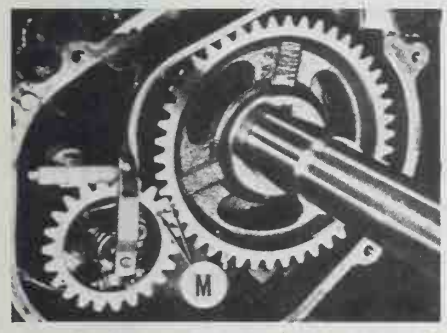


Fig. L36 — Align timing marks (M) as shown when reinstalling timing gears.

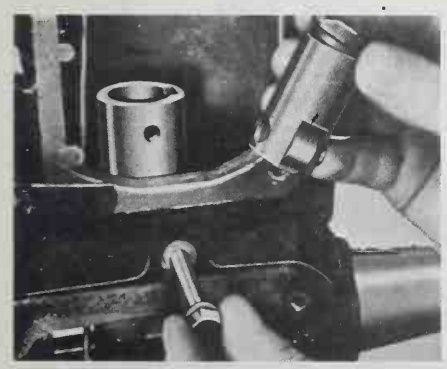


Fig. L37 — To service camshaft, remove fuel pump(s), fuel pump tappet(s), tappet guide locating pin(s) and guide(s).

Piston Ring Side Clearance	New Clearance	Maximum Wear Clearance
Firing Ring*	0.002 in.	0.004 in.
Compression Rings	0.005 in.	0.009 in.
Scraper Rings	0.002 in.	0.006 in.

*Special gage required.

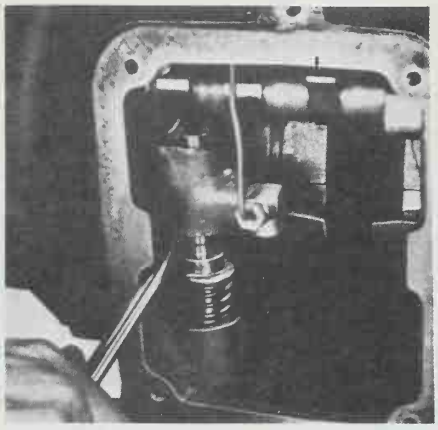


Fig. L38 — To remove camshaft, set oil pump to bottom of its travel and depress pump return spring until pump push rod is below level of camshaft bushings.

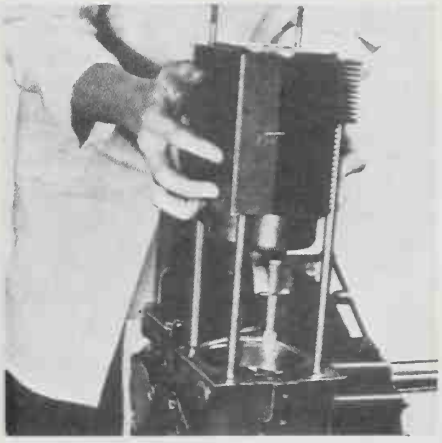


Fig. L39 — When reinstalling piston, connecting rod and cylinder barrel, flat sided fins must face flywheel.

When reinstalling piston, stagger ring end gap around piston. The words "CAMSHAFT SIDE" are stamped on top of piston and must be installed toward camshaft.

CYLINDER BARREL AND CONNECTING ROD

The standard cylinder bore is 3.751-3.752 inches. If cylinder is scored or worn, it must be resized to 0.010, 0.020 or 0.040 inch oversize. When reinstalling cylinder, flat sided fins must face the flywheel.

The forged steel connecting rod is used with a conventional two-piece steel backed copper lead bearing which is precision finished. New rod bearing has a running clearance of 0.0015-0.003 inch on new crankpin and a maximum wear clearance of 0.0055 inch. Rod bearings are available in undersizes of 0.010, 0.020 and 0.040 inch for use with reground crankshaft. Torque connecting rod nuts to 32 ft.-lbs.

Small end of rod is fitted with a copper faced steel backed bushing. New bushing to new piston pin clearance is 0.002 inch with a maximum wear clearance of 0.003 inch.

CAMSHAFT

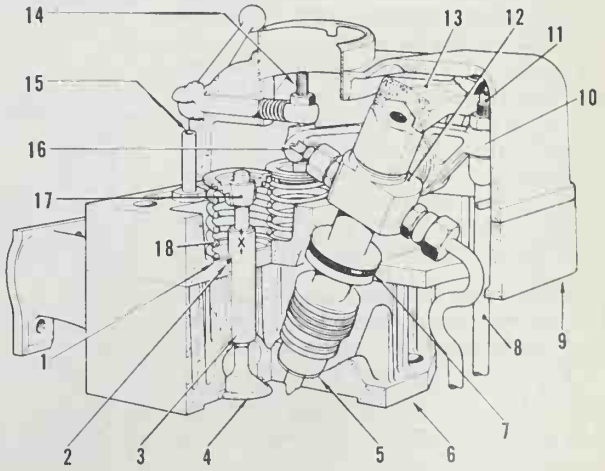
A steel camshaft rides in porous bronze bushings. Bushing on flywheel end, has a standard running clearance of 0.0055-0.006 inch with a maximum wear clearance of 0.009 inch. The other cam bushings have a standard clearance of 0.007-0.009 inch and a maximum wear clearance of 0.011 inch. Camshaft end play is not adjustable.

To remove camshaft, drain fuel and disconnect fuel lines. Remove cylinder head, fuel pump housing door, crank-

Fig. L40 — Cross-sectional view of cylinder head assembly.

1. Retaining plate
2. Valve guide seal
3. Intake valve guide
4. Intake valve
5. Injector gasket
6. Cylinder head
7. Injector seal
8. Push rod
9. Top plate
10. Rocker arm assy.
11. Rocker arm adjusting screw
12. Injector
13. Injector clamp
14. Compression release lever assy.
15. Breather tube
16. Leak-off pipe
17. Valve spring keepers
18. Valve spring

X. 0.495-0.515 inch



case door and gear cover. Disconnect speeder spring. Remove fuel pump(s), fuel pump tappet(s), tappet guide locating pin and guide. Set oil pump to bottom of its travel and depress pump return spring (Fig. L38) until pump push rod is below level of camshaft bushings. Hold valve tappets up and remove camshaft.

Examine cam bushings for scars or wear. Check cam lobes and gear for any chipping or damage. When reinstalling camshaft, reverse order of removal and line up "O" timing marks on cam gear and crankshaft gear (Fig. L36).

CRANKSHAFT AND MAIN BEARINGS

The steel crankshaft rides in two-piece steel backed copper lead lined main bearings. Intermediate main bearings are used in multi-cylinder engines; one in ST2 and two in ST3. The intermediate bearings are the split shell type contained in a housing located in crankcase by a hollow dowel which is tapped on one end. Standard main bearing clearance is 0.002-0.004 inch with maximum wear clearance of 0.006 inch. Bearings of 0.010, 0.020 and 0.040 inch undersize are available. Install new bearings in crankcase and main bearing housing so oil groove and hole is at top.

Standard crankshaft journal diameter is 2.499-2.4995 inches. Crankpin diameter is 2.4995-2.500 inches. Crankshaft end play is 0.005 inch (new) and maximum wear is 0.009 inch. End play is controlled by metal shims installed between main bearing housing and crankcase. Shims are available in thicknesses of 0.003, 0.005 and 0.010 inch.

OIL PUMP

Two types of plunger oil pumps are used. Early model pump required a separate pressure regulator (Fig. L28). The self regulating pump (A through J–Fig. L29) was introduced in ST1 engines in May 1978. By end of 1978, all multi-cylinder engines were equipped with self regulating pumps.

To service oil pump, drain crankcase oil. Remove crankcase door and turn engine until oil pump push rod is at its highest point. On early models, compress return spring and remove snap ring. Loosen and remove suction valve (early type) or pump plug (late type) from bottom of crankcase.

NOTE: Pump assembly is under spring tension and care should be taken to prevent loss or damage to pump parts.

Clean and inspect all parts and renew any showing excessive wear or other damage. Reassemble by reversing disassembly procedure.

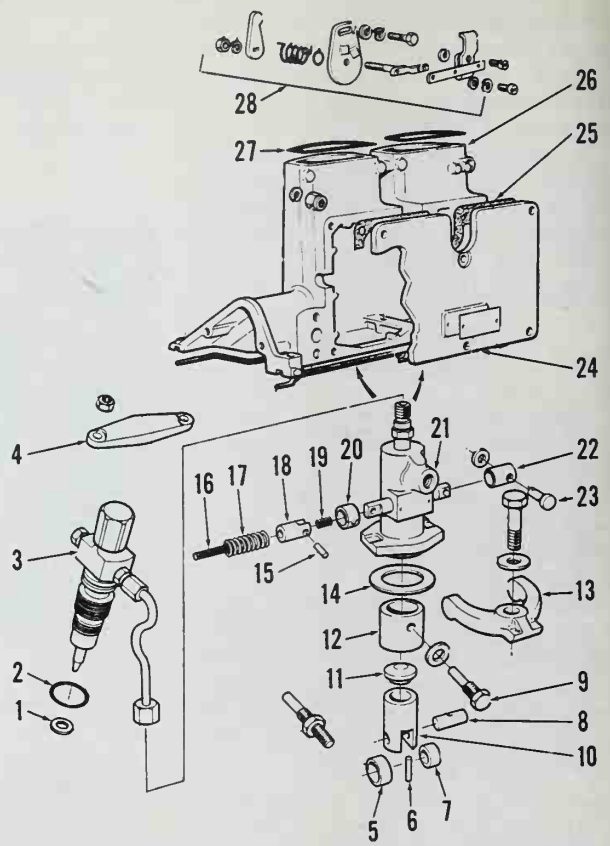


Fig. L41—Exploded view of typical fuel pump and housing assembly.

1. Injector gasket
2. Injector seal
3. Injector
4. Injector clamp
5. Roller
6. Retaining pin
7. Roller bushing
8. Roller pin
9. Tappet guide locating pin
10. Tappet
11. Tappet cap
12. Tappet guide
13. Fuel pump clamp
14. Shim (0.005 or 0.010 inch)
15. Pin
16. Fuel pump rod
17. Spring
18. Shackle
19. Spring
20. Spring clip
21. Fuel pump
22. Stop sleeve
23. Pin
24. Fuel pump housing door
25. Gasket
26. Fuel pump housing
27. Gasket
28. Engine control assembly

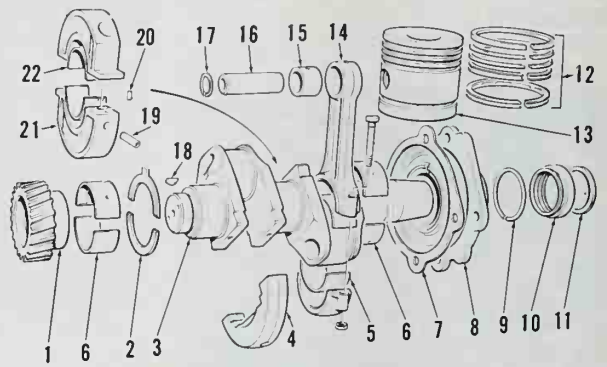


Fig. L42—Exploded view of typical crankshaft, connecting rod and piston assembly.

1. Crankshaft gear
2. Split thrust washer
3. Crankshaft assembly
4. Balance weight
5. Rod bearings
6. Main bearings
7. Shim (0.003, 0.005 and 0.010 inch)
8. Main bearing housing
9. Oil slinger
10. Oil seal
11. Felt
12. Piston rings (5)
13. Piston
14. Connecting rod
15. Piston pin bushing
16. Piston pin
17. Retainer
18. Key
19. Locating dowel
20. Dowel
21. Center main bearing housing
22. Center main bearing

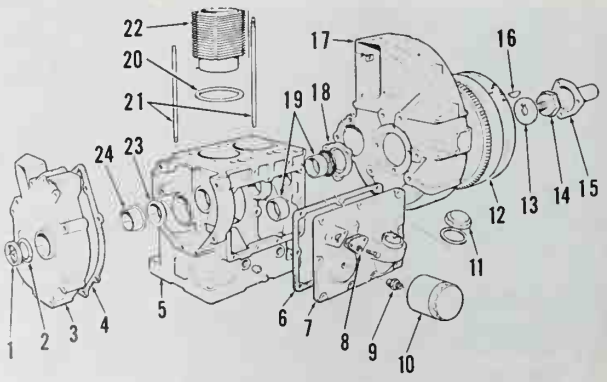


Fig. L43—Exploded view of typical crankcase assembly.

1. Oil seal
2. Oil slinger
3. End cover
4. End cover gasket
5. Crankcase assembly
6. Crankcase door gasket
7. Crankcase door
8. Blanking plate and gasket
9. Union
10. Oil filter
11. Oil filler cap and seal
12. Flywheel assembly
13. Lockwasher
14. Flywheel retaining screw
15. Crankshaft extension
16. Key
17. Fan shroud
18. Camshaft end cover
19. Camshaft bushings
20. Cylinder barrel gasket
21. Cylinder studs
22. Cylinder barrel
23. Camshaft bushing
24. End cover bushing

LISTER

MODEL	No. Cyl.	Bore	Stroke	Displ.
HR2	2	4¼ in.	4½ in.	127.5 cu. in.

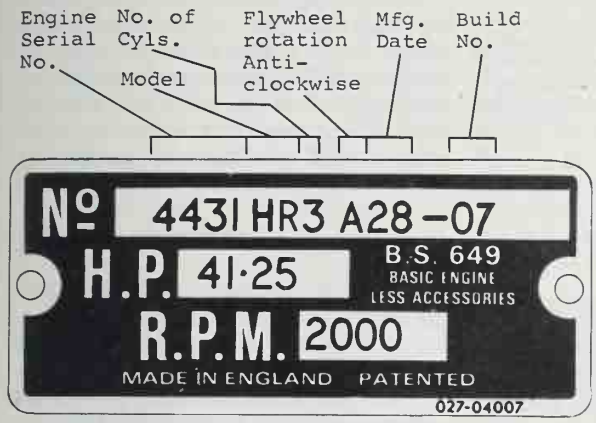


Fig. L49—View of typical engine identification plate used. To insure use of proper parts and specifications, use complete number.

Engines in this section are four-stroke type with vertical cylinders and direct fuel injection. Engine type can be identified by last two digits of engine number found on plate attached to fuel pump housing door (Fig. L49). Standard crankshaft rotation is counter-clockwise as viewed from flywheel end.

MAINTENANCE

STARTING PROCEDURES

HR engines have a manual crank start as standard equipment. Electric starters may be found on some engines. Refer to Accessory Section for service.

Before starting, check fuel and oil levels. If engine is equipped with fuel primer pump, prime fuel filter by using lever on pump. Move compression release levers away from flywheel and crank engine slowly 3-10 times according to temperature and period of "down time" in order to prime oil system and combustion chambers. In cold weather, lift overload stop to allow pumps to deliver extra fuel (Fig. L50). After priming, crank engine until maximum speed is obtained and release compression release levers.

CAUTION: Do not allow handle to continue to rotate on running shaft.

If engine is equipped with an electric starter, do not crank engine more than 10-15 seconds at a time.

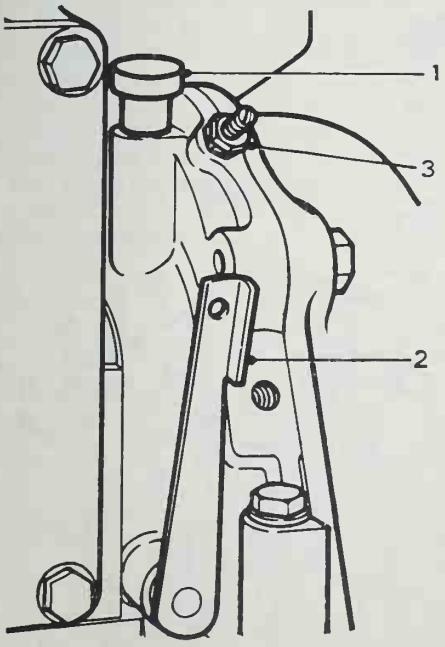


Fig. L50—Basic engine controls used on Model HR engines.

1. Overload trip
2. Control lever
3. Governor adjusting screw

LUBRICATION

Lister recommends lubricating oils with API service classification of CC or CD. Straight mineral oils or oils of less detergency are not suitable. If operated with high load factor, in high air temperatures or if the sulphur content in the fuel exceeds 0.6%, API CD oils or equivalent are recommended. Oil change interval is every 250 hours operation with filter change at the same time. Crankcase capacity is 19 pints.

If operating temperatures fall below 10° F., an SAE 10W weight oil is recommended. In temperatures between 10° to 85° F. use SAE 20-20W and above 85° F. use SAE 30 or 10W-40.

FUEL SYSTEM

No. 2 diesel fuel is recommended for most conditions. No. 1 diesel should be used for light duty or cold weather conditions. Fuel filter should be renewed every 1500 hours or more frequently if operated under dusty or dirty conditions.

Whenever fuel filter is changed or fuel line opened, air must be bled from the system. To bleed system, fill fuel tank and remove fuel pump door. Loosen bleed screw on top of fuel filter body; tighten when air-free flow is obtained. Start with fuel pump nearest the filter and loosen bleed screws one at a time. Tighten screw when air-free flow is obtained.

CAUTION: Care should be taken to prevent large flow of fuel into crankcase.

FUEL PUMP. A separate Bryce Berger fuel pump is used for each cylinder. It is recommended that all service of fuel pumps, other than renewal, be performed by an approved Service Department.

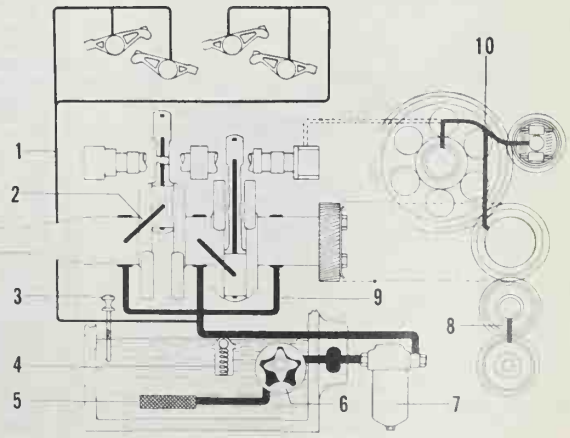


Fig. L51—Cross-section view of typical lubrication system.

1. Oil pipe to rocker arm
2. Oil passage for rod bearings
3. Dipstick
4. Pressure relief valve
5. Pick-up screen
6. Oil pump
7. Oil filter
8. Oil feed to idler gear
9. Oil pipe to main bearings
10. Oil pipe to gear train

If pump is removed for service, pump timing must be checked and adjusted after installation. To check timing, set control to "RUN" position and turn flywheel to the firing position. Set mark, FP on early models or Z on late models on flywheel opposite arrow on fan shroud (Fig. L52). Remove fuel delivery line, delivery valve holder, delivery valve and spring. If fuel flows from pump, turn crankshaft counterclockwise until flow ceases.

Reinstall delivery valve holder and turn crankshaft clockwise until fuel flow starts then turn counterclockwise until flow ceases. Firing mark should be opposite arrow or up to 3/16-inch before arrow. If not, shims below pump body must be adjusted. Shims of 0.005 inch and 0.010 inch are available. A 0.005 inch shim will retard timing approximately 1½° (approx. ¼-inch on a 20 inch diameter flywheel).

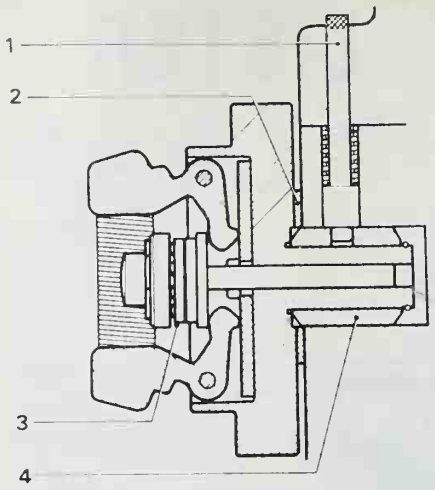


Fig. L54—Governor gear is driven directly by the camshaft and runs in a renewable bearing.

1. Spring loaded dowel pin
2. Thrust washer
3. Thrust bearing and shaft assembly
4. Governor bearing

FUEL INJECTOR. Injector nozzle has four holes of 0.010 in. Injector opening pressure is 2650 psi. Leak down rate, measured with a hand pump and gage, must be such that pressure will drop from 2205 to 1470 psi within 10 to 55 seconds.

To check injector spray, remove injector and reconnect externally to fuel pump. Crank engine about 60 rpm. All sprays should have the same appearance and length. If one hole is totally blocked or dribbles, nozzle must be renewed or cleaned and rebuilt by an authorized Service Department.

GOVERNOR

Two types of gear driven flyweight governors are used and are located in top of gear case. A constant or variable speed (Fig. L53) governor assembly rotates in a renewable bearing (4—Fig. L54) and is driven by the camshaft. The

Fig. L52—To check fuel pump timing, set control lever to "RUN" position and align timing marks on flywheel and fan shroud as shown.

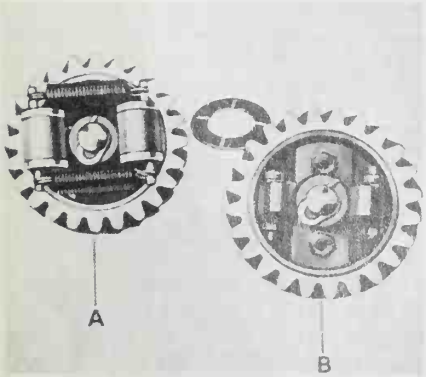


Fig. L53—Two types of gear driven flyweight governors are used. A constant speed "A" or a variable speed "B" governor is located at the top of the gear case.

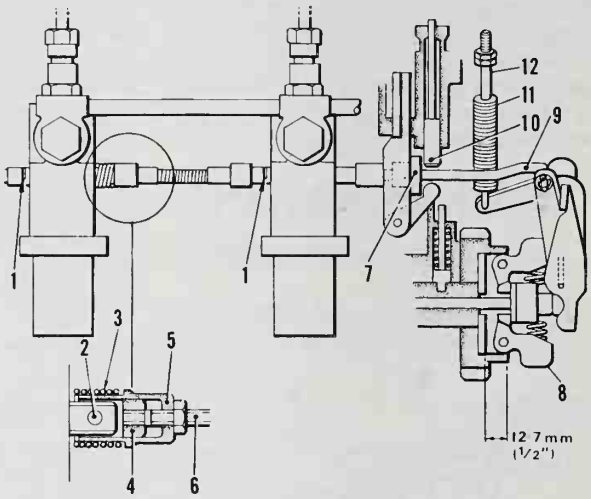


Fig. L55—To set fuel pump and governor, set engine control to "RUN" position. Refer to text for details.

1. Calibration mark
2. Shackle pin
3. Idling spring
4. Shackle
5. Adjusting sleeve
6. Connecting rod
7. Overload stop
8. Governor flyweight assembly
9. Rod
10. Overload trip
11. Speeder spring
12. Adjusting screw

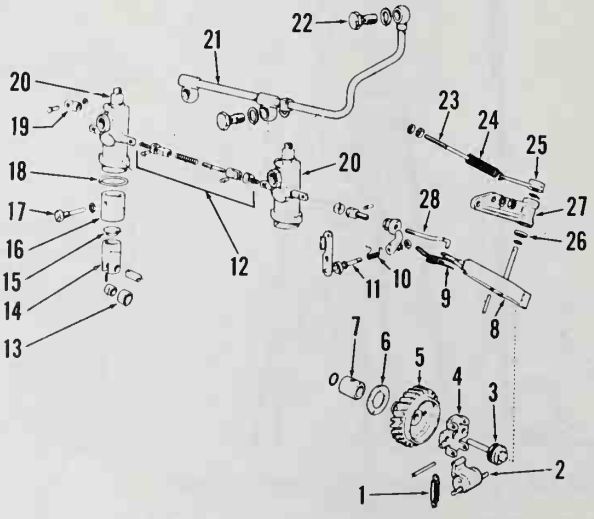


Fig. L56—Exploded view of fuel pump and governor assemblies.

1. Governor weight spring
2. Governor weight
3. Thrust bearing and shaft assy.
4. Weight carrier
5. Governor gear
6. Thrust washer
7. Bearing
8. Governor lever
9. Spring
10. Return spring
11. Stopping lever assy.
12. Rack assembly
13. Roller and bushing
14. Tappet
15. Tappet cap
16. Tappet guide
17. Locating pin
18. Shim (0.005 or 0.010 inch)
19. Stop sleeve
20. Fuel pump
21. Fuel line
22. Swivel union plug
23. Adjusting screw
24. Speeder spring
25. Governor lever
26. Ball bearing
27. Bracket

governor lever operates the fuel pumps. Governor weights and springs may be serviced separately. To insure use of correct parts and adjustments, contact an authorized Service Department.

To calibrate fuel pump linkage and set governor, set engine control to "RUN" position. Adjust fuel pump linkage so calibration marks (1–Fig. L55) coincide with sides of pump bodies within 0.005 inch. Rack must move freely after adjustment. Adjust overload stop (7–Fig. L55) so when it touches overload trip (10), calibration marks are aligned with edge of pump bodies.

To set governor, lift overload trip. Adjust rod (9) (remove cotter pin and screw in or out), with calibration marks aligned, so the distance between governor weight and bottom edge of thrust bearing is ½-inch.

Engines equipped with variable speed governors use an adjustable idling spring (insert–Fig. L55). The spring rides against fuel pump and applies pressure on pump rack to eliminate "hunting" or surging. To adjust idling spring (3), main speeder spring (11) must be completely loosened. Rotate adjusting sleeve (5) until idle speed is about one third rated engine speed. Main speeder spring should be adjusted so it just begins to increase engine speed. Idle speed is 750-850 rpm.

REPAIRS

TIGHTENING TORQUES

Recommended tightening torques are as follows: Values given are in ft.-lbs.

Connecting rod nuts	68
Cylinder head nuts	80
Flywheel set screw	400
Injector cap nuts	65
Injector clamp nuts	15
Injector pipe nuts	21
Fuel pump delivery valve holder	40
Valve rocker nuts	15

CYLINDER HEAD AND VALVE COVER

Valve cover contains the compression release assembly. Whenever any service is done on head or valve train, compression release should be adjusted. Access to release adjustment is through oil filler cap. To adjust, turn piston to TDC and move compression release lever towards flywheel. Loosen locknut and adjust screw until exhaust valve touches piston. Back the screw off ½-turn and tighten locknut. Repeat procedure for each cylinder.

Cylinder head consists of two parts. Top half (top plate) is cast iron and contains breather tube, valve springs and rocker arm assemblies. The lower half (cylinder head) is aluminum alloy fitted with valve seats (Fig. L57). Valve guides are a press fit. Note: The two rubber blanking plugs in top face of the heads should not be removed.

After servicing cylinder head, piston to cylinder head clearance should be checked. To check clearance, place two pieces of lead wire 0.062 inch thick on cylinder head, clear of valve recesses and combustion chamber and as near as possible in line with piston pin. Tighten head to torque of 80 ft.-lbs. and turn piston twice past TDC. Remove head and measure lead wire. Thickness should be 0.042-0.045 inch. Shims of 0.003 inch placed between cylinder head and gasket adjust clearance.

VALVE SYSTEM

Valve spring free length should be 2.242-2.328 inches. Lister recommends that valve springs be renewed after 6000 hours of operation. Valve guides are a press fit. Intake guide is fitted with a rubber seal, (the guides are not interchangeable). Valve stem diameter is 0.3718-0.3723 inch and valve guide bore is 0.3745-0.3753 inch. Clearance for new valve stem to new guide is 0.0022-0.0035 inch with maximum wear clearance of 0.005 inch.

Inspect valve seats for nicks, cracks or pitting. Regrind seats or if not suitable for further service, renew cylinder head. Valve seat angles should be 45.5°. Seat width should be 0.107-0.127 inch for intake and 0.100-0.114 inch for exhaust. Valve face angles are 45°-45.5°.

Rocker arm bushing bore is 1.0000-0.10005 inches. Rocker shaft is 0.9985-0.9990 inch in diameter. Initial clearance is 0.001-0.002 inch with maximum wear clearance of 0.003 inch.

To adjust valve clearance, turn crankshaft until piston is at TDC with both valves closed and loosen locknut. Adjust screw to obtain correct clearance. Tighten locknut and recheck clearance. Repeat procedure for each cylinder. Both valves have 0.002 inch clearance (cold).

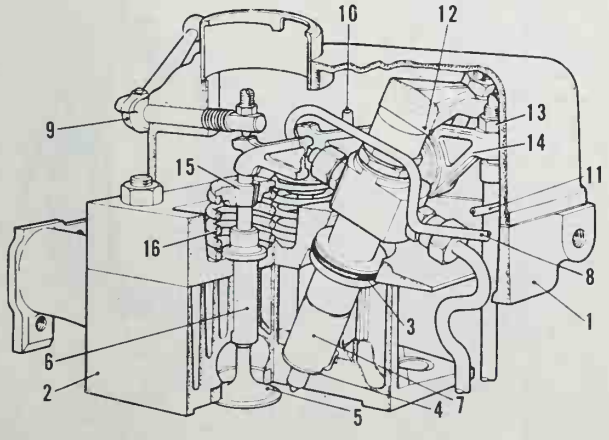


Fig. L57–Cross-sectional view of cylinder head assembly.

1. Top plate
2. Cylinder head
3. Injector seal
4. Injector gasket
5. Exhaust valve
6. Valve guide
7. Injector
8. Leak off pipe
9. Compression release lever
10. Breather tube
11. Oil pipe to rocker arms
12. Injector clamp
13. Rocker arm adjusting screw
14. Rocker arm
15. Valve keepers
16. Valve spring

PISTON, PISTON PIN AND RINGS

Piston is made of low expansion alloy. Piston diameter (at bottom of skirt) is 4.2425-4.2435 inches. Running clearance of new piston in new cylinder is 0.0095 inch with maximum wear clearance of 0.016 inch. The words "CAMSHAFT SIDE" are stamped on top of piston and must be installed toward camshaft.

Each piston is equipped with five rings: A barrel faced chrome firing ring; 2 taper faced compression rings; one spring expander scraper ring above piston pin and one slotted scraper ring below piston pin. Ring clearances are as follows (measurements are in inches):

Ring Gap	New Clearance	Maximum Wear Clearance
Fire ring	*	*
Compression rings	0.019-0.026	0.038
Top scraper ring	0.026-0.036	0.048
Bottom scraper	0.021-0.028	0.038

Ring Side Clearance	New Clearance	Maximum Wear Clearance
Fire ring	*	*
rings	0.004-0.006	0.008
Scraper rings (both)	0.002-0.004	0.006

*Special gage required.

Piston pins, 1.5623-1.5625 inches in diameter, ride in a copper faced steel backed bushing in the small end of the connecting rod. New piston pin has a clearance of 0.0008-0.0018 inch in new

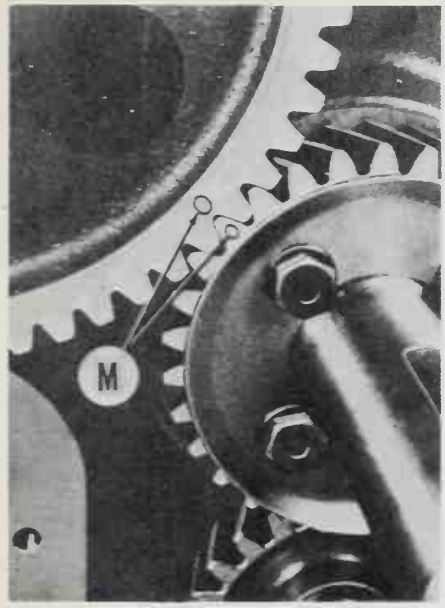


Fig. L58 – Align timing marks (M) as shown when reinstalling timing gears.

bushing with a 0.003 inch maximum wear clearance. Pistons and rings are available in 0.010, 0.020 and 0.040 inch oversizes.

CYLINDER BARREL AND CONNECTING ROD

Standard bore is 4.253-4.254 inches. If cylinder barrel is scored or excessively worn, cylinder should be rebored to 0.010, 0.020 or 0.040 inch oversize. Before disassembly, each cylinder should be marked (1, 2 or 3 cylinder). A "V" notch cut in top fin of barrel must be installed toward flywheel end.

Forged steel connecting rod is used with conventional split steel backed copper lead bearing that is precision finished. Crankpin diameter is 2.7487-2.7492 inches. New bearing to new crankpin clearance is 0.002-0.0035 inch with a maximum wear clearance of 0.0055 inch.

Connecting rod and cap are marked on one side with "double" cylinder numbers (11, 22 or 33). When reinstalling rod and piston assembly, all marks must face camshaft side of engine. Torque rod bolt nuts to 68 ft.-lbs.

CAMSHAFT

To remove camshaft, remove cylinder heads, fuel pump housing door, crankcase door and gear case cover. Release speeder spring, disconnect and remove governor link assembly. Disconnect fuel lines and remove fuel pumps and injectors. Remove fuel pump tappet guide locating pins and lift out tappet assemblies. Remove oil supply pipe plug from camshaft locating bushing. Lift valve tappets and carefully withdraw camshaft assembly and locating bushing.

Steel camshaft is carried in bronze bushings at flywheel end and crankcase

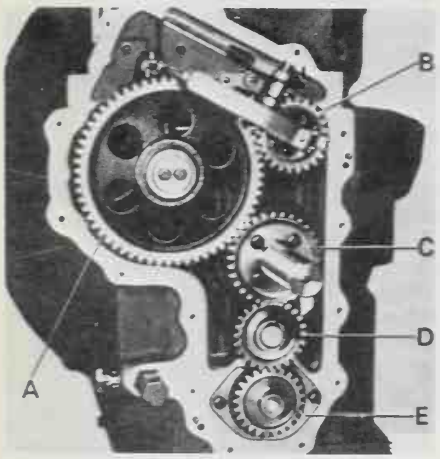


Fig. L59 – Basic gear train used on HR engines. Initial backlash between gears is 0.001-0.009 inch with maximum backlash of 0.012 inch.

A. Camshaft gear
B. Governor gear
C. Crankshaft gear
D. Idler gear
E. Oil pump gear

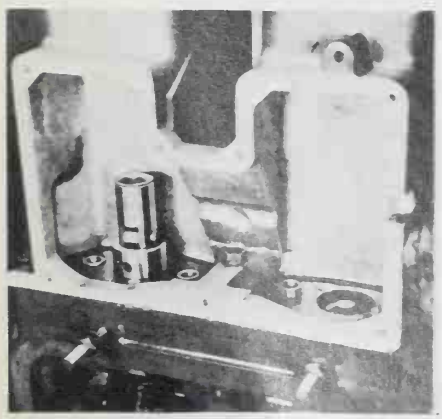


Fig. L60 – To service camshaft, remove fuel pumps, fuel pump tappets, tappet guide locating pins and guides.

Fig. L61 – Exploded view of crankshaft and camshaft assemblies.

1. Upper center main bearing housing
2. Lower center main bearing housing
3. Center main bearing
4. Main bearing
5. Split thrust washer
6. Thrust washer
7. Main bearing
8. Idler gear shaft and plug
9. Oil pump gear
10. Idler gear
11. Camshaft
12. Rod bearing
13. Crankshaft
14. Oil slinger
15. Balance weight
16. Rod bearing
17. Camshaft bushing
18. Piston ring
19. Piston pin
20. Retaining ring
21. Key
22. Camshaft bearing
23. Crankshaft gear
24. Camshaft gear
25. Locating plate
26. Piston rings
27. Piston
28. Rod bushing
29. Connecting rod

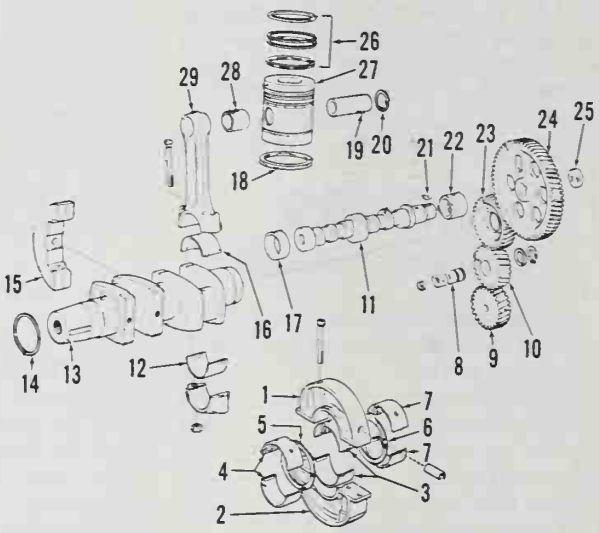
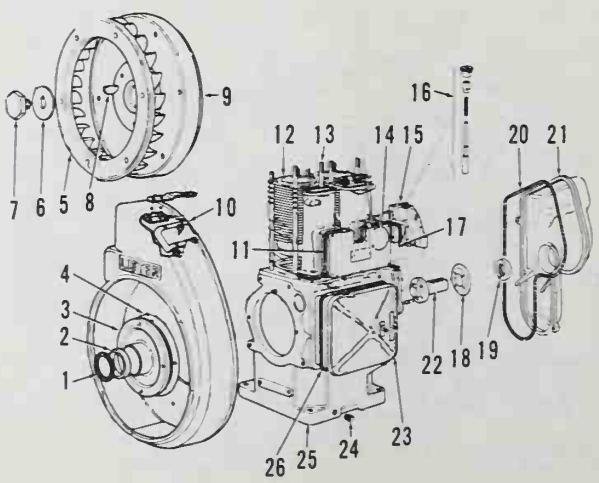


Fig. L62 – Exploded view of basic crankcase assembly.

1. Felt washer
2. Oil retaining ring
3. Main bearing housing
4. Bearing housing gasket
5. Fan
6. Lockwasher
7. Flywheel retaining screw
8. Key
9. Flywheel
10. Fan shroud
11. Gasket
12. Cylinder barrel
13. Stud
14. Fuel pump housing door
15. End plate
16. Overload trip assy.
17. End plate gasket
18. Oil slinger
19. Oil seal
20. Gear cover gasket
21. Gear cover
22. Crankshaft extension
23. Crankcase door
24. Drain plug
25. Crankcase assy.
26. Crankcase door gasket



dividers. A cast iron bushing is used on gear end and is secured by oil supply line plug. All bushings, except locating bushings, are a press fit with a new clearance of 0.0023-0.0032 inch and maximum wear clearance of 0.005 inch. Install bushings with "O" mark towards top. Locating bushing new clearance is 0.002-0.0037 inch with maximum wear clearance of 0.005 inch. Install with locating hole to top. Camshaft end play is 0.005-0.010 inch.

Timing marks on camshaft and crankshaft should be aligned as shown in Fig. L58. Fuel pump timing should be checked as described in Fuel System paragraph.

CRANKSHAFT AND BEARINGS

Steel crankshaft rides in steel backed copper lead lined split bushings at either end of shaft. The center bearing is located in crankcase by a hollow dowel pin. New bearing clearance is 0.002-0.004 inch with maximum wear clearance of 0.006 inch. Crankshaft end play is 0.005-0.010 inch and can be adjusted with shims installed between main bearing housing and crankshaft. Shims are available in thicknesses of 0.003, 0.005 and 0.010 inch. Undersize bearings are available in 0.010, 0.020 and 0.040 inch for use with reground crankshaft.

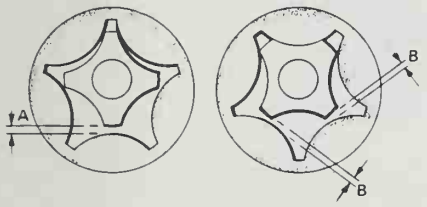


Fig. L63—The rotary oil pump wear limits are as follows: A—0.080 inch; B—0.007 inch; End clearance—0.006 inch.

OIL PUMP

Rotary oil pump is driven by an idler gear from crankshaft gear. Working oil pressure is 30-45 psi. To remove oil pump, drain oil and remove end cover. Unbolt and remove pump assembly. Renew oil pump if clearances (Fig. L63) are as follows:

Point A .....0.080 in.
Point B .....0.007 in.
End clearance .....0.006 in

SERVICING LISTER ACCESSORIES

STARTERS

MANUAL STARTERS. All Lister diesels have manual starting as standard equipment. Normal starting is from gear end (Figs. L75, L76 and L77). On LT engines and some ST engines, starting can be effected from flywheel end through geared-up starting (Figs. L78 and L79).

LT units bolt directly to flywheel and use a radius arm (10—Fig. L78) to stabilize gear box. ST units are bolted to fan shroud and use a dog plate (11—Fig. L79) on the flywheel to engage starter. Both units use normal engine oil to lubricate gears. Fill to oil plug level. All parts shown may be serviced separately.

ELECTRIC STARTERS. ST and HR engine may be equipped with a 12 volt starter. The starters are secured to the fan shroud by three bolts. The starter motor used on ST engines is a 1998219 Delco Remy motor. HR engines use a 1107567 Delco Remy motor. **DO NOT** crank engine with starter continuously for more than 10 seconds. If service becomes necessary, it is recommended it be done by an approved Service Department. Refer to Fig. L80 for basic wiring diagram used on ST and HR engines.

FUEL SYSTEM

LIFT PUMP. A fuel lift pump, when required, is fitted on the crankcase door

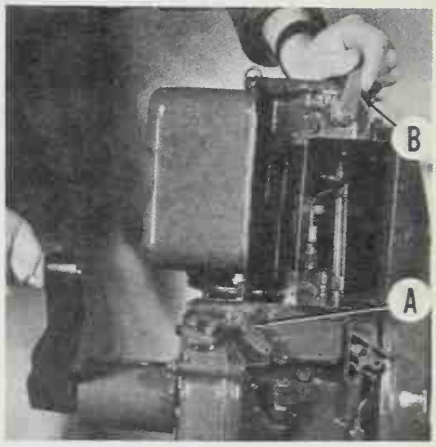


Fig. L75—To manually start LT engines, set engine control (A) to start position and move compression release lever (B) towards flywheel.

Fig. L76—ST engines are standard equipped with manual start from camshaft or gear side.

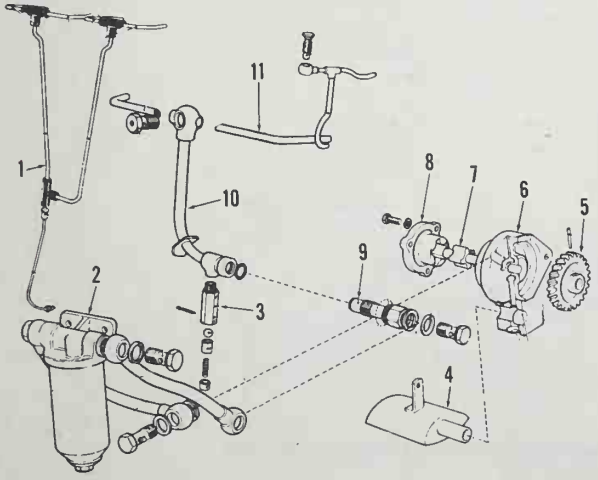
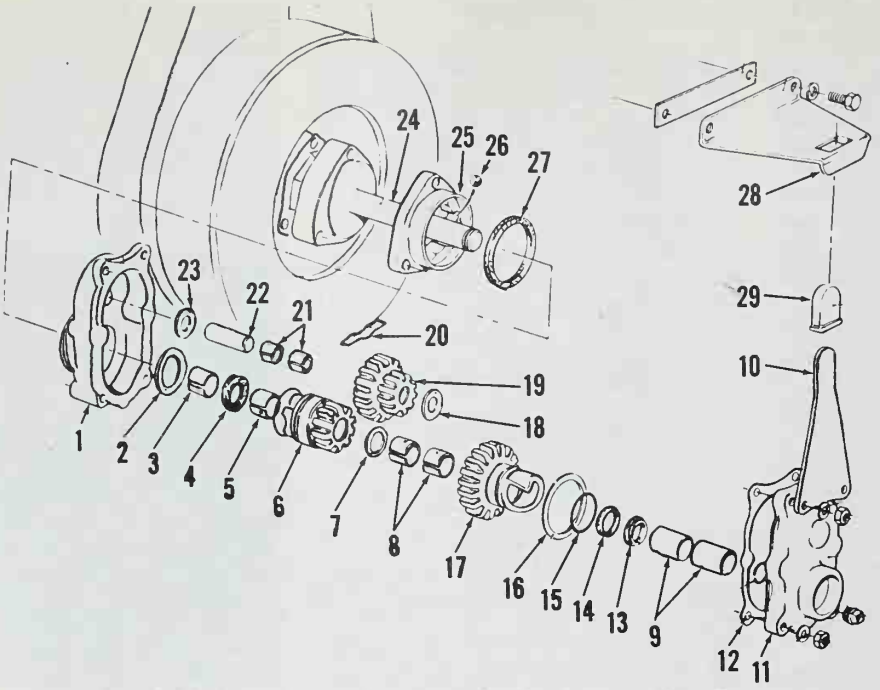


Fig. L64—Exploded view of lubrication system used.

1. Oil pipe between cylinders
2. Oil filter and mounting bracket
3. Oil pressure relief valve assy.
4. Pick-up screen
5. Drive gear
6. Pump housing
7. Spindle and impeller
8. Eccentric ring
9. Connector
10. Main oil supply pipe
11. Oil pipe to main bearing, camshaft and governor

Fig. L77—View of Model HR manual start and coupled compression release levers.



1. Gearcase
2. Washer
3. Bushing
4. Felt ring
5. Bushing
6. Ratchet and gear assy.
7. Washer
8. Drive gear bushings
9. Starting handle bushings
10. Radius arm
11. Cover
12. Gasket
13. Collar
14. Felt ring
15. "O" ring
16. Washer
17. Drive gear
18. Washer
19. Intermediate gear
20. Detent spring
21. Intermediate gear bushings
22. Intermediate gear shaft
23. Washer
24. Shaft extension
25. Clutch housing
26. Ball
27. Felt seal
28. Radius arm bracket
29. Radius arm bushing

Fig. L78—Exploded view of geared-up starter used on some LT engines.

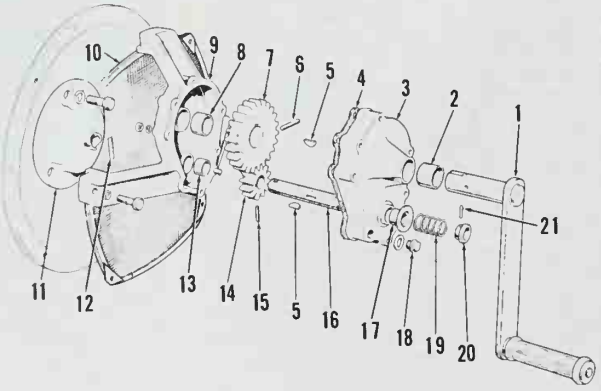


Fig. L79—Exploded view of geared-up starting used on some ST2 and ST3 engines.

1. Starting handle
2. Shaft extension bushing
3. Cover
4. Gasket
5. Key
6. Pin
7. Shaft extension gear
8. Bushing
9. Gear box
10. Fan shroud guard
11. Dog plate
12. Clutch pin
13. Bushing
14. Engagement gear
15. Pin
16. Engagement shaft

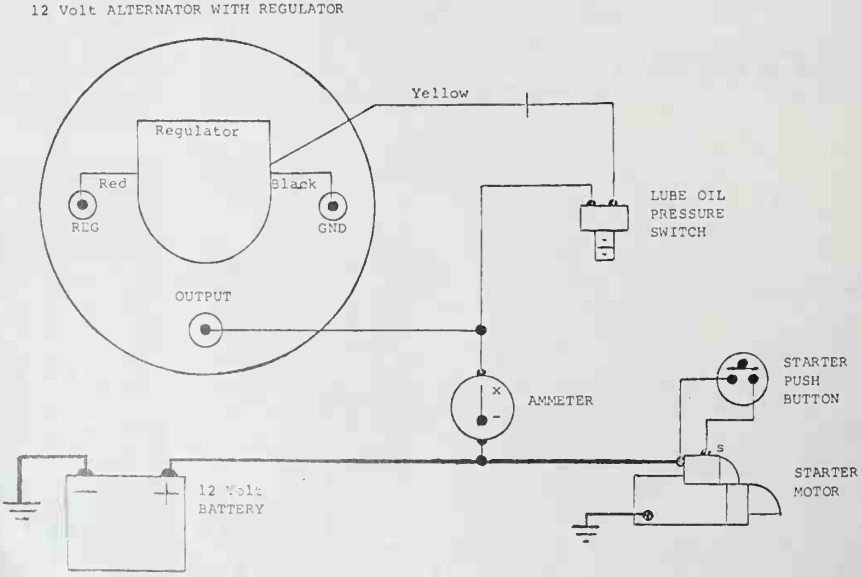


Fig. L80—View of typical 12 volt wiring used on ST and HR engines. Lister uses a Motorola alternator # MR12N600 on all engines.

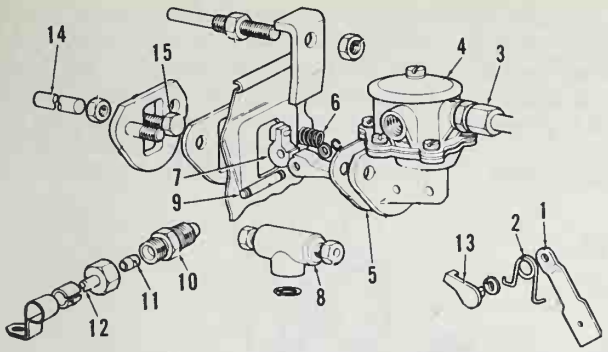


Fig. L81—Exploded view of fuel lift pump.

1. Primer arm
2. Return spring
3. 5/16-inch union fitting
4. Lift pump
5. Gasket
6. Spring
7. Arm
8. "T" fitting and gasket
9. Pin
10. Union
11. Ferrel
12. Union nut
13. Lever
14. Push rod
15. Push rod adjusting screw

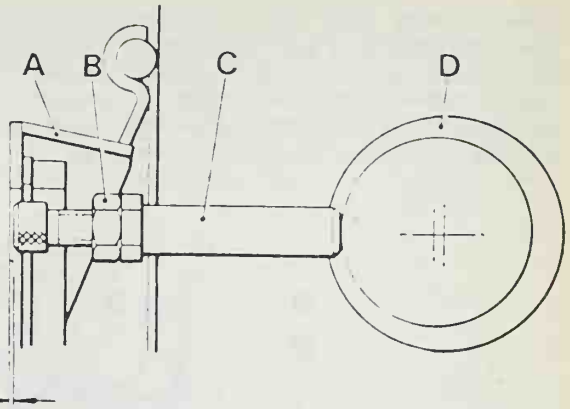


Fig. L83—View of lift pump adjuster used on HR engines. Push rod clearance (E) is 0.018-0.020 inch.

A. Crankcase door
B. Locknut
C. Push rod
D. Camshaft

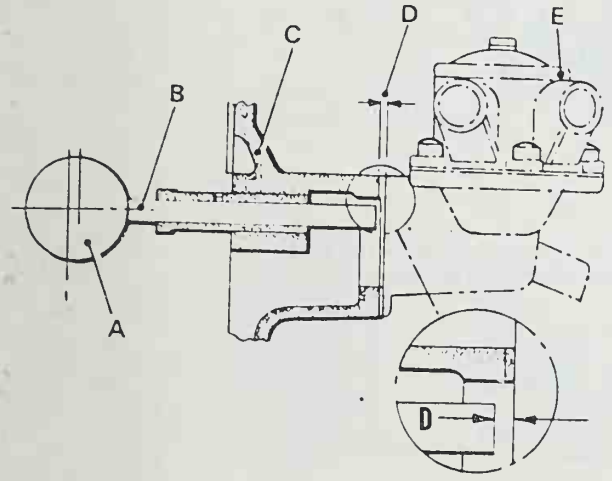


Fig. L82—Cross-sectional view of lift pump used on ST engines. Push rod clearance (D) is 1/32 to 3/64-inch.

A. Camshaft
B. Push rod
C. Crankcase door
D. Gasket
E. Lift pump

and operated by a push rod (14—Fig. L81) or (B—Fig. L82) riding against the camshaft. Inlet side of pump is connected to main fuel supply and outlet feeds fuel filter. Complete pump repair kits are available. After completing service, check push rod clearance.

To check clearance, insert push rod and turn engine over until the rod is at its maximum outward travel. On ST engines, install pump gasket and measure clearance. Pump clearance (D—Fig. L82) is 1/32 to 3/64-inch. Add pump gaskets as necessary to obtain correct clearance.

On HR engines, with push rod at its maximum outward travel, measure

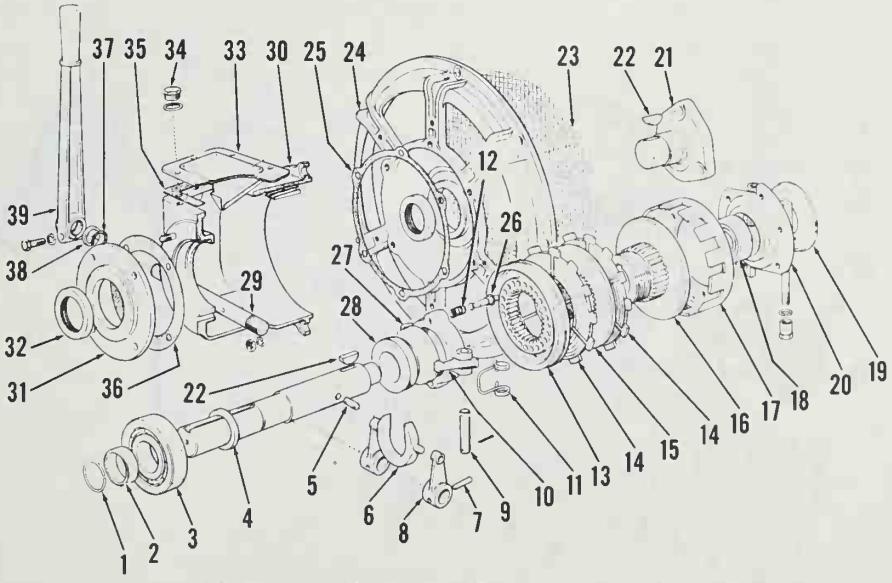


Fig. L84—Exploded view of multi-plate clutch used on ST engines.

1. Retaining ring
2. Oil seal bushing
3. Ball bearing
4. Clutch shaft assy.
5. Locating pin
6. Sliding yoke
7. Pin
8. Operating lever
9. Pin
10. Clutch engaging arms
11. Spring
12. Locating pin spring
13. Pressure plate
14. Clutch plates
15. Driven disc
16. Clutch hub
17. Clutch body
18. Bearing
19. Oil slinger
20. Clutch drive member
21. Crankshaft extension
22. Key
23. Guard
24. Adapter
25. Gasket
26. Plunger
27. Adjusting ring
28. Engaging cone
29. Operating shaft
30. Clutch housing
31. End cover
32. Oil seal
33. Inspection cover
34. Plug
35. Gasket
36. End cover gasket
37. Seal
38. Seal retainer
39. Operating lever

distance from push rod to face of crankcase door (E – Fig. L83). Distance should be 0.018-0.020 inch. To adjust, remove rod and lengthen or shorten adjuster as required. Reinstall push rod and pump.

CLUTCH. Some ST models are equipped with a multi-plate set type clutch (Fig. L84). The lever operated clutch is self-locking. The oil capacity is approximately 5/8-pint of SAE 10 weight oil.

Some HR models are equipped with a single plate clutch for direct drive (Fig. L85) or with a reduction gear (Fig. L86). Clutch lubrication is supplied by engine lubrication through a restrictor plug fitted in end of crankshaft.

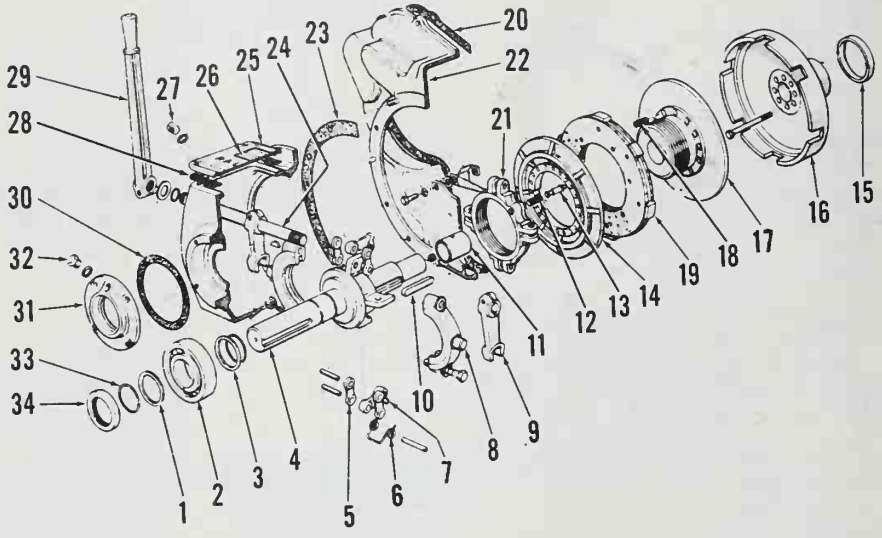


Fig. L85 – Exploded view of direct drive clutch used on HR engines.

1. Retaining washer
2. Ball bearing
3. Retaining ring and washer
4. Clutch shaft assy.
5. Link
6. Spring
7. Toggle lever and link
8. Yoke
9. Operating lever
10. Key
11. Bearing
12. Spring
13. Plunger
14. Pressure plate
15. Spigot ring
16. Clutch drive member
17. Clutch hub
18. Spring
19. Clutch plate
20. Gasket
21. Adjusting ring
22. Adapter
23. Gasket
24. Operating shaft assy.
25. Clutch housing
26. Inspection cover
27. Plug
28. Gasket
29. Operating lever
30. Gasket
31. End cover
32. Oil plug
33. Retaining ring
34. Oil seal

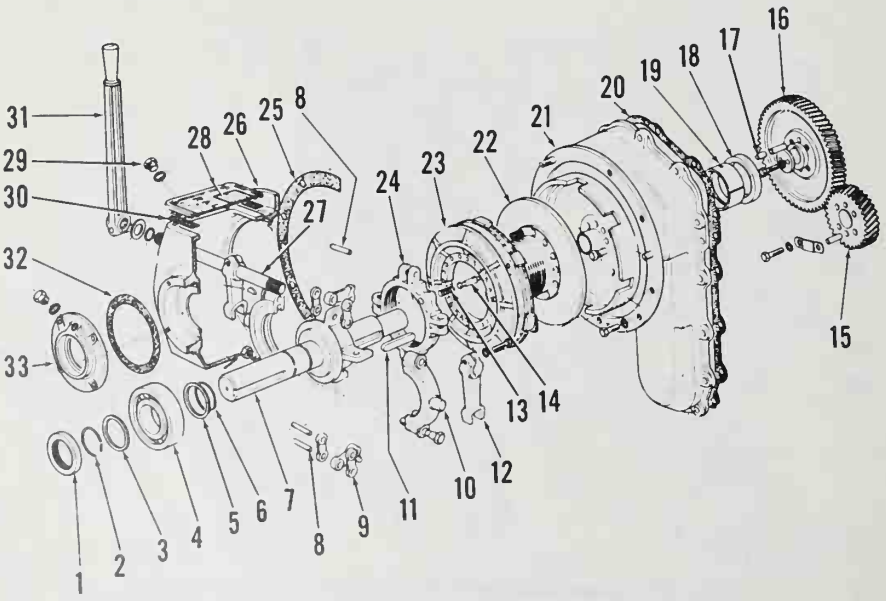


Fig. L86 – Exploded view of direct-drive clutch with 2:1 reduction gear used on HR engines.

1. Oil seal
2. Retaining ring
3. Washer
4. Ball bearing
5. Washer
6. Retaining ring
7. Clutch shaft assy.
8. Fulcrum
9. Toggle lever and link
10. Operating yoke
11. Key
12. Operating lever
13. Spring
14. Plunger
15. Crankshaft gear assy.
16. Camshaft gear
17. Dowel
18. Spigot ring
19. Split bearing
20. Gasket
21. Adapter
22. Clutch hub
23. Clutch plate assy.
24. Adjusting ring
25. Gasket
26. Clutch housing
27. Operating shaft
28. Inspection cover
29. Plug
30. Gasket
31. Operating lever
32. Gasket
33. End cover assy.

To adjust clutch, stop engine and remove inspection cover. Pull plunger (26–Fig. L84 or 13–Fig. L85) and rotate adjusting ring (27–Fig. L84 or 21–Fig. L85) clockwise one to three holes. Check "feel" of clutch lever. Do not adjust more tightly than is necessary to transmit full power without slip. Clutch output shaft must turn freely in "neutral" position.

REDUCTION GEAR. A 2:1 or 3:1 reduction gear may be attached to flywheel end on Models ST2 and ST3 (Fig. L87). The gear assembly is secured to fan shroud and a splined drive engages with a shaft extension bolted to the flywheel. A multi-purpose gear lubricant is used in gear box.

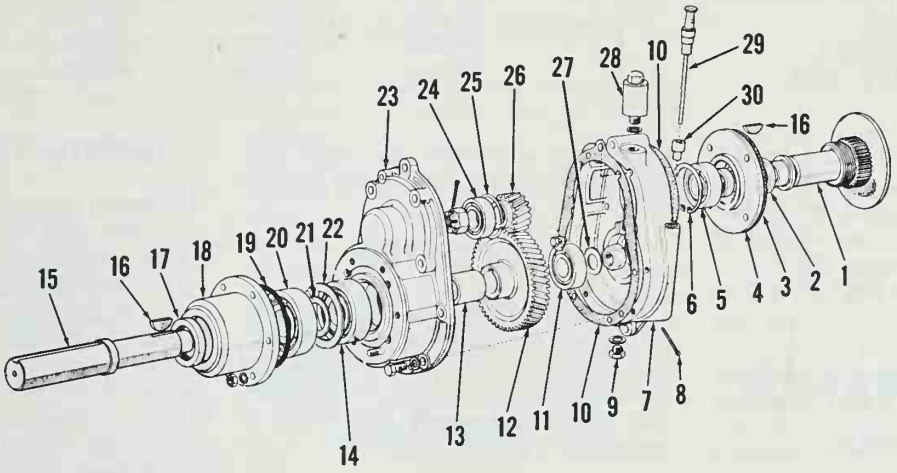


Fig. L87–Exploded view of 2:1 or 3:1 reduction gear used on some ST engines.

1. Clutch shaft assy.
2. Oil seal
3. Gasket
4. Adapter
5. Bearing
6. Snap ring
7. Gear case
8. Cotter pin
9. Drain plug
10. Gasket
11. Bearing
12. Gear (2:1 or 3:1)
13. Spacer
14. Bearing
15. Secondary shaft
16. Key
17. Oil seal
18. Bearing housing
19. Oil ring
20. Bearing
21. Inner spacing washer
22. Outer spacing washer
23. Gear case end cover
24. Roller bearing
25. Retaining ring
26. Pinion (2:1 or 3:1)
27. Packing shim
28. Oil breather
29. Dipstick
30. Adapter

LOMBARDINI

LOMBARDINI ENGINE, INC.
3402 Oakcliff Road, B-2
Doraville, Georgia 30340

Model	No. Cyls.	Bore	Stroke	Displ.
500	1	70 mm	68 mm	262 cc
520	1	78 mm	68 mm	325 cc
530	1	82 mm	68 mm	359 cc

Lombardini Model 500, 520 and 530 engines are four-stroke, air-cooled diesel engines. The cylinder head and cylinder block are aluminum. Crankshaft rotation is counter-clockwise at pto end.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0° C (32° F), SAE20W for temperatures between 0° C (32° F) and 20° C (68° F), and SAE 40 for temperatures above 20° C (68° F). API classification for oil should be CD. Oil sump capacity is one liter.

A renewable oil filter is located in side of engine block. Manufacturer recommends removing filter (22–Fig. L1-1) and installing a new filter after every 300 hours of operation.

ENGINE SPEED ADJUSTMENT

Idle speed is adjusted by turning idle speed screw (I–Fig. L1-2). Idle speed should be 1000-1050 rpm. Maximum governed speed is adjusted by turning high speed screw (H). Maximum governed speed under load should be 3600 rpm.

FUEL SYSTEM

FUEL FILTER. The fuel filter may be located inside the fuel tank as shown in Fig. L1-3 or a cartridge type filter as shown in Fig. L1-4 may be used. Renew fuel filter after every 300 hours of operation or sooner if required.

BLEED FUEL SYSTEM. If equipped with cartridge filter (F–Fig. L1-4), unscrew bleed screw and allow fuel to flow until air-free, then retighten screw.

On gravity flow fuel systems (Fig. L1-3), loosen fuel line fitting on injection pump and allow fuel to flow until air-free, then retighten fitting.

On models equipped with a fuel pump (L–Fig. L1-4), loosen fuel line fitting on injection pump and operate fuel pump primer lever until air-free fuel flows from fitting, then retighten fitting.

On all models, loosen high pressure injection line at injector. Rotate engine crankshaft to operate injection pump until air-free fuel flows from injection line. Retighten injection line.

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G–Fig. L1-3 and L1-4) between pump body and mounting surface on crankcase. To check injection pump timing, unscrew delivery line (D) fitting from delivery union (1–Fig. L1-5). Unscrew delivery union and remove spring (3), washer (4) and valve (5), then screw delivery union (1) into pump body. Move throttle control lever to full speed position. Rotate engine in normal direction (clockwise at flywheel end) so piston is on compression stroke.

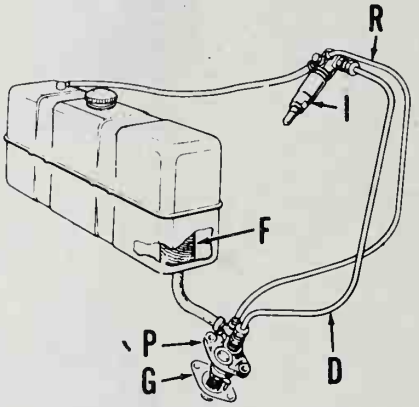


Fig. L1-3 – Diagram of fuel system.

D. Delivery line
F. Fuel filter
G. Shim gasket
I. Injector
P. Injection pump
R. Return line

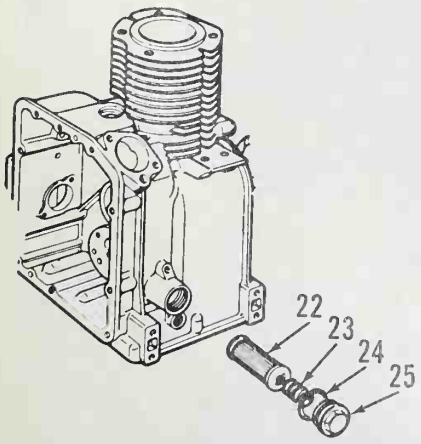


Fig. L1-1 – Exploded view of oil filter.

22. Oil filter
23. Spring
24. "O" ring
25. Plug

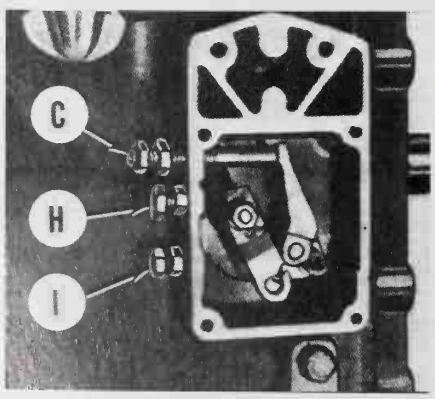


Fig. L1-2 – Turn screw (I) to adjust low idle speed and screw (H) to adjust high idle speed. Torque control screw (C) must be adjusted as outlined in text.

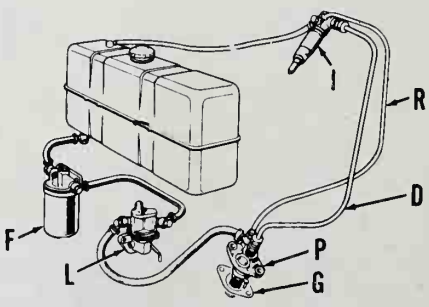


Fig. L1-4 – Diagram of fuel system used on some models.

D. Delivery line
F. Fuel filter
G. Shim gasket
I. Injector
L. Fuel pump
P. Injection pump
R. Return line

Note fuel in delivery union will spill out of union. Stop engine rotation at moment fuel ceases to spill out of union. Timing dot (R–Fig. L1-6) on fan plate should align with injection timing dot (I) on fan shroud. Correct injection timing is 26° 20' to 28° 20' for Model 500 before serial number 1447084, Model 520 before serial 1448128 and Model 530 before serial number 1457466. Correct injection timing is 29° 20' to 31° 20' for models after the aforementioned serial numbers. To advance injection timing, remove shim gaskets (G–Fig. L1-3 and L1-4); install shim gaskets to retard injection timing. Shim gaskets are available in thicknesses of 0.1, 0.3 and 0.5 mm. Reinstall removed pump components after checking injection timing. Tighten injection pump retaining screws to 29 N·m.

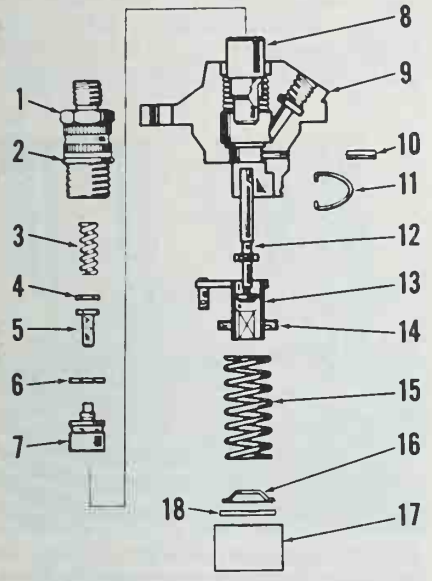


Fig. L1-5–View of injection pump.

1. Delivery union
2. "O" ring
3. Spring
4. Washer
5. Delivery valve
6. Gasket
7. Delivery valve seat
8. Barrel
9. Pump body
10. Pin
11. Clip
12. Plunger
13. Control sleeve
14. Spring seat
15. Spring
16. Spring retainer
17. Tappet
18. Spacer

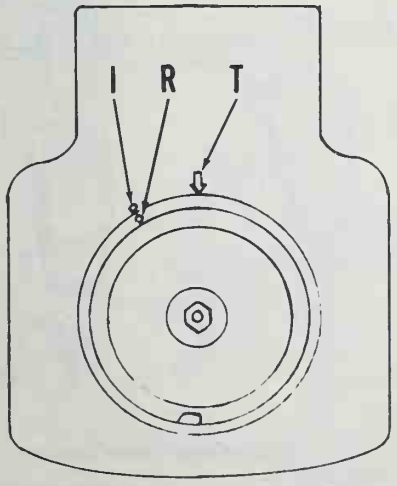


Fig. L1-6–Injection should occur when timing dot (R) of fan plate is aligned with injection timing dot (I) on fan shroud. Piston is at TDC when timing dot (R) and arrow (T) are aligned.

REPAIRS

TIGHTENING TORQUES

Refer to following table for tightening torques. All values are in newton meters.

Connecting rod	33.3
Crankcase cover	29
Cylinder head	39.2
Flywheel	147
Injection pump	29
Injector nozzle nut	60-90
Injector retainer plate	12
Oil pump	11.8

VALVE TAPPET GAP

Valve tappet gap may be adjusted after removing rocker arm cover. Valve tappet gap should be 0.15 mm for both valves with engine cold. Note that there are two adjusting screws (Fig. L1-7) in exhaust rocker arm on some models. Adjusting screw (V) nearer rocker arm shaft is used to adjust valve clearance while outer screw (C) adjusts compression release gap on models so equipped.

COMPRESSION RELEASE

Some models are equipped with a manual compression release so the exhaust valve may be held open to aid starting. Compression release components (24 through 29–Fig. L1-8) are mounted in the cylinder head. Rotating shaft (26) will force the exhaust rocker arm (10) to slightly open the exhaust valve.

The compression release is adjusted by turning outer adjusting screw (C–Fig. L1-7) in exhaust valve rocker arm. Adjust compression release gap AFTER adjusting exhaust valve tappet gap. With compression release lever (L) in off position, clearance between adjusting screw and shaft should be 0.9-1.1 mm.

Diameter of compression release shaft (26–Fig. L1-8) is 9.37-10.00 mm while lobe height is 8.45-8.50 mm.

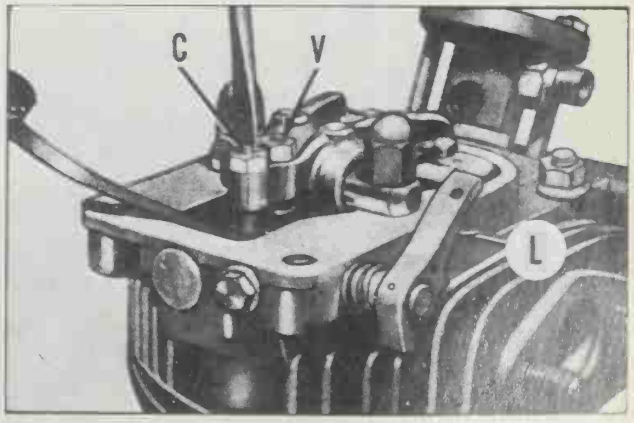


Fig. L1-7–With compression lever (L) in off position, turn adjusting screw (C) so clearance is 0.9-1.1 mm (0.035-0.043 in.) between screw and shaft. Adjusting screw (V) determines valve clearance.

CYLINDER HEAD AND VALVE SYSTEM

Manufacturer does not recommend removing a hot cylinder head as deformation may result.

Valve face angle is 45 degrees and minimum valve head margin is 0.5 mm. Valve seat angle is 45 degrees with a seat width of 1.4-1.6 mm. Valve seats are renewable and must be installed with head heated to 160°-180° C (320°-356° F). Valve seals are used on intake valves. Valve stem diameter is 6.98-7.00 mm while valve guide diameter is 7.03-7.05 mm. Desired valve stem clearance is 0.03-0.07 mm. Valve guides are renewable and oversize valve guides are available. Exhaust valve guide is bronze. Note locating ring (15–Fig. L1-8) around top of each guide. The cylinder head should be heated to 160°-180° C (320°-356° F) when installing valve guides.

Valve spring free length should be 42 mm. Valve spring pressure should be 225.4 newtons at 32 mm.

The rocker arms are supported by rocker arm shaft (6). Desired clearance between shaft and rocker arms is 0.03-0.06 mm. Renew shaft and rocker arms if clearance exceeds 0.1 mm.

The cylinder head gasket is available in varying thicknesses. Gasket thickness is determined by measuring piston height at top dead center (TDC) as shown in Fig. L1-9. Measure from piston crown to gasket seating surface of cylinder. Subtract measurement from 0.6-0.7 mm to obtain required gasket

thickness. Cylinder head gaskets are available in thicknesses of 0.5 mm, 0.6 mm, 0.7 mm and 0.8 mm.

Tighten cylinder head nuts in a crossing pattern to 39.2 N·m.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and injection line and immediately cap or plug all openings. Unscrew retainer plate nuts and lift off retainer plate (1–Fig. L1-10) being careful not to lose dowel pin (2). Injector may now be carefully removed from cylinder head. Do not lose shims between injector and cylinder head.

Tighten injector retaining plate nuts to 12 N·m. If accessible, measure protrusion of nozzle into combustion chamber. Nozzle tip should extend 2.5-3.0 mm above adjacent combustion chamber surface. Adjust position of nozzle by installing shims between injector and cylinder head. Shims are available in thicknesses of 0.5 mm and 1.0 mm.

TESTING. WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector operation may be checked. Only clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Opening pressure with a new spring (4–Fig. L1-10) should be 20.5-22.5 MPa while opening pressure with a used spring should be 19.6-21.5 MPa. Opening pressure is adjusted by varying number and thickness of shims (5). Valve should not show leakage at orifice spray holes for 10 seconds at 17.6 MPa.

OVERHAUL. Clamp nozzle body (3–Fig. L1-10) in a vise with nozzle tip pointing upward. Remove nozzle holder nut (11). Remove nozzle tip (9) with valve (10) and spacer (8). Invert nozzle body (3) and remove spring seat (6), shim (5) and spring (4). Thoroughly clean all parts in a suitable solvent. Clean inside orifice end of nozzle tip with a wooden cleaning stick. The 0.20 mm diameter orifice spray holes may be cleaned by inserting a cleaning wire slightly smaller than spray hole. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle holder nut (11) to 60-90 N·m.

INJECTION PUMP

Refer to Fig. L1-5 for view of injection pump. Disassembly and reassembly is evident after inspection of pump and referral to Fig. L1-5. Note that slot in barrel (8) must align with pin (10) and helix in plunger (12) must face pin (10).

The following tests may be used to check injection pump if necessary test equipment is available. With a suitable pressure gage connected to delivery union (1), operate pump. With control sleeve (13) at mid-point, pump pressure should be at least 29.4 MPa. Pump pressure should be at least 39.2 MPa with control sleeve in maximum fuel position. To check delivery valve, move control sleeve (13) to mid-point position and operate pump. After maximum

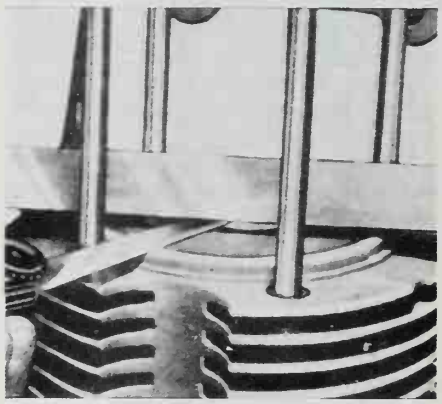


Fig. L1-9–Measure piston height in cylinder and refer to text for cylinder head gasket thickness.

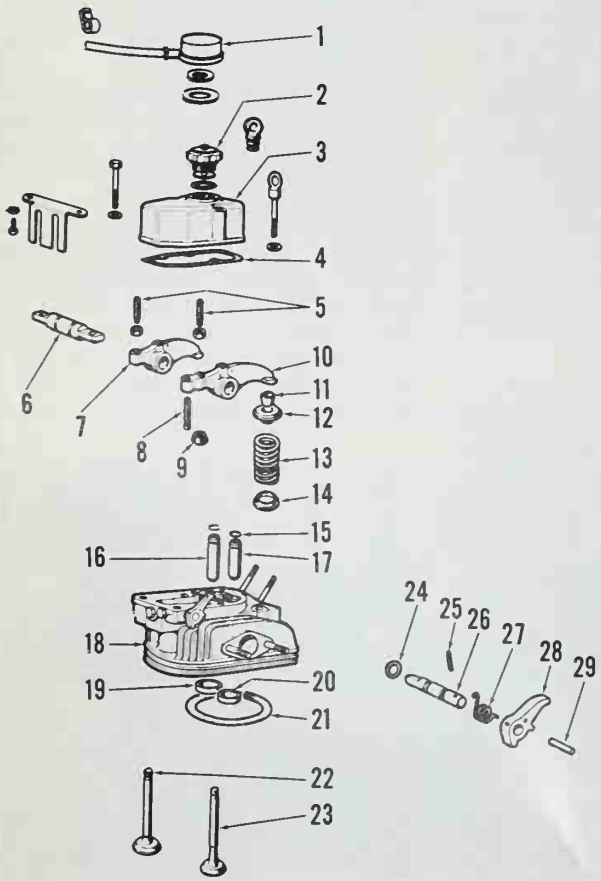


Fig. L1-8–Exploded view of cylinder head assembly.

1. Breather
2. Fill cap
3. Rocker cover
4. Gasket
5. Valve adjusting screws
6. Rocker arm shaft
7. Intake rocker arm
8. Compression release adjusting screw
9. Valve seal
10. Exhaust rocker arm
11. Valve keepers
12. Spring retainer
13. Spring
14. Spring seat
15. Locating rings
16. Intake valve guide
17. Exhaust valve guide
18. Cylinder head
19. Intake valve seat
20. Exhaust valve seat
21. Head gasket
22. Intake valve
23. Exhaust valve
24. "O" ring
25. Pin
26. Compression release shaft
27. Spring
28. Compression release lever
29. Pin

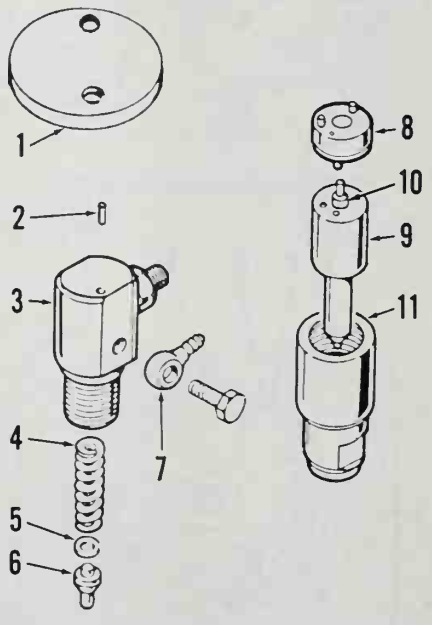


Fig. L1-10–Exploded view of injector.

1. Clamp plate
2. Dowel pin
3. Nozzle body
4. Spring
5. Shim
6. Spring seat
7. Return line fitting
8. Spacer
9. Nozzle tip
10. Valve
11. Nozzle holder nut

pressure is reached, pressure should drop sharply to a pressure 2940-4900 kPa less than maximum pressure if delivery valve is operating properly. Maximum delivery rate of pump is 44-46 cc at 1800 rpm for 1000 pump strokes.

Outside diameter of tappet (17) is 27.96-27.98 mm while maximum allowable clearance in tappet guide bore is 0.10 mm. Thickness of spacer (18) should be 3.45-3.55 mm.

When installing injection pump, place shim gaskets (G–Fig. L1-3 or L1-4) under pump then engage control sleeve (13–Fig. L1-5) pin with governor arm (F–Fig. L1-11). Tighten pump retaining screws to 29 N·m. Loosen clamp nut (N) then move throttle lever (T) to full throttle. Push governor lever (L) in until it stops thus moving injection pump control sleeve to maximum delivery. Tighten clamp nut (N).

Torque control screw (C–Fig. L1-2 and L1-12) allows additional fuel usage under high torque load. The tip (T–Fig. L1-12) is backed by spring (S). Tip (T) must travel 0.2-0.3 mm when 400-430 grams is forced against tip. To adjust torque control screw, run engine at high idle with no load and turn screw so there is 2.1-2.3 mm gap (G) between tip (T) and lever (L). Tighten locknut.

Refer to INJECTION PUMP TIMING section to time injection pump.

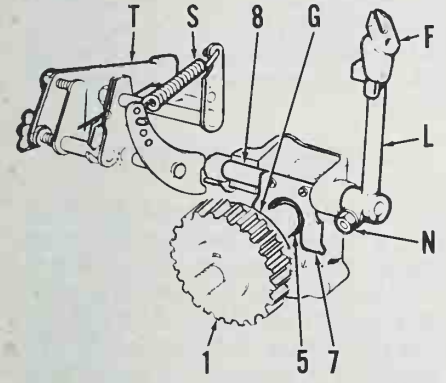


Fig. L1-11–View of governor mechanism. Refer to text for operation.

GOVERNOR

All models are equipped with a flyweight centrifugal type governor which is attached to the back of oil pump drive gear as shown in Fig. L1-11. The oil pump drive gear (1) is driven by the crankshaft and rotates governor flyweight assembly (G). The flyweights are interlocked with sleeve (5) to move fork (7) and rotate attached shaft. As the fork shaft rotates, governor lever (L) forces arm (F) against a pin in the fuel injection pump control sleeve thereby changing fuel flow to cylinder. Throttle lever (T) operates through governor spring (S) to control engine speed.

Governor components must move freely for proper governor operation. Governor spring (S–Fig. L1-11) free length should be 56.9-57.0 mm. At a spring length of 71.9-72.0 mm, spring tension should be 13.7-15.7 newtons.

Spindle (8–Fig. L1-13) diameter is 7.95 mm. Desired clearance between spindle and bores in oil pump body (13) is 0.06-0.10 mm with a maximum allowable clearance of 0.15 mm.

On most 3600 rpm models, hook governor spring end in second hole from governor lever end.

OIL PUMP

Refer to Fig. L1-13 for an exploded view of oil pump. The oil pump is accessible after removing crankcase cover (3–Fig. L1-14). Clearance between gears and pump body walls must not exceed 0.15 mm. Renew oil pump if components are excessively worn or damaged. Tighten pump mounting screws evenly to 11.8 N·m.

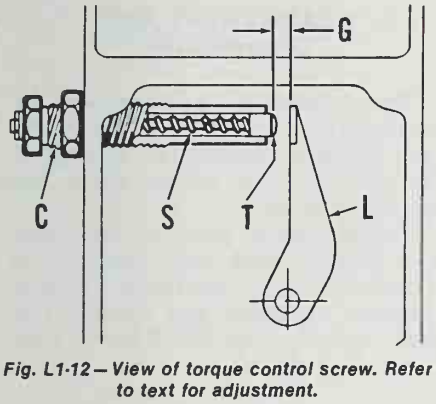


Fig. L1-12–View of torque control screw. Refer to text for adjustment.

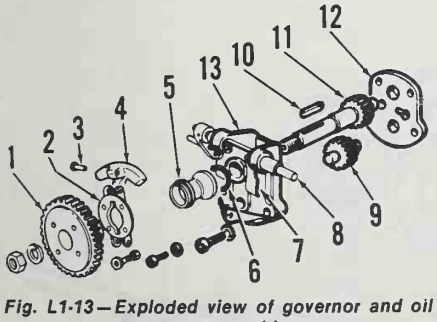


Fig. L1-13–Exploded view of governor and oil pump assembly.

1. Drive gear
2. Governor frame
3. Pins
4. Weights
5. Sleeve
6. Stop
7. Fork
8. Spindle
9. Gear
10. Key
11. Gear & shaft
12. Cover
13. Oil pump body

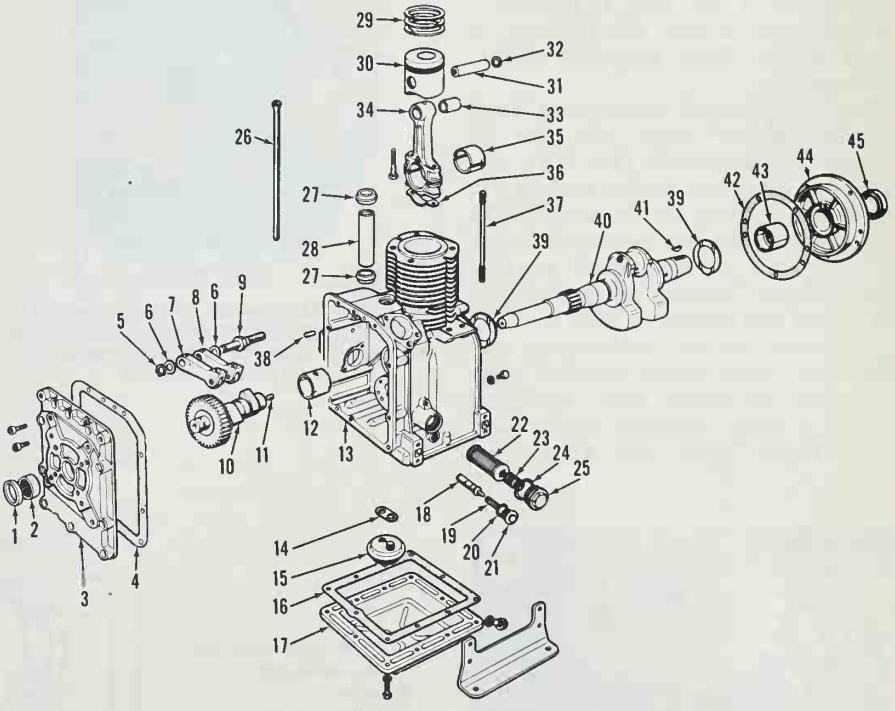


Fig. L1-14–Exploded view of engine.

1. Seal
2. Roller bearing
3. Crankcase cover
4. Gasket
5. Snap ring
6. Washer
7. Exhaust cam follower
8. Intake cam follower
9. Stud
10. Camshaft
11. Plug
12. Bushing
13. Engine block
14. Gasket
15. Oil pickup
16. Gasket
17. Oil pan
18. Oil pressure relief valve
19. Spring
20. Gasket
21. Plug
22. Oil filter
23. Spring
24. "O" ring
25. Plug
26. Push rods
27. Seal
28. Push rod tube
29. Piston rings
30. Piston
31. Piston pin
32. Snap ring
33. Bushing
34. Connecting rod
35. Rod bearing
36. Lock plate
37. Studs
38. Dowel pins
39. Thrust washers
40. Crankshaft
41. Key
42. Gasket
43. Bushing
44. Support
45. Seal

CAMSHAFT, CAM FOLLOWERS AND PUSH RODS

The camshaft rides directly in crankcase cover and crankcase bulkhead and is accessible after removing crankcase cover (3–Fig. L1-14). Cam followers (7 and 8) pivot on stud (9) and transfer motion to push rods (26) which pass through tube (28) to rocker arms. In addition to valve actuating lobes, a lobe is ground on the camshaft to operate the fuel injection pump.

Oil passages in the camshaft may be cleaned after removing plug (11). Be sure plug is securely reinstalled. Lobe height for intake and exhaust valves should be 33.14-33.15 mm while lobe height for injection pump should be 33.99-34.00 mm. Camshaft bearing journal diameters are 19.937-19.950 mm and 25.937-25.950 mm.

Desired clearance between cam followers and pivot stud (9) is 0.03-0.06 mm with a maximum clearance of 0.1 mm.

Install camshaft so timing marks (M–Fig. L1-15) are aligned. If timing marks are absent from gears, proceed as follows: Position piston at top dead center (TDC) then install camshaft so intake cam follower is on opening side of cam lobe and exhaust cam follower is on closing side of cam lobe. If necessary, remesh gears so cam followers are at same height. Mark gears for future reference.

Depth of camshaft in crankcase must not be greater than 0.10 mm as measured from thrust face (TF–Fig. L1-15) to crankcase gasket surface (G). Camshaft end play should be 0.10-0.30 mm and is adjusted by varying thickness of crankcase cover gasket (4–Fig. L1-14). Apply Loctite to crankcase cover (3) screws and tighten to 29 N·m.

The push rods are contained in tube (28) and must cross between cam followers and rocker arms. Push rod nearer cylinder connects intake cam follower and rocker arm while outer push rod connects exhaust cam follower and rocker arm.

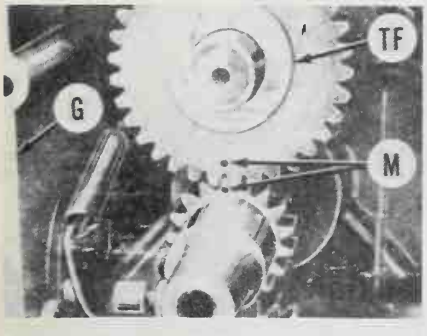


Fig. L1-15—View of camshaft and crankshaft timing marks (M). Measure depth of camshaft thrust face (TF) from crankcase gasket surface (G) as outlined in text.

PISTON AND ROD UNIT

REMOVE AND REINSTALL. Piston and connecting rod may be removed after removing cylinder head and oil pan.

When installing piston and rod, note that depression (D–Fig. L1-16) in piston crown is closer to one side of piston. Install piston so depression side of piston is nearer flywheel. Some pistons also have an arrow embossed in piston crown as shown in Fig. L1-16. Properly installed, arrow on piston crown will point towards flywheel.

The connecting rod and cap have machined serrations which must mate during assembly. Match marks on rod and cap must be on same side. Tighten connecting rod screws to 33.3 N·m.

PISTON, PIN AND RINGS

The piston may be equipped with two or three compression rings and an oil control ring. Piston ring end gap is 0.25-0.40 mm for all compression rings and 0.20-0.35 mm for the oil ring. Maximum side clearance is 0.22 mm for top compression ring, 0.17 mm for second, and if used, third compression ring and 0.12 mm for oil control ring.

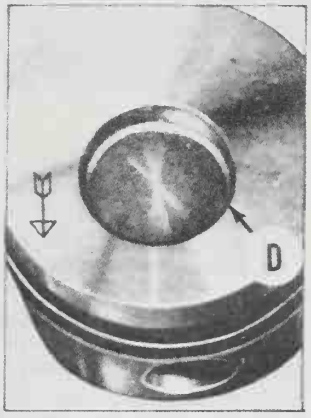


Fig. L1-16—Install piston so depression (D) is nearer flywheel side of engine. Some pistons may have an arrow on crown and arrow must point towards flywheel.

Clearance between piston pin and bushing should be 0.015-0.030 mm. Renew pin if excessively worn or damaged.

Piston to cylinder wall clearance should be 0.11-0.14 mm with a maximum allowable clearance of 0.28 mm. When determining clearance, measure piston diameter at a point 2 mm from bottom of piston skirt perpendicular to piston pin. Piston and rings are available in standard size and oversizes of 0.50 mm and 1.0 mm.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Clearance between piston pin and bushing should be 0.015-0.030 mm. An insert type bearing is used in connecting rod big end. Desired rod bearing clearance is 0.03-0.06 mm while maximum allowable clearance is 0.10 mm. Big end bearings are available in undersizes of 0.25 mm and 0.50 mm.

CRANKSHAFT AND CRANKCASE

The crankshaft is supported by bushing (12–Fig. L1-14) in the crankcase bulkhead, bushing (43) in support (44) and by roller bearing (2) in the crankcase cover.

Desired bearing clearance for center and flywheel end main bearings is 0.03-0.06 mm. Crankshaft journal diameter for center and flywheel end main bearings is 39.99-40.00 mm.

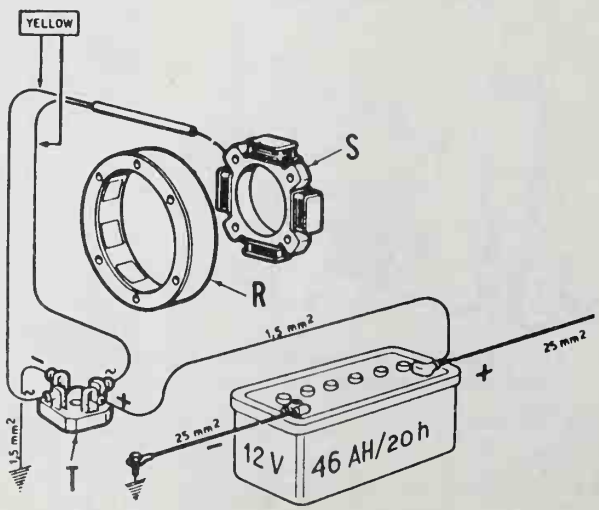


Fig. L1-17—Alternator wiring schematic.
R. Rotor
S. Stator
T. Rectifier

Center and flywheel end main bearings are available in standard size and undersizes of 0.5 mm and 1.0 mm. Crankshaft journal diameter at pto end is 27.94-28.00 mm. Crankshaft must be renewed if pto end journal is worn more than 0.10 mm.

The crankshaft has drilled oil passages to circulate oil. Expansion plugs located adjacent to crankpin may be removed to clean oil passages, however, new plugs must be installed securely.

ELECTRIC STARTER

Early models are equipped with a Prestolite MGL-4002A electric starter while later models are equipped with Bosch starter B.001.214.002.

The Prestolite starter is secured by clamps to the cylinder block and a rubber spacer ring between starter pinion housing and steel stamped backplate is used to properly locate starter. Rubber spacer ring thickness should be 14.5-15.5 mm. The Bosch starter is bolted to a cast aluminum backplate.

ALTERNATOR

An alternator is mounted on the flywheel end of engine to recharge the battery. The stator is secured to the engine crankcase while a ring of magnets is carried by the flywheel. Note wiring schematic in Fig. L1-17. The magnet ring may be removed from the flywheel if faulty. Stator and rotor are available only as an assembly.

LOMBARDINI

Model	No. Cyls.	Bore	Stroke	Displ.
710	1	90 mm	94 mm	598 cc
720	1	95 mm	94 mm	666 cc

Lombardini Model 710 and 720 engines are four-stroke, air-cooled diesel engines. The cylinder block and cylinder head are aluminum. Crankshaft rotation is counterclockwise at pto end.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0° C (32° F), SAE 20W for temperatures between 0° C (32° F) and 20° C (68° F), and SAE 40 for temperatures above 20° C (68° F). API classification for oil should be CD. Oil sump capacity is 2.2 liters. Manufacturer recommends renewing oil after every 100 hours of operation.

A renewable oil filter is located inside of engine block and can be renewed after removing cover plate (0 – Fig. L2-1). Manufacturer recommends renewing filter after every 300 hours of operation.

Both models are equipped with a pressurized oil system. Refer to Fig. L2-2 for a diagram of the oil circuit.

ENGINE SPEED ADJUSTMENT

Idle speed is adjusted by turning idle speed screw (I – Fig. L2-3). Idle speed should be 1000-1050 rpm. Maximum governed speed is adjusted by turning high speed screw (H). Maximum governed speed under load should be 3000 rpm.

FUEL SYSTEM

FUEL FILTER. The fuel filter is located inside the fuel tank as shown in Fig. L2-4. Renew fuel filter after every 300 hours of operation or sooner if required.

BLEED FUEL SYSTEM. To bleed fuel system, loosen fuel line fitting on injection pump and allow fuel to flow until air-free, then retighten fitting. Loosen high pressure injection line at injector, then rotate engine crankshaft to operate injection pump until air-free fuel flows from injection line. Retighten injection line.

INJECTION PUMP TIMING

Injection pump timing is 25°-27° BTDC and is adjusted using shim gaskets (G – Fig. L2-4) between pump body and mounting surface on crankcase. To check injection pump timing, unscrew delivery line (D) fitting from delivery union (1 – Fig. L2-5). Unscrew delivery valve holder and remove spring (3), washer (4) and valve (5), then screw delivery valve holder (1) into pump body.

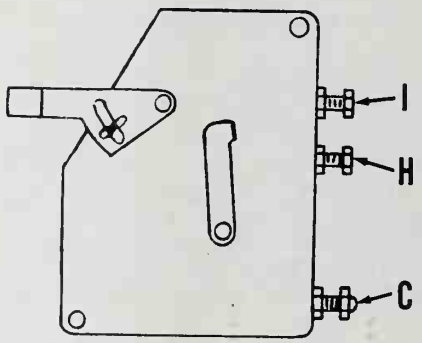


Fig. L2-3 – View of speed adjusting screws: (I) Low idle speed; (H) High idle speed; (C) Torque control. Refer to text for adjustment.

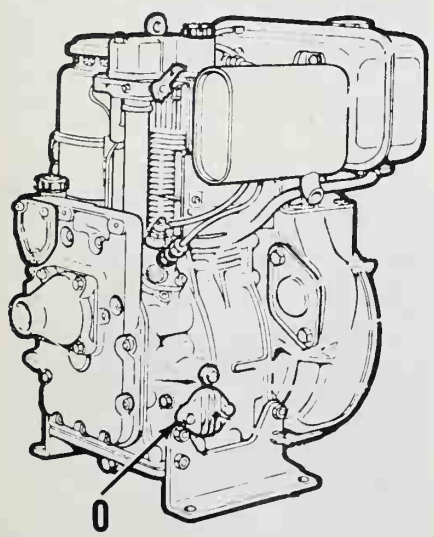


Fig. L2-1 – Remove plate (O) for access to oil filter.

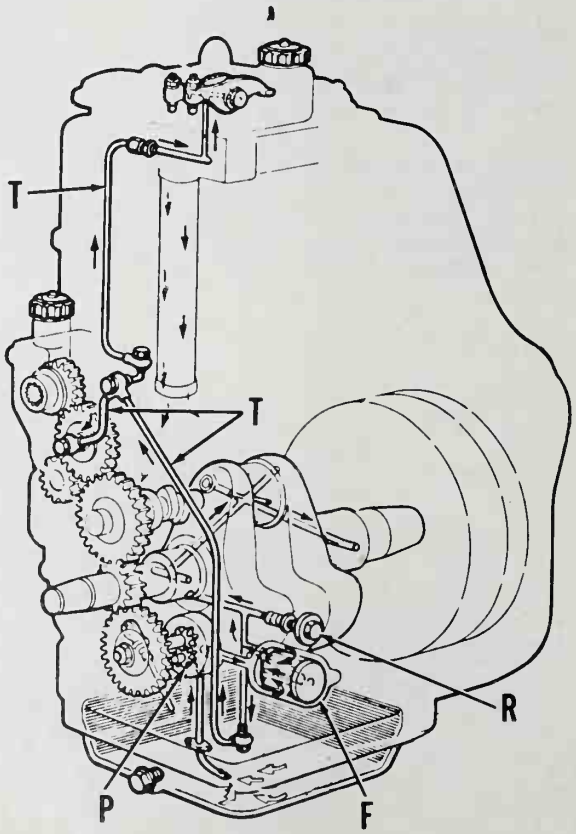


Fig. L2-2 – Diagram of engine oil lubrication circuit. Note oil tubes (T) which route oil to engine top end.

F. Oil filter
P. Oil pump
R. Oil relief valve
T. Oil tubes

Move throttle control lever to full speed position. Rotate engine in normal direction (counterclockwise at pto) so piston is on compression stroke. Note fuel in delivery valve holder will spill out of union. Stop engine rotation at moment fuel ceases to flow out. Timing dot (R – Fig. L2-6) on fan plate should align with injection timing dot (I) on fan shroud. To advance injection timing, remove shim gaskets (G – Fig. L2-4); install shim gaskets to retard injection timing. Reinstall removed pump components after checking injection timing. Tighten injection pump retaining screws to 29 N·m.

REPAIRS

TIGHTENING TORQUES

Refer to following table for tightening torques. All values are in newton meters.

Connecting rod	49
Crankcase cover	24.5
Cylinder head	58.8
Flywheel	294
Idler gear	19.6
Injection pump	29.4
Injector nozzle nut	60-90
Injector retainer plate	9.8
Main bearing support	29.4
Oil pump body	9.8
Oil pump gear	49

VALVE TAPPET GAP

Valve tappet gap may be adjusted after removing rocker arm cover. Valve tappet gap should be 0.15 mm for both valves with engine cold. Note that there are two adjusting screws (Fig. L2-7) in exhaust rocker arm. Adjusting screw (V) nearer rocker arm shaft is used to adjust valve clearance while outer screw (C) adjusts compression release gap.

COMPRESSION RELEASE

A manual compression release is located in the cylinder head so the exhaust valve can be held open to aid starting. Rotating shaft (24 – Fig. L2-8) forces the exhaust rocker arm to slightly open the exhaust valve.

The compression release is adjusted by turning outer adjusting screw (C – Fig. L2-7) in exhaust valve rocker arm. Adjust compression release gap AFTER adjusting exhaust valve tappet gap. With compression release lever in off position, clearance between adjusting screw and shaft should be 0.9-1.1 mm.

Diameter of compression release shaft (24 – Fig. L2-8) is 9.37-10.00 mm while lobe height is 8.45-8.50 mm.

CYLINDER HEAD AND VALVE SYSTEM

Do not remove a hot cylinder head as head may deform.

Valve face angle is 45 degrees and minimum valve head margin is 0.4 mm. Valve seat angle is 45 degrees with a seat width of 1.4-1.6 mm. Valve seats are renewable and must be installed with head heated to 160°-180° C (320°-356° F). A valve seal is used on the intake valve. Valve stem diameter is 7.98-8.00 mm while valve guide diameter is 8.03-8.05 mm. Desired valve stem clearance is 0.03-0.07 mm. Valve guides are renewable and oversize valve guides are available. Exhaust valve guide is bronze. Note locating ring (14 – Fig. L2-8) around top of each guide. Outside of oversize valve guide must be machined so outer diameter is 0.05-0.06 mm greater than hole in head.

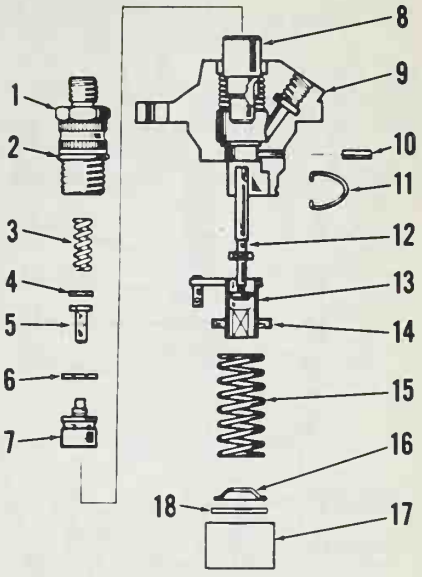


Fig. L2-5 – View of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Spring
4. Washer
5. Delivery valve
6. Gasket
7. Delivery valve seat
8. Barrel
9. Pump body
10. Pin
11. Clip
12. Plunger
13. Control sleeve
14. Spring seat
15. Spring
16. Spring retainer
17. Tappet
18. Spacer

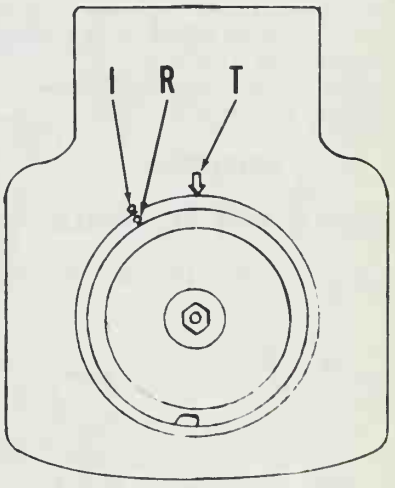


Fig. L2-6 – Injection should occur when timing dot (R) of fan plate is aligned with injection timing dot (I) on fan shroud. Piston is at TDC when timing dot (R) and arrow (T) are aligned.

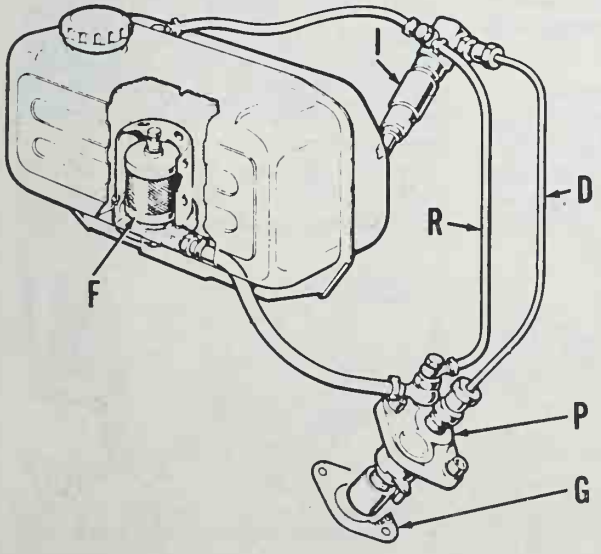


Fig. L2-4 – Diagram of fuel circuit.

D. High pressure line
F. Fuel filter
G. Shim gasket
I. Injector
P. Injection pump
R. Return line

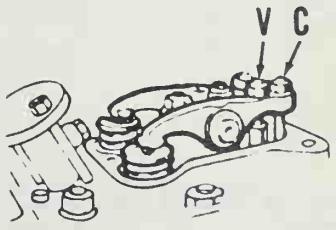


Fig. L2-7 – Adjust exhaust valve tappet gap by turning adjustment screw (V). Adjust compression release by turning adjustment screw (C). Refer to text.

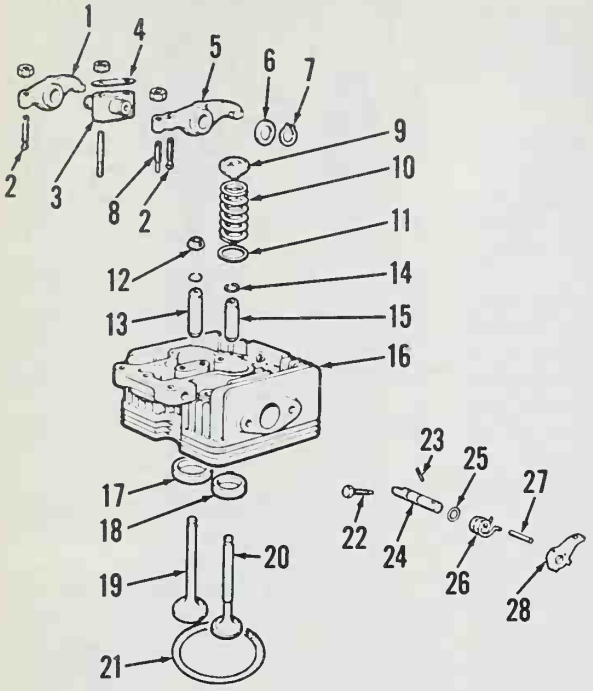


Fig. L2-8 – Exploded view of cylinder head.

1. Intake rocker arm
2. Valve adjusting screws
3. Rocker stand
4. Plate
5. Exhaust rocker arm
6. Washer
7. Snap ring
8. Compression release adjusting screw
9. Spring retainer
10. Valve spring
11. Washer
12. Valve seal
13. Intake valve guide
14. Circlip
15. Exhaust valve guide
16. Cylinder head
17. Intake valve seat
18. Exhaust valve seat
19. Intake valve
20. Exhaust valve
21. Head gasket
22. Locating screw
23. Pin
24. Compression release shaft
25. Washer
26. Spring
27. Pin
28. Compression release lever

The cylinder head should be heated to 160°-180° C (320°-356° F) when installing valve guides.

Desired clearance between rocker arms and shafts is 0.03-0.06 mm. Maximum clearance is 0.1 mm.

Tighten cylinder head nuts in a crossing pattern to 58.8 N·m.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and injection line and immediately cap or plug all openings. Unscrew retainer plate (1 – Fig. L2-9) being careful not to lose dowel pin (2). Injector may now be carefully removed from cylinder head. Do not lose shims between injector and cylinder head.

Tighten injector retaining plate nuts to 9.8 N·m. If accessible, measure protrusion of nozzle into combustion chamber. Nozzle tip should extend 3.5-4.0 mm above adjacent combustion chamber surface. Adjust position of nozzle by installing 0.5 mm shims between injector and cylinder head.

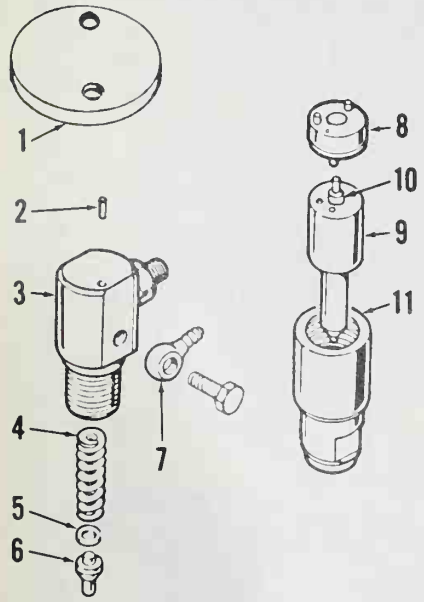


Fig. L2-9 – Exploded view of injector.

1. Clamp plate
2. Dowel pin
3. Nozzle body
4. Spring
5. Shim
6. Pressure pin
7. Return line fitting
8. Spacer
9. Nozzle
10. Valve
11. Nozzle holder nut

TESTING. WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector operation may be checked. Only clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Opening pressure with a new spring (4 – Fig. L2-9) should be 21.6-22.5 MPa while opening pressure with a used spring should be 20.6-21.6 MPa. Opening pressure is adjusted by varying number and thickness of shims (5). Valve should not show leakage at orifice spray holes for 10 seconds at 19.1 MPa.

OVERHAUL. Clamp nozzle body (3 – Fig. L2-9) in a vise with nozzle tip pointing upward. Remove nozzle holder nut (11). Remove nozzle tip (9) with valve (10) and spacer (8). Invert nozzle body (3) and remove spring seat (6), shim (5) and spring (4). Thoroughly clean all parts in a suitable solvent. Clean inside orifice end of nozzle tip with a wooden cleaning stick. The orifice spray holes may be cleaned by inserting a 0.28 mm cleaning wire. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle holder nut (11) to 60-90 N·m.

INJECTION PUMP

Refer to Fig. L2-5 for view of injection pump. Disassembly and reassembly is evident after inspection of pump and referral to Fig. L2-5. Note that slot in barrel (8) must align with pin (10) and helix in plunger (12) must face pin (10).

The following tests may be used to check injection pump if necessary test equipment is available. With a suitable pressure gage connected to delivery valve holder (1), operate pump. With control sleeve (13) at mid-point, pump pressure should be at least 29.4 MPa. Pump pressure should be at least 39.2 MPa with control sleeve in maximum fuel position. To check delivery valve, move control sleeve (13) to mid-point position and operate pump. After maximum pressure is reached, pressure should drop sharply to a pressure 2940-4900 kPa less than maximum pressure if delivery valve is operating properly. Maximum delivery rate of pump is 44-46 cc at 1800 rpm for 1000 pump strokes.

Outside diameter of tappet (17) is 27.96-27.98 mm while maximum allowable clearance in tappet guide bore

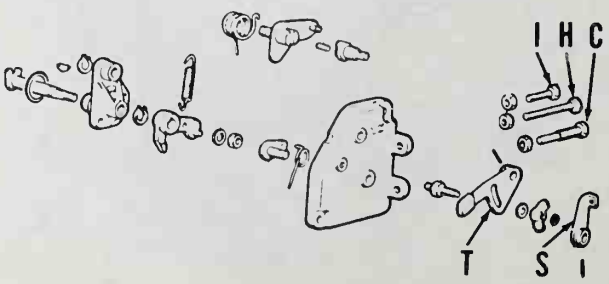


Fig. L2-10 – Exploded view of throttle mechanism.

C. Torque control
H. High speed screw
I. Idle speed screw
S. Stop lever
T. Throttle lever

is 0.10 mm. Thickness of spacer (18) should be 3.45-3.55 mm.

When installing injection pump, place shim gaskets (G – Fig. L2-4) under pump then engage control sleeve (13 – Fig. L2-5) pin with governor arm (42 – Fig. L2-11). Tighten pump retaining screws to 29.4 N·m. Loosen clamp screw (C) then move throttle lever (T) to full throttle. Push governor lever (44) in until it stops thus moving injection pump control sleeve to maximum delivery. Tighten clamp screw (C).

Refer to INJECTION PUMP TIMING section to time injection pump.

GOVERNOR

Both models are equipped with a flyball centrifugal type governor which is attached to the back of the oil pump drive gear (32 – Fig. L2-11 or L2-13). The oil pump drive gear (32) is driven by the crankshaft and rotates governor flyball assembly (34). Flyball housing (34) is interlocked with fork (29). As the flyballs move, the shaft attached to fork (29) is rotated thereby moving governor lever (44) and arm (42). Arm (42) mates with the pin on the injection pump control sleeve (13 – Fig. L2-5) to regulate fuel flow to cylinder. Throttle lever (T – Fig. L2-11) operates through governor spring (27) to control engine speed.

Torque control screw (C – Fig. L2-12) allows additional fuel usage under high torque load. The tip (T) is backed by spring (S). To adjust torque control screw, run engine at high idle with no load and turn screw so gap (G) between tip (T) and lever (L) is 2.1 mm on Model 710 or 2.3 mm on Model 720. Tighten locknut.

Inspect governor components and renew any which are damaged or excessively worn. Mechanism must move freely for proper governor operation.

OIL PUMP

R&R AND OVERHAUL. The oil pump is mounted on the crankcase bulkhead and is accessible after removing crankcase cover. Refer to Fig. L2-13 for an exploded view of oil pump.

Clearance between gears and pump body walls must not exceed 0.15 mm. Tighten oil pump mounting screws to 9.8 N·m. Tighten oil pump drive gear nut to 49 N·m.

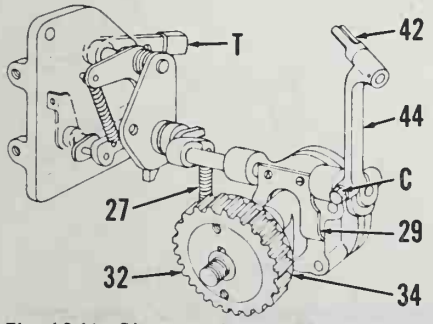


Fig. L2-11 – Diagram of governor assembly. Refer to text for operation and adjustment.

CAMSHAFT, CAM FOLLOWERS AND PUSH RODS

R&R AND OVERHAUL. The camshaft rides in the crankcase bulkhead and crankcase cover (2 – Fig. L2-14) and is accessible after removing cover. Cam

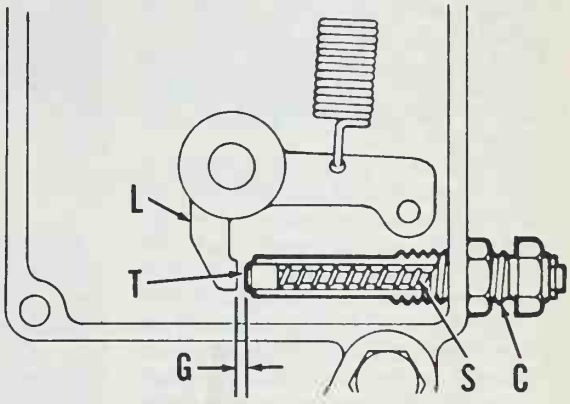


Fig. L2-12 – Diagram of torque control screw. Refer to text for adjustment.

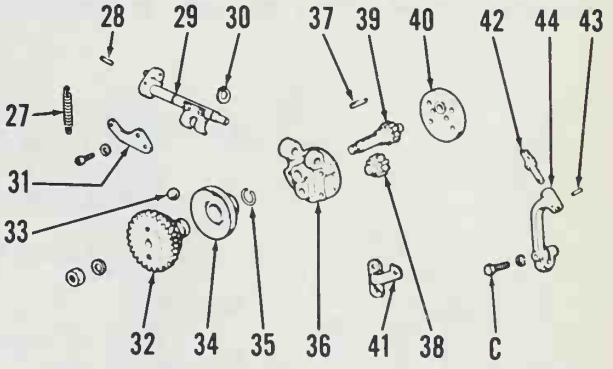


Fig. L2-13 – Exploded view of governor and oil pump.

27. Governor spring
28. Pin
29. Shaft & fork
30. Snap ring
31. Spring plate
32. Oil pump drive gear
33. Governor balls (3)
34. Flyball housing
35. Circlip
36. Oil pump body
37. Key
38. Driven gear
39. Drive gear & shaft
40. Oil pump plate
41. Bracket
42. Governor arm
43. Pin
44. Governor lever

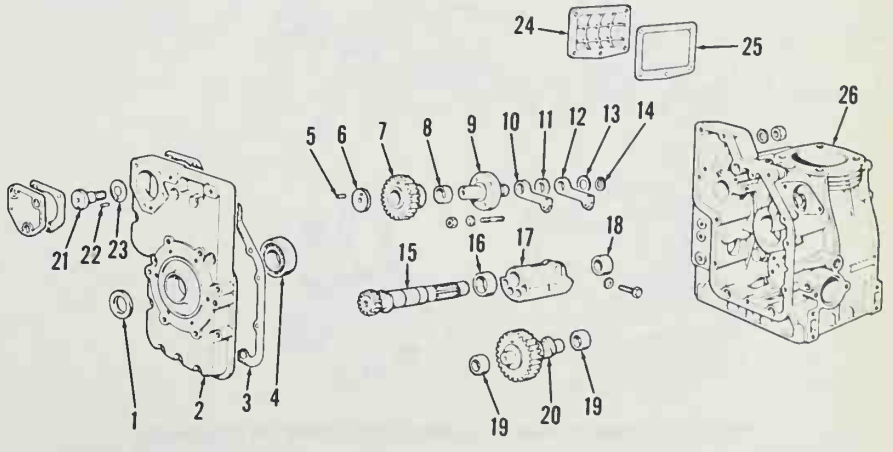


Fig. L2-14 – Exploded view of camshaft, balancer and cam follower assemblies.

1. Seal
2. Crankcase cover
3. Gasket
4. Bearing
5. Pin
6. Washer
7. Idler gear
8. Bushing
9. Pivot shaft
10. Exhaust cam follower
11. Spacer
12. Intake cam follower
13. Washer
14. Snap ring
15. Balancer shaft
16. Bearing
17. Balancer
18. Bearing
19. Bearing
20. Camshaft
21. Stud
22. Pin
23. Washer
24. Side cover
25. Gasket
26. Cylinder block

followers (10 and 12) pivot on shaft (9) and transfer motion to push rods (56 – Fig. L2-15) which pass through tube (57) to rocker arms. A lobe is ground on the camshaft to actuate the fuel injection pump.

Intake and exhaust lobe height should be 29.36-29.56 mm and injection pump lobe height should be 42.6-42.8 mm. Bearing journal diameter should be 19.98-20.00 mm for both journals.

Pivot shaft (9 – Fig. L2-14) diameter should be 14.973-15.000 mm. Maximum clearance between shaft and cam followers is 0.10 mm.

Note that roller pin in cam follower is welded to one side of cam follower. Install cam followers so welds are on opposite sides of followers and not together. Install camshaft so timing marks on camshaft, crankshaft and idler gear are aligned. If timing marks are absent, proceed as follows: Position piston at top dead center, then install camshaft so intake cam follower is on opening side of cam lobe and exhaust cam follower is on closing side of cam lobe (exhaust lobe is adjacent to injection pump lobe). If necessary, remesh gears so cam followers are at same height. Mark gears for future reference.

Camshaft end play should be 0.30-0.45 mm and is adjusted by varying thickness of crankcase cover gasket (3 – Fig. L2-14).

The push rods are contained in a tube (57 – Fig. L2-15) and must cross between cam followers and rocker arms. Push rod nearer cylinder connects intake cam follower and rocker arm while outer push rod connects exhaust cam follower and rocker arm. Push rod tube (57) is sealed by grommets (58) at both ends.

BALANCER

REMOVE AND REINSTALL. To remove balancer weight and shaft, remove crankcase cover (2 – Fig. L2-14) and side cover (24). Loosen clamp screw and while holding weight, withdraw balancer shaft (15). Remove balancer weight (17) out side of engine.

Reverse disassembly procedure to install balancer. Note that with piston at top dead center (TDC), balancer weight is down and slightly inclined towards injection pump.

PISTON AND ROD UNIT

REMOVE AND REINSTALL. Piston and connecting rod may be removed after removing cylinder head and oil pan.

When installing piston and rod, note that depression (D – Fig. L2-16) in piston crown is closer to one side of piston. Install piston so depression side of piston is nearer injection pump. Some pistons also have an arrow embossed in piston. Properly installed, arrow on piston crown will point towards balancer.

Tighten connecting rod screws to 49 N·m.

PISTON, PIN AND RINGS

The piston is equipped with three compression rings and an oil control ring. Ring end gap is 0.35-0.55 mm for all compression rings and 0.25-0.40 mm for the oil control ring. Maximum piston ring side clearance is 0.15 mm for the top piston ring and 0.1 mm for other rings.

Standard piston diameter measured at bottom of piston skirt perpendicular to piston pin is 89.85-89.86 mm for Model 710 and 94.85-94.86 mm for Model 720. Piston to cylinder clearance should be 0.14-0.17 mm. Piston and rings are available in standard size and oversizes of 0.5 mm and 1.0 mm.

Piston pin diameter is 27.995-28.005 mm. Clearance between piston pin and connecting rod bushing should be 0.015-0.025 mm. Maximum allowable clearance is 0.070 mm.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Inner diameter of bushing should be 28.020 mm. Clearance between piston pin and

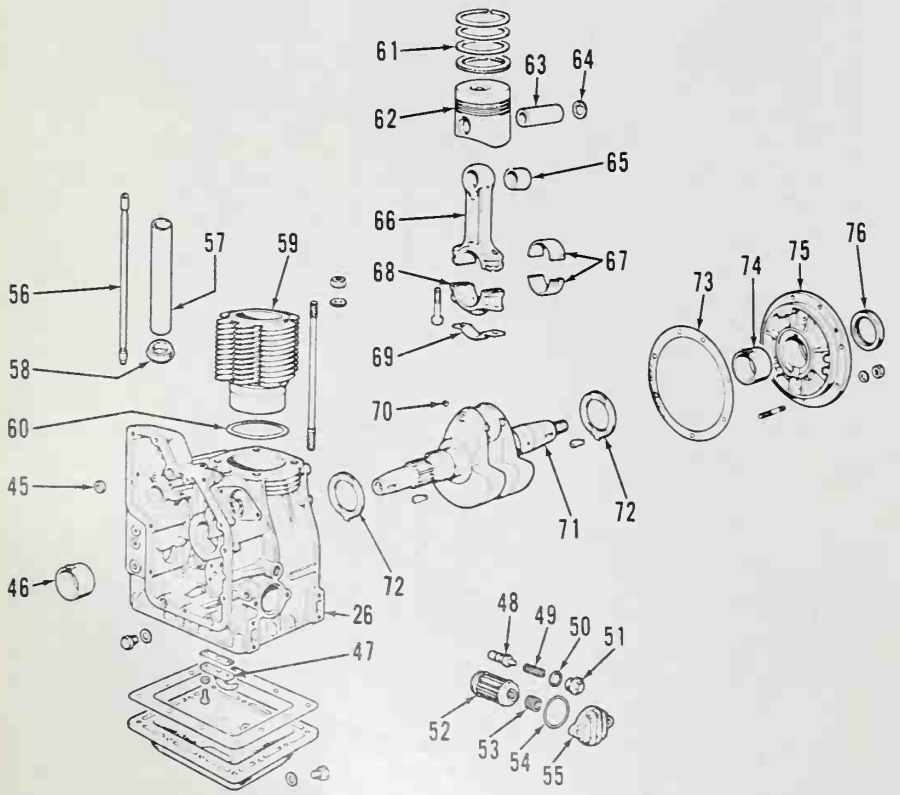


Fig. L2-15 – Exploded view of crankshaft, piston and rod assemblies.

26. Cylinder block
45. Hollow dowel (3)
46. Main bearing
47. Oil pickup
48. Oil pressure relief valve
49. Spring
50. Washer
51. Plug
52. Oil filter
53. Spring
54. Gasket
55. Plate
56. Push rods
57. Push rod tube
58. Grommets (2)
59. Cylinder
60. Gasket
61. Piston rings
62. Piston
63. Piston pin
64. Snap rings
65. Bushing
66. Connecting rod
67. Bearing
68. Rod cap
69. Lockplate
70. Expansion plug
71. Crankshaft
72. Thrust washers
73. Gasket
74. Main bearing
75. Bearing support
76. Seal

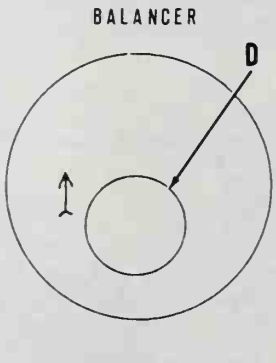


Fig. L2-16 – Depression (D) in piston crown should be nearer injection pump and arrow should point towards balancer.

rod bushing should be 0.015-0.025 mm with a maximum allowable clearance of 0.070 mm.

An insert type bearing is used in connecting rod big end. Desired rod bearing clearance is 0.03-0.06 mm, while maximum allowable clearance is 0.10 mm. Big end bearings are available in standard and undersizes.

CRANKSHAFT AND CRANKCASE

The crankshaft is supported by sleeve bearings (46 and 74 – Fig. L2-15) in the crankcase bulkhead and support (75), and by bearing (4 – Fig. L2-14) in the crankcase cover (2).

Desired bearing clearance for center and flywheel end main bearings is 0.03-0.07 mm. Standard diameter for center and flywheel end main bearing journals is 49.99-50.00 mm. Center and flywheel end main bearings are available in standard and undersizes.

The crankshaft has drilled oil passages to circulate oil. Expansion plugs located adjacent to crankpin may be removed to clean oil passages, however, be sure new plugs are installed securely.

Thrust washer (72 – Fig. L2-15) thickness is 2.31-2.36 mm. Crankshaft end play is adjusted by varying thickness of support gasket (73). Desired end play is 0.10-0.30 mm. Tighten support retaining nuts to 29.4 N·m.

ALTERNATOR

Some models are equipped with an alternator and regulator. The stator is attached to the crankcase cover while a ring of magnets is carried by the flywheel. The magnet ring may be removed from the flywheel if faulty.

LOMBARDINI

Model	No. Cyls.	Bore	Stroke	Displ.
832	2	100 mm	105 mm	1648 cc
833	3	100 mm	105 mm	2472 cc
834	4	100 mm	105 mm	3296 cc
L27	2	100 mm	105 mm	1648 cc
L40	3	100 mm	105 mm	2472 cc
L54	4	100 mm	105 mm	3296 cc

Engines covered in this section are four-stroke, air-cooled diesel engines. Crankcase, cylinders and cylinder head are cast iron. Crankshaft rotation is counterclockwise at pto end. Number 1 cylinder is cylinder nearest flywheel. Firing order is 1-3-2 on Models 833 and L40, and 1-3-4-2 on Models 834 and L54.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0° C (32° F), SAE 20W for temperatures between 0° C (32° F) and 20° C (68° F), and SAE 40 for temperatures above 20° C (68° F). API classification for oil should be CD. Oil sump capacity is 3.5 liters on Models 832 and L27, 5.5 liters on Models 833 and L40, and 8 liters on Models 834 and L54. Manufacturer recommends renewing oil after every 100 hours of operation.

A renewable oil filter is mounted on side of crankcase. Manufacturer recommends renewing filter after every 400 hours of operation.

All models are equipped with a pressurized oil system. Refer to Fig. L3-1 for a diagram of the oil circuit.

ENGINE SPEED ADJUSTMENT

Models 834 and L54

Engine application will determine engine speed settings. Manufacturer recommends that personnel experienced with Bosch fuel injection pumps should adjust engine speed settings.

All Other Models

Idle speed is adjusted by turning idle speed screw (I – Fig. L3-3). Idle speed should be 900-950 rpm. Maximum governed speed is adjusted by turning high speed screw (H). Maximum governed speed under load is 2200 rpm for Models L27 and L40, and 2600 rpm for Models 832 and 833.

FUEL SYSTEM

FUEL FILTER. Models 834 and L54 are equipped with two renewable fuel filters while all other models are equipped with a single renewable fuel filter. Renew the fuel filter after every 300 hours of operation or sooner if required.

BLEED FUEL SYSTEM. To bleed the fuel system on Models 834 and L54, open the bleed screw on fuel filter housing then operate primer (M – Fig. L3-4) on fuel transfer pump until air-free fuel flows. Retighten bleed screw. Open the fuel injection pump bleed screw (B), then operate primer (M) until air-free fuel flows and retighten bleed screw. Loosen high pressure line fittings at injectors. Rotate engine to operate fuel injection pump until air-free fuel flows from fittings, then retighten fittings.

To bleed fuel system on all other models, loosen bleed screw on fuel filter housing then operate primer (M – Fig. L3-5) on fuel transfer pump until air-free fuel flows. Retighten bleed screw. Open injection pump bleed screw, on models so equipped, or loosen inlet fuel line fitting at injection pump. Operate primer (M) until air-free fuel flows, then tighten bleed screw or fuel fitting. Loosen high pressure line fittings at injectors. Rotate engine to operate fuel injection pump until air-free fuel flows then retighten fittings.

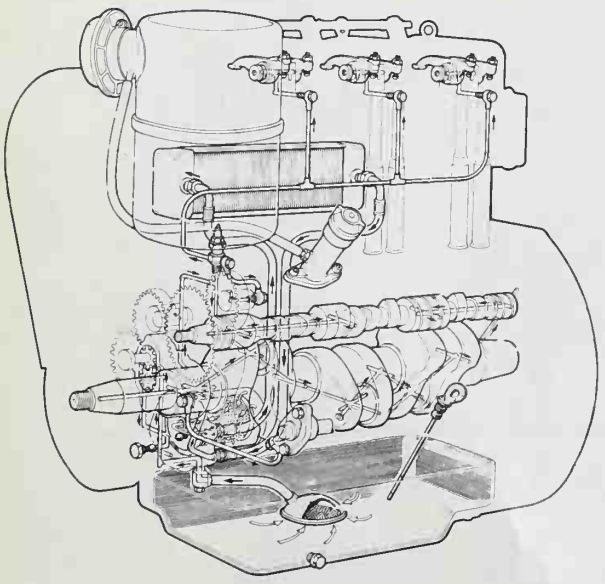


Fig. L3-1 – Drawing of lubrication system.

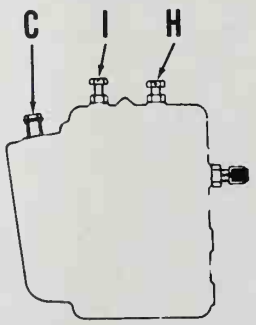


Fig. L3-3 – Drawing showing location of low idle speed screw (I), high idle speed screw (H) and torque control screw (C) on all models except 834 and L54.

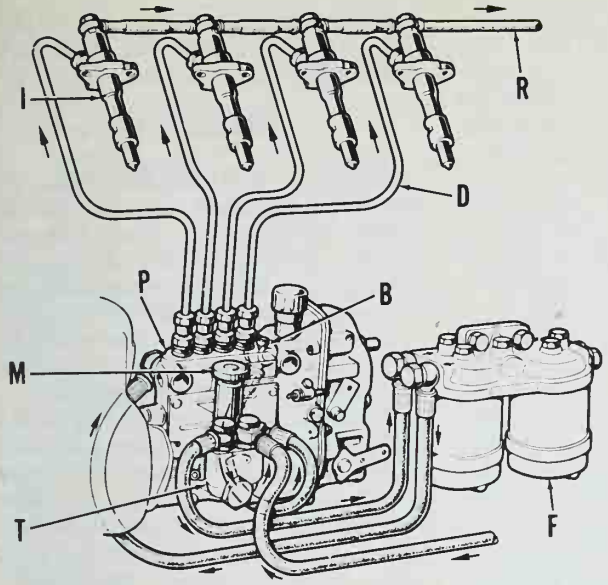


Fig. L3-4—Fuel circuit diagram for Models 834 and L54.

B. Pump bleed screw
D. High pressure delivery line
F. Fuel filters
I. Injector
M. Primer
R. Fuel return line
T. Fuel transfer pump

INJECTION PUMP TIMING

Models 834 and L54

Injection occurs between 28°30' and 30°. To check injection pump timing on Models 834 and L54, rotate crankshaft so injection timing mark (I—Fig. L3-6 or L3-7) is aligned with reference mark (M). Disconnect number 1 injection line from fuel injection pump. Loosen clamp (C—Fig. L3-8) and remove delivery valve holder (H). Remove spring (S) and delivery valve (D) then reinstall delivery valve holder (H). If available, attach a spill pipe to holder. Loosen injection pump retaining nuts. Operate primer pump (M—Fig. L3-4) and rotate injection pump so fuel flows from delivery valve holder or spill pipe. Rotate injection pump until fuel just stops flowing and tighten injection pump retaining nuts to 29.4 N·m. Reinstall delivery valve and spring and connect injection line.

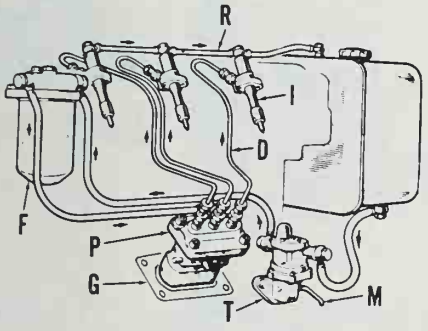


Fig. L3-5—Fuel circuit diagram for Models 833 and L40. Models 832 and L27 are similar.

D. High pressure delivery line
F. Fuel filter
G. Shim gasket
I. Injector
M. Primer lever
P. Fuel injection pump
R. Fuel return line
T. Fuel pump

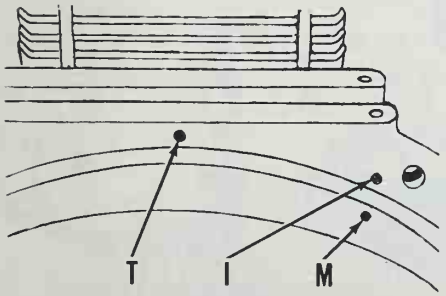


Fig. L3-6—View of timing marks located on flywheel of some models.

I. Injection
M. Reference mark
T. Top dead center

All Other Models

Fuel injection occurs between 25° and 26° 5'. Injection timing is adjusted using shim gaskets (G—Fig. L3-5) between pump body and mounting surface on crankcase. To check injection timing, unscrew number 1 cylinder delivery injection line (D) fitting from delivery valve holder (25—Fig. L3-9). Unscrew delivery valve holder (25) and remove spring (23) and delivery valve (22) and then screw delivery valve holder (25) into pump. Move throttle to full speed position. Rotate engine in normal direction (counter-clockwise at pto) so number 1 piston is on compression stroke. Note fuel in delivery valve holder will spill out of holder. Stop rotation at moment fuel ceases to flow out of holder. Timing marks (I and M—Fig. L3-6 and L3-7) should be aligned. To advance injection timing, remove shim

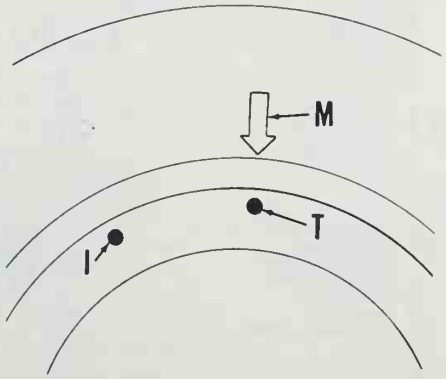


Fig. L3-7—View of timing marks on crankshaft pulley used on some models.

I. Injection
M. Reference mark
T. Top dead center

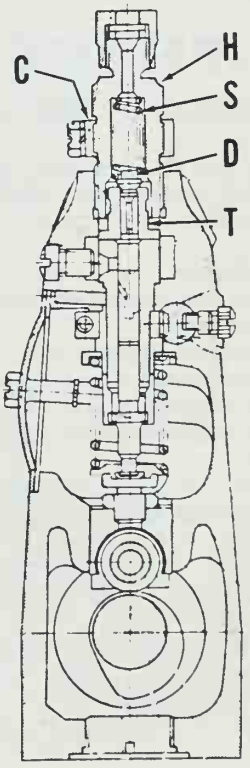


Fig. L3-8—Cross-sectional view of Bosch PES fuel injection pump.

C. Clamp
D. Delivery valve
H. Delivery valve holder
S. Spring
T. Delivery valve seat

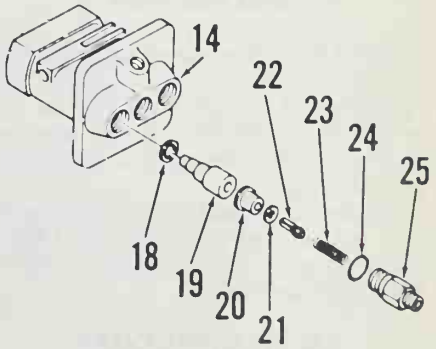


Fig. L3-9—Partial exploded view of fuel injection pump used on all models except 834 and L54.

14. Pump body
18. Packing
19. Barrel
20. Delivery valve seat
21. Gasket
22. Delivery valve
23. Spring
24. "O" ring
25. Delivery valve holder

gaskets (G–Fig. L3-5); install shim gaskets to retard injection timing. Reinstall removed pump parts after checking timing. Tighten injection pump retaining screws to 29.4 N·m.

FAN BELT TENSION

All models are equipped with a belt-driven, cooling fan. Belt tension is adjusted by varying the number of shims between fan pulley halves. Belt tension is correct when thumb pressure applied midway between pulleys deflects belt approximately 1 cm.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques. All values are in newton meters.

Camshaft gear	196
Camshaft retainer	19.6
Connecting rod	49
Crankshaft drive gear	490
Crankshaft pulley	441
Cylinder head	78.4
Exhaust manifold	19.6
Fan nut	34.3
Flywheel	343
Governor retainer	19.6
Idler gear	137
Injector	19.6
Injection pump	29.4
Intake manifold	19.6
Intermediate gear	137.2
Main bearing cap	49
Main bearing support	
Center	49
End	39.2
Oil pan	29.4
Oil pump	34.3
Rocker arm shaft	12.7
Timing gear cover	19.6
Timing gear housing	19.6

COOLING FAN

All models are equipped with an axial cooling fan to force air around the cylinders and through the oil cooler attached to the fan shroud. Fan housing (8–Fig. L3-10) is mounted on the timing gear housing.

Overhaul is evident after inspection of unit and referral to Fig. L3-10. Adjust belt tension as outlined in FAN BELT TENSION section.

VALVE TAPPET GAP

Valve tappet gap may be adjusted after removing rocker arm cover. Valve tappet gap should be 0.3 mm for both valves with the engine cold.

CYLINDER HEAD AND VALVE SYSTEM

Valve face angle is 45 degrees and minimum valve head margin is 0.40 mm. Valve seat angle is 45 degrees with a seat width of 1.4-1.6 mm. Valve seats are renewable and must be installed with head heated to 160°-180° C (320°-356° F). Valve seals are used on intake valves. Valve stem diameter is 8.98-9.00 mm and valve guide inner diameter is 9.03-9.05 mm. Desired valve stem clearance is 0.03-0.07 mm. Valve guides are renewable and oversize guides are available. Unscrew rocker arm shaft locating screw (3–Fig. L3-11), then use a suitable puller to remove the rocker arm shaft. The head should be heated to 160°-180° C (320°-356° F) before pressing or driving rocker arm shaft into head. Clearance between rocker arms and shaft should be 0.03-0.06 mm with a maximum allowable clearance of 0.1 mm.

Valve spring free length should be 54.56 mm. Valve spring pressure should be 412.6-420.4 newtons at a length of 26.3-26.5 mm.

Before tightening cylinder head nuts, install manifolds so heads are properly mated with manifolds. Tighten cylinder head retaining nuts using a crossing pattern, in 20 N·m increments, until final torque of 78.4 N·m is reached.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and injection line and immediately cap or plug all openings. Unscrew injector retaining nuts and carefully remove injector being careful not to lose shims between injector and cylinder head.

Tighten injector retaining nuts to 19.6 N·m. If accessible, measure protrusion of nozzle into combustion chamber. Nozzle tip should extend 3.5-4.2 mm above adjacent combustion chamber surface. Adjust position of nozzle by installing shims between injector and cylinder head. Shims are available in thicknesses of 0.5, 1.0 and 1.5 mm.

TESTING. WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector operation may be checked. Only

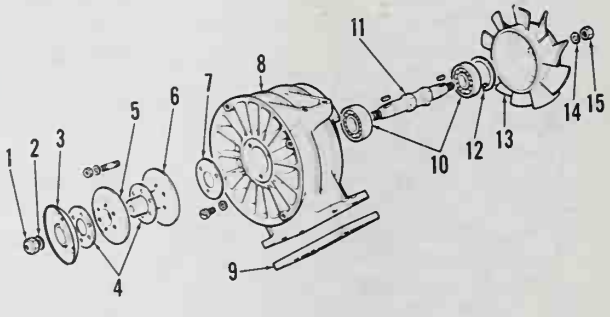


Fig. L3-10—Exploded view of cooling fan. Models 834 and L54 are equipped with two drive belts while one belt is used on all other models.

1. Nut
2. Washer
3. Pulley half
4. Shims
5. Center pulley half
6. Drive pulley half
7. Washer
8. Fan housing
9. Spacer
10. Bearings
11. Shaft
12. Snap ring
13. Fan
14. Washer
15. Nut

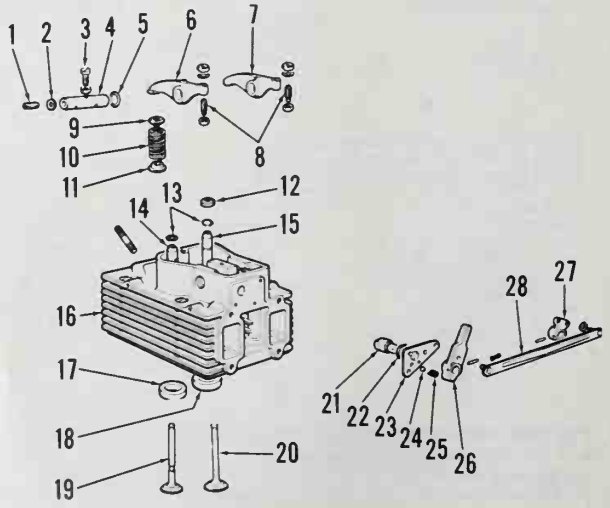


Fig. L3-11—Exploded view of cylinder head assembly.

1. Plug
2. Washer
3. Locating screw
4. Rocker arm shaft
5. Washer
6. Exhaust rocker arm
7. Intake rocker arm
8. Adjuster screw
9. Spring retainer
10. Valve spring
11. Spring seat
12. Seal
13. Circlip
14. Exhaust valve guide
15. Intake valve guide
16. Cylinder head
17. Exhaust valve seat
18. Intake valve seat
19. Exhaust valve
20. Intake valve
21. Compression release
22. Washer
23. Plate
24. Ball
25. Spring
26. Lever
27. Arm
28. Link

clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Opening pressure with a new spring (5 – Fig. L3-12) should be 21.6-22.5 MPa while opening pressure with a used spring should be 20.6-21.6 MPa. Opening pressure is adjusted by turning adjusting screw (2). Valve should not show leakage at orifice spray holes for 10 seconds at 17.6 MPa.

OVERHAUL. Clamp nozzle body (7 – Fig. L3-12) in a vise with nozzle tip pointing upward. Unscrew nozzle holder nut (10), then remove nozzle (9) and valve (8). Invert nozzle body (7) and remove adjusting screw (2), spring seat (4), spring (5) and push rod (6). Thoroughly clean all parts in a suitable solvent. Clean inside orifice end of nozzle with a wooden cleaning stick. The orifice spray holes may be cleaned by inserting a 0.20 mm cleaning wire. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle holder nut (10) to 49 N·m.

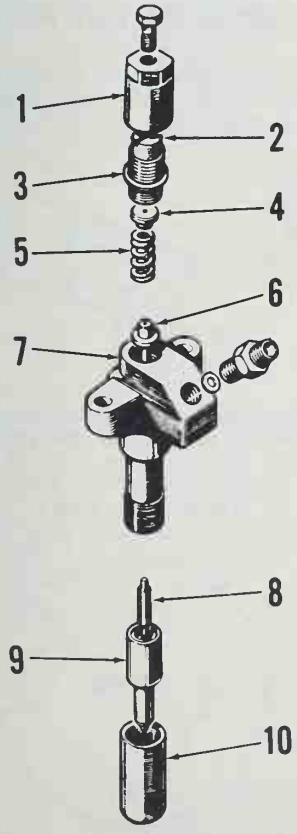


Fig. L3-12 – Exploded view of injector.

1. Cap nut
2. Adjusting screw
3. Gasket
4. Spring seat
5. Spring
6. Push rod
7. Body
8. Valve
9. Nozzle
10. Nozzle nut

INJECTION PUMP

Models 834 And L54

R&R AND OVERHAUL. Models 834 and L54 are equipped with a Bosch PES type fuel injection pump. If not present, make timing marks for future reference on injection pump flange and mounting adapter. Disconnect fuel lines and control linkage, then unscrew retaining nuts and remove fuel injection pump.

The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

When installing injection pump, align timing marks on injection pump flange and mounting adapter. If marks are not present, proceed as follows: Mount injection pump in a vise with delivery valve holders (H – Fig. L3-8) pointing up. Loosen clamp (C) and remove delivery valve holder (H) for number 1 cylinder (farthest from mounting flange). Remove spring (S) and delivery valve (D) then reinstall delivery valve holder (H). If available, attach a spill pipe to holder. Connect an external fuel supply to injection pump fuel inlet so pump is gravity fed with fuel. Turn injection pump shaft in a counter-clockwise direction, as viewed at shaft end. Then, stop shaft rotation at moment fuel stops flowing from delivery valve holder or spill pipe. Remove plug (P – Fig. L3-12A) and install a suitable screw that will bear lightly against pump shaft to prevent shaft rotation. If available, Mercedes tool number 700-589-86-73 may be used. Rotate engine crankshaft so injection timing mark (I – Fig. L3-6 or L3-7) is aligned with reference mark (M). Install injection pump on engine and tighten pump retaining nuts to 29.4 N·m. Reinstall delivery valve and spring, fuel injection lines and drain plug (P – Fig. L3-12A). If crankshaft or injection pump shaft moved slightly during installation, refer to INJECTION PUMP TIMING and recheck pump timing.

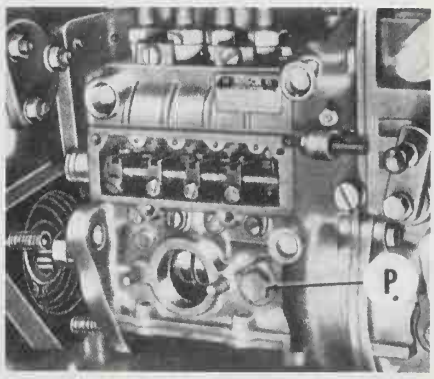


Fig. L3-12A – View of Bosch injection pump used on Models 834 and L54 showing location of drain plug (P).

All Other Models

R&R AND OVERHAUL. To remove injection pump, disconnect fuel lines, unscrew retaining screws and remove pump. Do not lose shim gaskets (G – Fig. L3-5).

The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

When installing pump, engage pin on pump control rack with governor fork. Tighten injection pump screws to 29.4 N·m. If pump is renewed or overhauled, or original shim gaskets are not used, refer to INJECTION PUMP TIMING section and adjust pump timing.

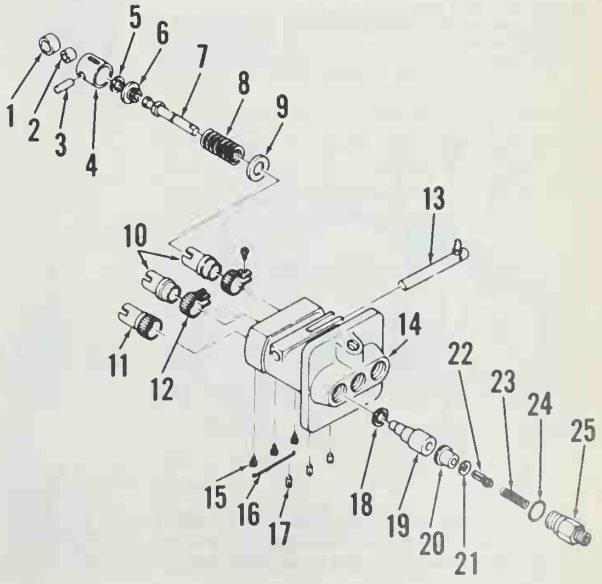


Fig. L3-13 – Exploded view of fuel injection pump used on Models 833 and L40. Models 832 and L27 are similar.

1. Outer roller
2. Inner roller
3. Pin
4. Guide
5. Shim
6. Spring retainer
7. Plunger
8. Spring
9. Spring seat
10. Control sleeve B
11. Control sleeve A
12. Sleeve B pinion
13. Control rack
14. Body
15. Guide pins
16. Retaining wire
17. Pins
18. Packing
19. Barrel
20. Delivery valve seat
21. Gasket
22. Delivery valve
23. Spring
24. "O" ring
25. Delivery valve holder

TIMING GEARS

To remove timing gear cover, remove fan belt guard, fan belt and crankshaft pulley. Unscrew and remove timing gear cover. Gears may be removed after unscrewing retaining nut or screw and by using a suitable puller. Refer to Fig. L3-15 or L3-16 for view of timing gears.

To remove the fuel injection pump drive gear (2 – Fig. L3-17) on Models 834 and L54, the fuel injection pump must be removed as previously outlined. Detach snap ring (4) and remove gear and hub. Unscrew gear retaining screws and separate the gear from the hub. Bushings (10) in adapter (9) are renewable.

Timing marks on crankshaft, idler and camshaft gears must be aligned as shown in Fig. L3-15 and L3-16. If timing gears do not have marks, proceed as follows: If not previously removed, remove cylinder head and push rod tubes on number 1 cylinder. Install crankshaft and camshaft gears, but do not install idler gear. Rotate crankshaft so number 1 piston is at top dead center. Rotate camshaft so number 1 cylinder intake valve tappet is opening (rising) and exhaust valve tappet is closing (going down) then stop rotation when tappets are at same height above crankcase surface. Install idler gear and mark crankshaft, idler and camshaft gears for future reference.

Tighten timing gear cover screws to 19.6 N·m. Adjust fan belt tension as outlined in FAN BELT TENSION section.

OIL PUMP

R&R AND OVERHAUL. The oil pump is mounted on the front of the engine and is accessible after removing the timing gear cover. Unscrew pump gear retaining nut then using a suitable puller, remove pump gear (1 – Fig. L3-18). Remove pump cover (3) and gears. Pump housing (6) surrounds the crankshaft and the crankshaft gear must be removed before pump housing can be removed. Note that screw (2) is drilled to allow oil flow through screw.

Oil clearance between oil pump housing and crankshaft should be 0.04-0.08 mm. Renew pump housing if clearance exceeds 0.13 mm. Maximum allowable backlash between gears is 0.15 mm. Maximum allowable clearance between gears and pump housing bore is 0.15 mm.

Assembly is reverse of disassembly procedure.

Normal oil pressure with engine running at 3000 rpm and oil hot is 303.8-352.8 kPa. Oil pressure is adjusted by removing plug (P – Fig. L3-19) and turning adjusting screw.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod may be removed after removing cylinder head and oil pan.

When installing piston and rod, note that depression (D – Fig. L3-20) in piston crown is closer to one side of piston. Install piston so depression side of piston is nearer injectors. Some pistons also have an arrow embossed on piston. Properly installed, arrow on piston crown will point towards injection pump.

Tighten connecting rod screws to 49 N·m. Refer to CYLINDER section and measure piston height in cylinder.

PISTON, PIN AND RINGS

The piston is equipped with three compression rings and an oil control ring. Ring end gap is 0.35-0.55 mm for all

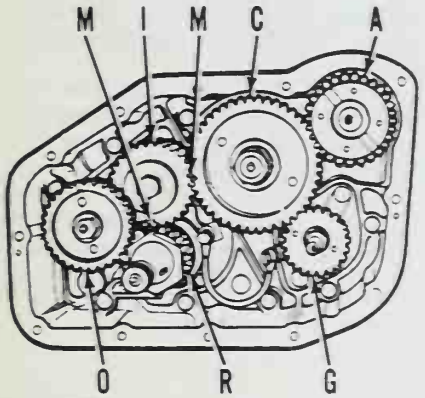


Fig. L3-15 – View of timing gears on Models 832, 833, L27 and L40.

A. Auxiliary drive gear
C. Camshaft gear
G. Governor gear
I. Idler gear
M. Timing marks
O. Oil pump gear
R. Crankshaft gear

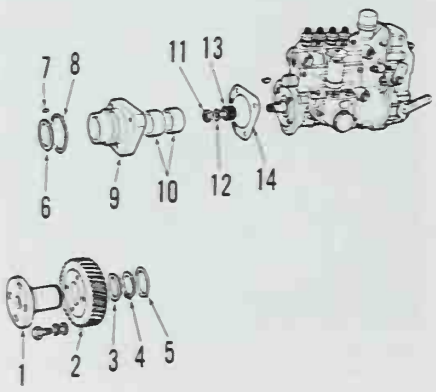


Fig. L3-17 – Exploded view of fuel injection pump drive assembly on Models 834 and L54.

1. Hub
2. Gear
3. Washer
4. Snap ring
5. Washer
6. Washer
7. Pin
8. "O" ring
9. Adapter
10. Bushings
11. Nut
12. Washer
13. Gear
14. Gasket

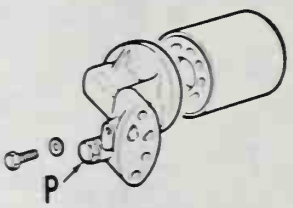


Fig. L3-19 – Remove plug (P) for access to oil pressure relief valve in filter adapter.

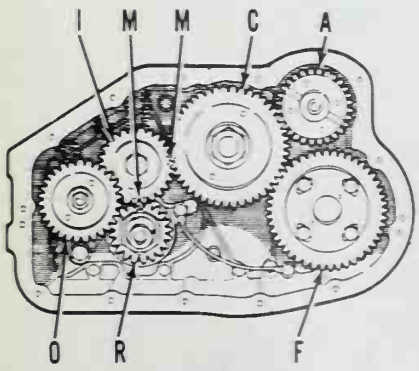


Fig. L3-16 – View of timing gears on Models 834 and L54. Refer to Fig. L3-15 for identification except for: F. Fuel injection pump drive gear.

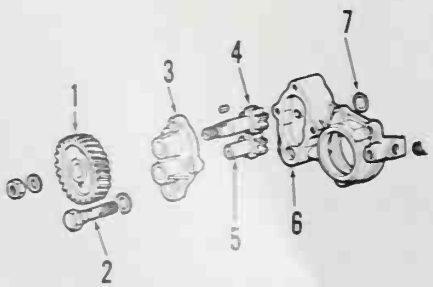


Fig. L3-18 – Exploded view of oil pump.

1. Drive gear
2. Special screw
3. Cover
4. Gear & shaft
5. Gear
6. Pump body
7. "O" ring

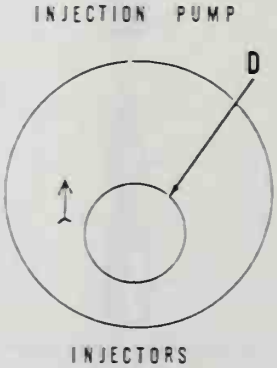


Fig. L3-20 – Arrow on piston crown should point towards injection pump and depression (D) should be near injectors.

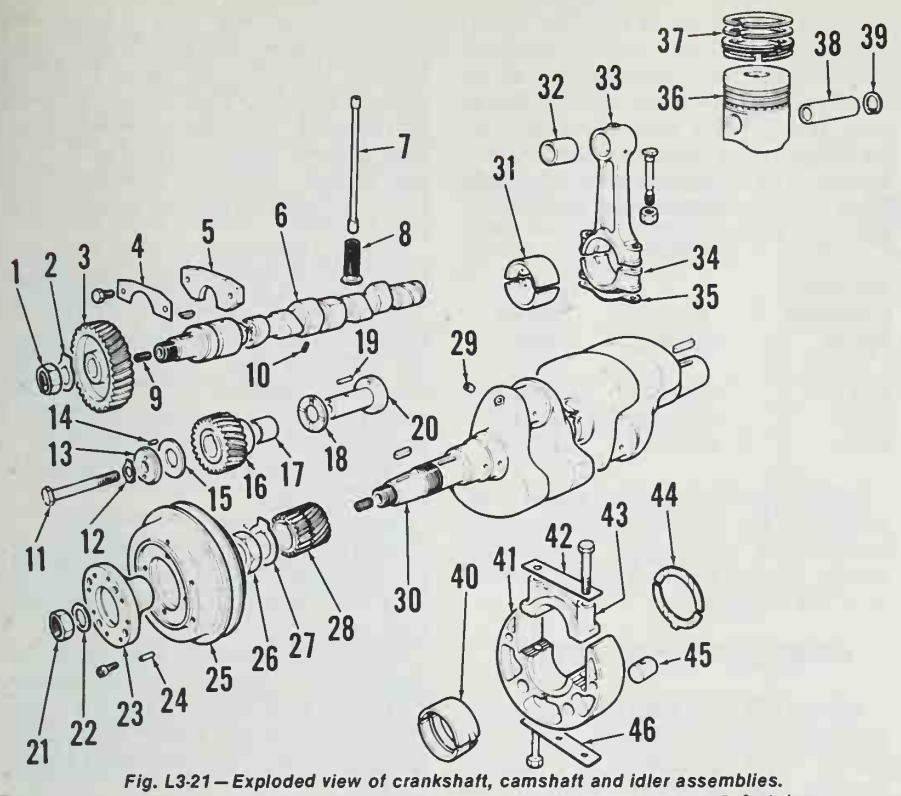


Fig. L3-21—Exploded view of crankshaft, camshaft and idler assemblies.

1. Nut
2. Tab washer
3. Camshaft gear
4. Lockplate
5. Retainer
6. Camshaft
7. Push rod
8. Tappet
9. Plug
10. Plug
11. Screw
12. Tab washer
13. Spacer
14. Pin
15. Washer
16. Idler gear
17. Bushing
18. Thrust washer
19. Pin
20. Idler shaft
21. Nut
22. Washer
23. Hub
24. Pin
25. Pulley
26. Nut
27. Tab washer
28. Gear
29. Plug
30. Crankshaft
31. Bearing
32. Bushing
33. Connecting rod
34. Rod cap
35. Lockplate
36. Piston
37. Piston rings
38. Piston pin
39. Snap ring
40. Bearing
41. Main bearing support
42. Lockplate
43. Main bearing cap
44. Thrust washer
45. Nut
46. Lockplate

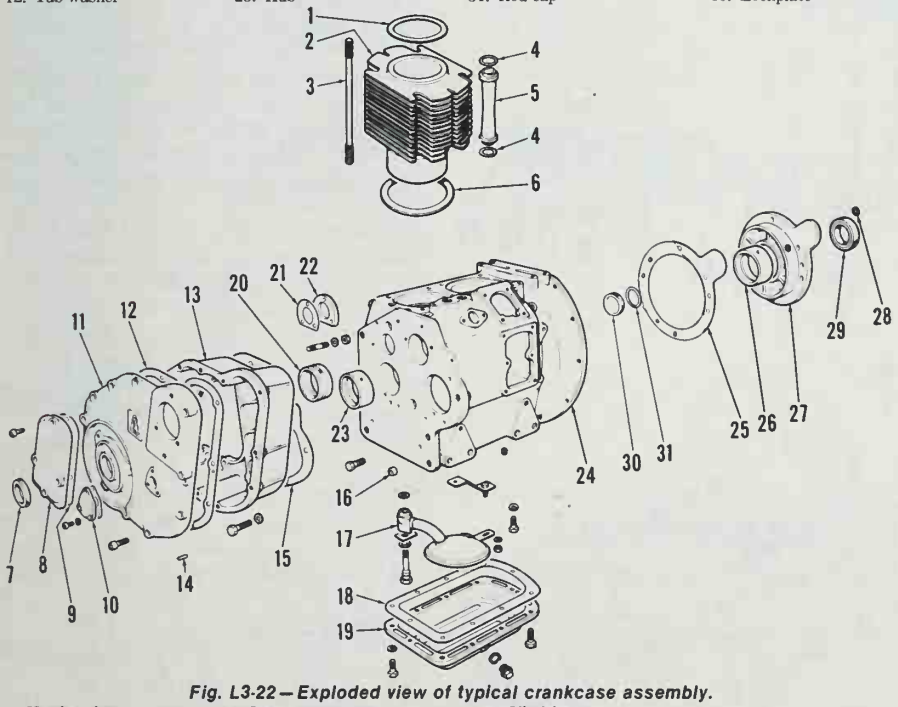


Fig. L3-22—Exploded view of typical crankcase assembly.

1. Head gasket
2. Cylinder
3. Stud
4. Seal
5. Push rod tube
6. Shim gasket
7. Seal
8. Cover
9. Gasket
10. Cover
11. Timing gear cover
12. Gasket
13. Gear housing
14. Pin
15. Gasket
16. Dowel
17. Oil pickup
18. Gasket
19. Oil pan
20. Camshaft bearing
21. Gasket
22. Cover
23. Main bearing
24. Crankcase
25. Gasket
26. Main bearing
27. Rear main bearing support
28. "O" ring
29. Oil seal
30. Camshaft cover
31. "O" ring

compression rings and 0.25-0.40 mm for the oil control ring. Piston ring side clearance should be 0.30 mm for top compression ring, 0.20 mm for second compression ring, 0.15 mm for third compression ring and 0.10 mm for oil control ring.

Standard piston diameter measured 2 mm from bottom of skirt, perpendicular to piston pin, is 99.800-99.810 mm. Piston to cylinder clearance should be 0.19-0.22 mm. Piston and rings are available in standard size and oversizes of 0.5 and 1.0 mm.

Clearance between piston pin and connecting rod should be 0.02-0.03 mm. Maximum allowable clearance is 0.07 mm.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Clearance between piston pin and rod bushing should be 0.02-0.03 mm with a maximum allowable clearance of 0.07 mm.

An insert type bearing is used in connecting rod big end. Desired rod bearing clearance is 0.04-0.07 mm with a maximum allowable clearance of 0.10 mm. Big end bearings are available in standard and undersizes.

CYLINDERS

All models are equipped with removable cylinders. Standard cylinder diameter is 100.00-100.02 mm. Cylinders may be bored to accept oversize pistons. Maximum allowable taper or out-of-round is 0.1 mm.

Piston height in cylinder is adjusted using shim gaskets (6—Fig. L3-22). With piston at top dead center, piston crown should be 0.0-0.1 mm below top of cylinder. Install shims (6) to obtain desired piston height.

GOVERNOR

Models 834 And L54

The governor on Models 834 and L54 is contained in the fuel injection pump housing. Governor service should be performed by a qualified diesel fuel injection shop.

All Other Models

Refer to Figs. L3-23 and L3-24 for exploded views of flyball type governor and control linkage. Governor sleeve (15—Fig. L3-23) slides on governor shaft (4) according to flyball (10) movement, and forces spindle (19) to contact governor arm (27—Fig. L3-24). The control rack pin of the fuel injection pump engages the fork in governor arm (27). Throttle lever (47) operates through

governor spring (31) to control engine speed.

The governor shaft assembly (Fig. L3-23) may be removed after removing timing gear cover. Unscrew retainer (6) screws and withdraw governor shaft. Inspect components for excessive wear or damage. Components must move easily without binding. When installing governor shaft, tighten retainer (6) screws to 19.6 N·m.

To synchronize governor linkage with fuel injection pump, remove cover (45 – Fig. L3-24) and loosen nuts (N – Fig. L3-25) securing eccentric (39). Fully rotate eccentric in counter-clockwise direction. With fuel injection pump removed, install tool (T) number 7276-2003-04 on Model 832 or number 7277-2003-05 on Model 833 so tool roller (R) engages fork on governor arm (27). Rotate eccentric (39) until all play is removed from governor but tool roller (R) is still free in fork. Tighten nuts (N), remove tool and install fuel injection pump.

Start spring (25 – Fig. L3-24) allows maximum fuel delivery when starting engine. Spring free length should be 42 mm.

Torque control screw (C – Fig. L3-24) allows additional fuel usage under high torque load. The torque control screw has a spring loaded tip which contacts lever (41). Torque control screw must match governed speed of engine. Check operation by measuring force needed to move tip the distance specified in the following table:

Maximum Governed Speed	Force (grams)	Travel (mm)
2200	400-420	1.00-1.10
2600	400-420	0.35-0.45
3000	625-650	0.35-0.45

The torque control screw may be disassembled for cleaning and lubrication, but do not interchange components. Torque control screw must be serviced as a unit assembly.

CAMSHAFT AND TAPPETS

R&R AND OVERHAUL. To remove camshaft, remove cylinder heads and timing cover as previously outlined. Remove fuel injection pump on all models except 834 and L54. Remove push rod tubes and push rods. Using suitable tools, hold up tappets so they will not fall into crankcase as camshaft is removed. Remove camshaft gear, then unscrew camshaft retainer (5 – Fig. L3-21) and withdraw camshaft from block. Remove oil pan for access to tappets.

The camshaft rides in sleeve bearings in the cylinder block. Standard camshaft bearing journal diameter is 47.94-47.96 mm. Camshaft bearing clearance should be 0.10-0.14 mm with a maximum allowable clearance of 0.20 mm. Camshaft bearings are available in standard and undersizes. Camshaft end play is 0.4-0.6 mm with a maximum allowable limit of 1.0 mm.

Outside diameter of tappets is 19.96-19.98 mm. Clearance between tappet and block should be 0.02-0.06 mm with a maximum allowable clearance of 0.10 mm.

Reverse disassembly procedure for reassembly. Tighten camshaft retainer screws to 19.6 N·m and camshaft gear nut to 196 N·m. Refer to TIMING GEARS section for proper gear timing.

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove pistons and timing gear cover as previously outlined. Remove idler gear, oil pump gear and crankshaft gear. Remove oil pump. Unscrew nuts securing rear bearing support (27 – Fig. L3-22) then unscrew capscrews securing center bearing support (41 – Fig. L3-21). Models 833 and L40 are equipped with two center supports (41) while Models 834 and L54 have three center supports. Carefully with-

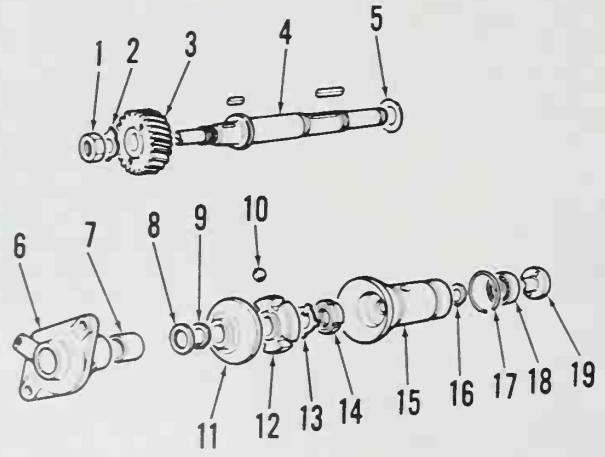


Fig. L3-23 – Exploded view of governor shaft.
1. Nut
2. Tab washer
3. Governor gear
4. Shaft
5. Washer
6. Retainer
7. Bushing
8. Washer
9. Snap ring
10. Balls (4)
11. Ball retainer
12. Ball carrier
13. Tab washer
14. Nut
15. Governor sleeve
16. Snap ring
17. Circlip
18. Bearing
19. Spindle

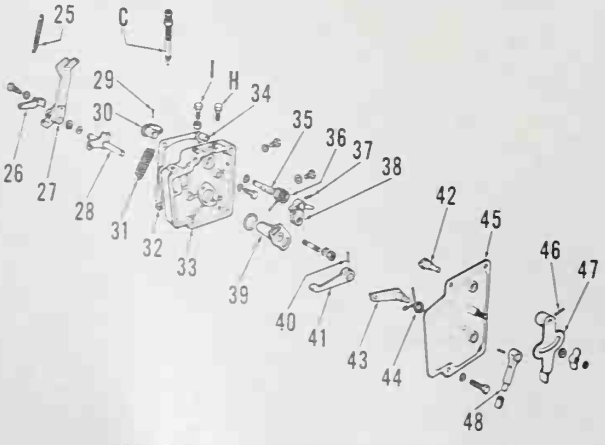


Fig. L3-24 – Exploded view of governor and throttle linkage.
C. Torque control screw
H. High idle speed screw
I. Low idle speed screw
25. Start spring
26. Lever
27. Arm
28. Spindle
29. Pin
30. Lever
31. Governor spring
32. Gasket
33. Control housing
34. Dowel
35. Shaft
36. Spring
37. Pin
38. Arm
39. Eccentric
40. Pin
41. Lever
42. Shaft
43. Lever
44. Spring
45. Clamp
46. Pin
47. Throttle lever
48. Stop lever

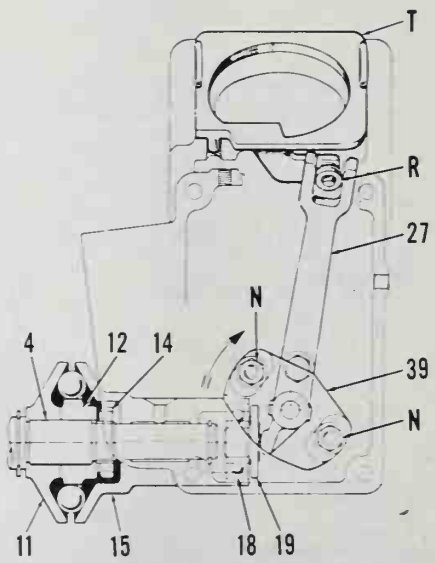


Fig. L3-25 – View of governor linkage. Refer to text and Fig. L3-24.

draw crankshaft assembly from cylinder block. Main bearing caps (43) may now be separated from bearing support (41).

Crankshaft main bearing journal diameter is 64.96-64.98 mm and main bearing clearance should be 0.05-0.08 mm with a maximum allowable clearance of 0.10 mm. Standard and undersize main bearings are available.

Standard crankpin journal diameter is 55.34-55.35 mm. Rod bearing clearance is 0.04-0.07 mm with a maximum allowable clearance of 0.10 mm. Standard and undersize rod bearings are available.

Crankshaft end play is controlled by thrust washer halves (44) mounted on center support (41) of Models 832 and L27, or on support nearest timing gear end of engine on all other models. Crankshaft end play should be 0.15-0.25 mm. Install new thrust washers if end play exceeds 0.5 mm.

Main bearing cap (43) has a serrated parting face. Install cap in support so reference numbers on cap and support are on same side. Tighten main bearing cap screws to 49 N·m. Tighten center main bearing support screws to 49 N·m and nuts securing rear main bearing support (27 – Fig. L3-22) to 39.2 N·m.

ALTERNATOR AND VOLTAGE REGULATOR

Refer to Fig. L3-27 or L3-28 for wiring schematic. Note that circuit in Fig. L3-28 includes an alternator warning light and the voltage regulator is different than the regulator used in circuit in Fig. L3-27.

The alternator stator is attached to the timing gear cover while a ring of magnets is carried inside the crankshaft pulley. To check alternator output, disconnect the two yellow leads and the red lead from the voltage regulator. Connect a voltmeter between the red lead and one yellow lead. With the engine running at 2200 rpm, alternator output should be 28-30 volts; at 2600 rpm, alternator output should be 32-36 volts; at 3000 rpm, alternator output should be 38-42 volts. Connect voltmeter to red lead and remaining yellow lead and repeat test. If voltage is insufficient, or the difference between tests is greater than 5 volts, then renew alternator. Stator and rotor are available only as a unit assembly.

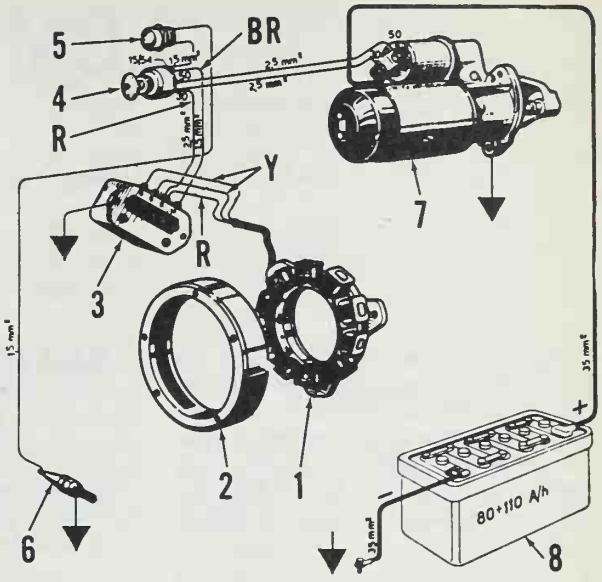


Fig. L3-27 – Wiring schematic applicable to models not equipped with alternator warning light as shown in Fig. L3-28.

BR. Brown
R. Red
Y. Yellow
1. Stator
2. Rotor
3. Voltage regulator
4. Switch
5. Oil pressure light
6. Oil pressure sender
7. Starter
8. Battery

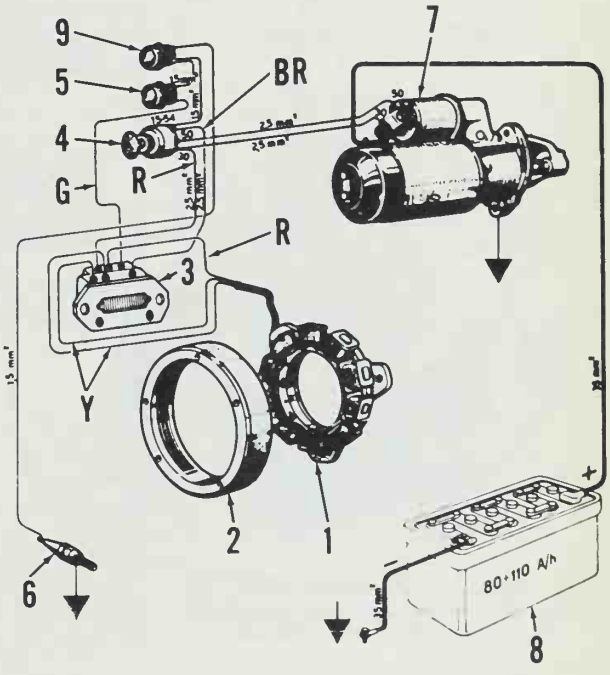


Fig. L3-28 – Wiring schematic of models equipped with an alternator warning light.

BR. Brown
G. Green
R. Red
Y. Yellow
1. Stator
2. Rotor
3. Voltage regulator
4. Switch
5. Oil pressure light
6. Oil pressure sender
7. Starter
8. Battery
9. Alternator light

ELECTRIC STARTER

Models 834 and L54 are equipped with a Bosch JD 12V-4PS electric starter. All other models may be equipped with either a Bosch JD 12V-1.8PS or Femsa MTL 12-6 electric starter.

LOMBARDINI

Model	No. Cyls.	Bore	Stroke	Displ.
904	2	90 mm	94 mm	1196 cc
914	2	95 mm	94 mm	1332 cc
L20	2	95 mm	94 mm	1332 cc

Engines covered in this section are four-stroke, air-cooled diesel engines. The crankcase is aluminum and the cylinders are cast iron. Crankshaft rotation is counterclockwise at pto end. Number one cylinder is nearer flywheel.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0° C (32° F), SAE 20W for temperatures between 0° C (32° F) and 20° C (68° F), and SAE 40 for temperatures above 20° C (68° F). API classification for oil should be CD. Oil sump capacity is 2.8 liters. Manufacturer recommends renewing oil after every 100 hours of operation.

A renewable oil filter is mounted on side of engine crankcase. Manufacturer recommends renewing filter after every 400 hours of operation.

All models are equipped with a pressurized oil system. Refer to Fig. L4-1 for a diagram of the oil circuit.

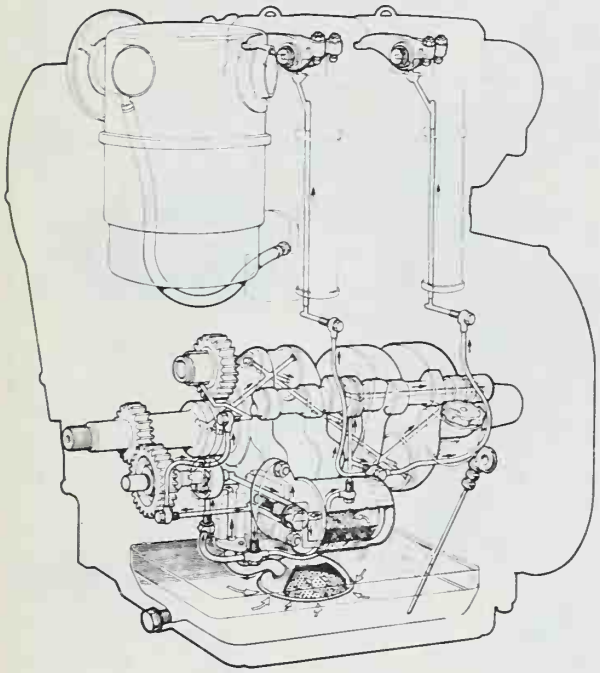


Fig. L4-1—Drawing of lubrication system.

ENGINE SPEED ADJUSTMENT

Idle speed is adjusted by turning idle speed screw (I—Fig. L4-2). Idle speed should be 900-950 rpm. Maximum governed speed is adjusted by turning high speed screw (H). Maximum governed speed under load is 3000 rpm for Models 904 and 914 and 2200 rpm for Model L20.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter is located in the fuel tank. Renew filter after every 300 hours of operation or sooner if required.

BLEED FUEL SYSTEM. To bleed fuel system, remove fuel injection pump bleed screw (B—Fig. L4-3), then operate fuel pump primer lever (P) until air-free

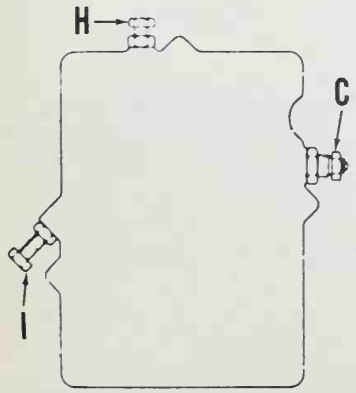


Fig. L4-2—Drawing showing location of low idle speed screw (I), high idle speed screw (H) and torque control screw (C).

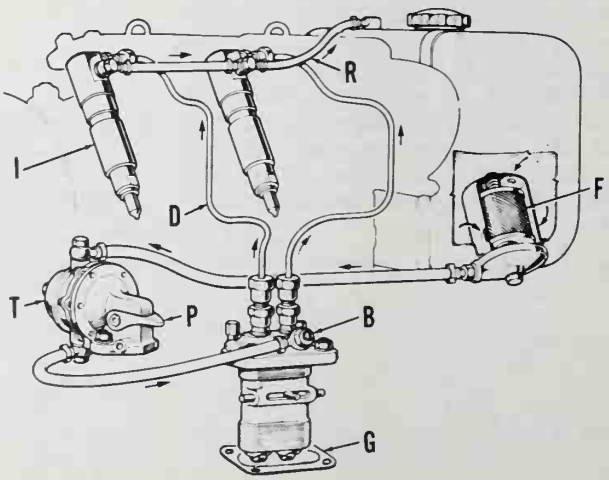


Fig. L4-3—Fuel circuit diagram.

B. Pump bleed screw
D. High pressure delivery line
F. Fuel filter
G. Shim gasket
I. Injector
P. Primer lever
R. Fuel return line
T. Fuel transfer pump

fuel flows from injection pump. Reinstall bleed screw (B). Loosen high pressure injection lines at injectors, then rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection lines. Retighten injection lines.

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G – Fig. L4-3) between pump body and mounting surface on crankcase. Injection should occur at 26° 45' – 28° 30' before top dead center. To check injection pump timing, unscrew high pressure injection line of number 1 cylinder from injection pump delivery valve holder (25 – Fig. L4-4). Unscrew delivery valve holder (25) and remove spring (23) and delivery valve (22), then screw delivery valve holder (25) back into pump. Move throttle control to full speed position. Operate primer lever (P – Fig. L4-3) while rotating engine in normal direction (counterclockwise at pto) so number 1 piston is on compression stroke. Note fuel will flow out of delivery valve holder. Stop engine rotation at moment fuel ceases to flow. Timing marks (I and M – Fig. L4-5 or L4-6) should be aligned. To advance ignition timing, remove shim gaskets (G – Fig. L4-3); install shim gaskets to retard injection timing. Tighten injection pump retaining screws to 24.5 N·m. Reinstall removed pump parts after checking timing.

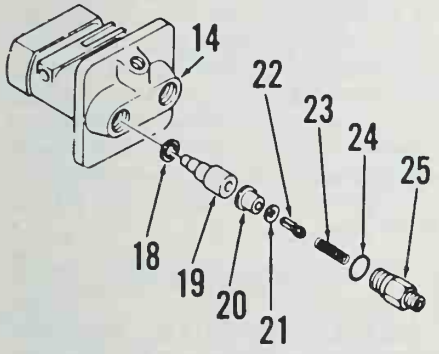


Fig. L4-4 – Partial exploded view of fuel injection pump.

14. Pump body
18. Packing
19. Barrel
20. Delivery valve seat
21. Gasket
22. Delivery valve
23. Spring
24. "O" ring
25. Delivery valve holder

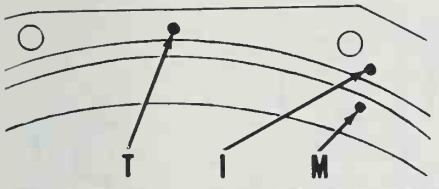


Fig. L4-5 – Drawing of flywheel timing marks used on some models.

I. Injection
M. Reference mark
T. Top dead center

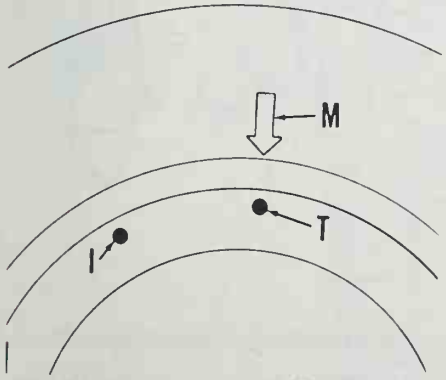


Fig. L4-6 – Drawing of crankshaft pulley timing marks used on some models.

I. Injection
M. Reference mark
T. Top dead center

FAN BELT TENSION

All models are equipped with a belt-driven cooling fan. Belt tension is adjusted by varying the number of shims between fan pulley halves. Belt tension is correct when thumb pressure applied midway between pulleys deflects belt approximately 1 cm.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques. All values are in newton meters.

Camshaft gear	196
Camshaft retainer	24.5
Connecting rod	49
Crankshaft pulley	294
Cylinder head	49
Exhaust manifold	24.5
Fan nut	24.5
Fan pulley	7.8
Fan pulley hub	24.5
Flywheel	294
Injection pump	24.5
Injector retainer plate	11.8
Intake manifold	24.5
Main bearing center support halves	24.5
Main bearing support	
Center	39.2
End	24.5
Oil pan	24.5
Oil pump gear	98
Rocker arm stand	24.5
Oil pump housing	24.5
Rope pulley	39.2
Timing gear cover	24.5

COOLING FAN

All models are equipped with an axial cooling fan to force air past the cylinders. The fan housing (4 – Fig. L4-10) is mounted on the crankcase. Alternator (7) is contained in the fan housing with the alternator rotor mounted on shaft (6).

Overhaul is evident after inspection of unit and referral to Fig. L4-10. Adjust belt tension as previously outlined.

VALVE TAPPET GAP

Valve tappet gap may be adjusted after removing rocker arm cover. Valve tappet gap should be 0.15 mm for both valves with engine cold. Note that there are two adjusting screws (Fig. L4-11) in exhaust rocker arm. Adjusting screw (V) nearer rocker arm shaft is used to

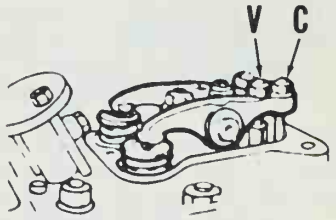


Fig. L4-11 – Drawing showing location of exhaust valve tappet adjusting screw (V) and compression release adjusting screw (C).

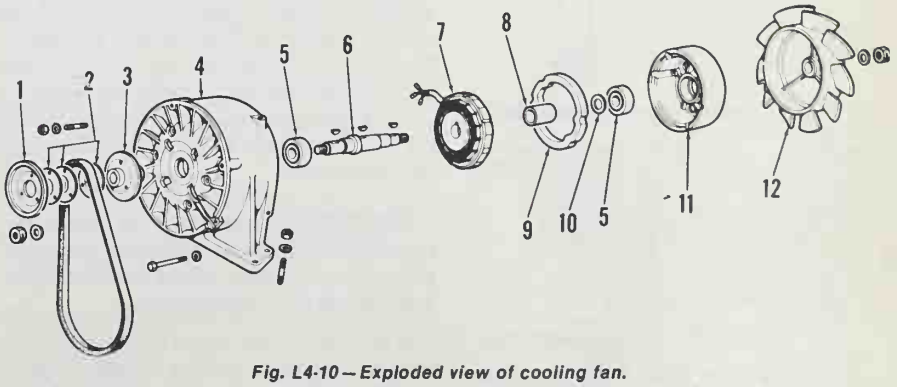


Fig. L4-10 – Exploded view of cooling fan.

1. Pulley half
2. Shims
3. Pulley hub
4. Fan housing
5. Bearing
6. Shaft
7. Alternator
8. Spacer
9. Spacer
10. Washer
11. Alternator housing
12. Fan

adjust valve clearance while outer screw (C) adjusts compression release gap.

COMPRESSION RELEASE

A manual compression release is located on each cylinder head so the exhaust valve can be held open to aid starting. Rotating shaft (28–Fig. L4-12) forces the exhaust rocker arm to slightly open the exhaust valve.

The compression release is adjusted by turning outer adjusting screw (C–Fig. L4-11) in exhaust valve rocker arm. Adjust compression release gap AFTER adjusting exhaust valve tappet gap. With compression release lever in off position, clearance between adjusting screw and shaft should be 0.9-1.1 mm.

Diameter of compression release shaft (28–Fig. L4-12) is 11.95-11.97 mm while lobe height is 10.4-10.5 mm.

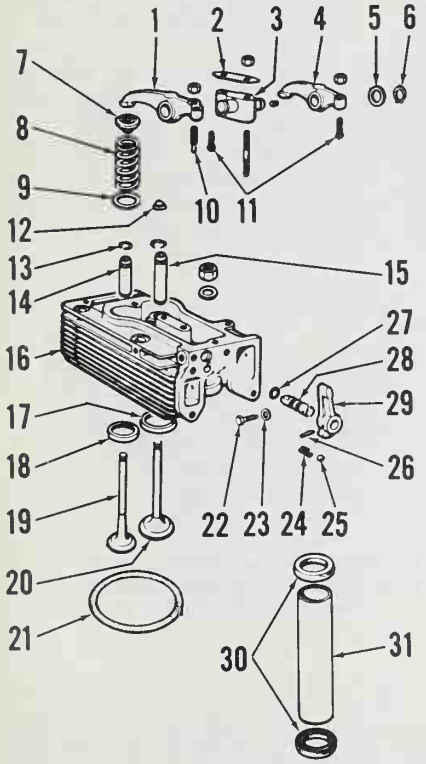


Fig. L4-12–Exploded view of cylinder head.

1. Exhaust rocker arm
2. Lockplate
3. Rocker arm stand
4. Intake rocker arm
5. Washer
6. Snap ring
7. Spring retainer
8. Valve spring
9. Spring seat
10. Compression release adjusting screw
11. Valve adjusting screws
12. Oil seal
13. Retaining ring
14. Exhaust valve guide
15. Intake valve guide
16. Cylinder head
17. Intake valve seat
18. Exhaust valve seat
19. Exhaust valve
20. Intake valve
21. Head gasket
22. Locating screw
23. Washer
24. Spring
25. Detent ball
26. Pin
27. "O" ring
28. Compression release shaft
29. Compression release lever
30. Seals
31. Push rod tube

CYLINDER HEAD AND VALVE SYSTEM

Do not remove cylinder head while hot as head may deform.

Valve face angle is 45 degrees and minimum valve head margin is 0.4 mm. Valve seat angle is 45 degrees with a seat width of 1.4-1.6 mm. Valve seats are renewable and must be installed with head heated to 160°-180° C (320°-356° F). Valve seals are used on intake valves. Valve stem diameter is 7.98-8.00 mm while valve guide diameter is 8.03-8.05 mm. Desired valve stem clearance is 0.03-0.07 mm. Valve guides are renewable and oversize valve guides are available. Note locating ring (13–Fig. L4-12) around top of each valve guide. Outside of oversize valve guide must be machined so outer diameter is 0.05-0.06 mm greater than hole in head. The cylinder head should be heated to 160°-180° C (320°-356° F) when installing valve guide.

Desired clearance between rocker arms and shafts is 0.03-0.06 mm. Maximum clearance is 0.1 mm.

Before tightening cylinder head nuts, install exhaust manifold, then tighten cylinder head nuts to 49 N·m.

When installing cylinder head, be sure oil tubes to head are properly connected as shown in Fig. L4-1. Before tightening cylinder head nuts, install exhaust and intake manifolds to correctly position head, then tighten cylinder head nuts to 49 N·m.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and injection line and immediately cap or plug all openings. Unscrew retainer plate (1–Fig. L4-13) being careful not to lose dowel pin (2). Injector may now be carefully removed from cylinder head. Do not lose shims between injector and cylinder head.

Tighten injector retainer plate nuts to 11.8 N·m. If accessible, measure protrusion of nozzle into combustion chamber. Nozzle tip should extend 4.0-4.5 mm above adjacent combustion chamber surface. Adjust position of nozzle by installing 0.5 mm shims between injector and cylinder head.

TESTING. WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector operation may be checked. Only clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Opening pressure with a new spring (4–Fig. L4-13) should be 21.6-22.5 MPa while opening pressure with a used spring should be 20.6-21.6 MPa. Opening pressure is adjusted by varying number and thickness of shims (5). Valve should not show leakage at orifice spray holes for 10 seconds at 19.1 MPa.

OVERHAUL. Clamp nozzle body (3–Fig. L4-13) in a vise with nozzle tip pointing upward. Remove nozzle holder nut (11). Remove nozzle tip (9) with valve (10) and spacer (8). Invert nozzle body (3) and remove spring seat (6), shim (5) and spring (4). Thoroughly clean all parts in a suitable solvent. Clean inside orifice end of nozzle tip with a wooden cleaning stick. The orifice spray holes may be cleaned by inserting a 0.28 mm cleaning wire. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle holder nut (11) to 60-90 N·m.

INJECTION PUMP

R&R AND OVERHAUL. To remove injection pump, disconnect fuel lines, unscrew retaining screws and remove pump. Do not lose shim gaskets (G–Fig. L4-3).

The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

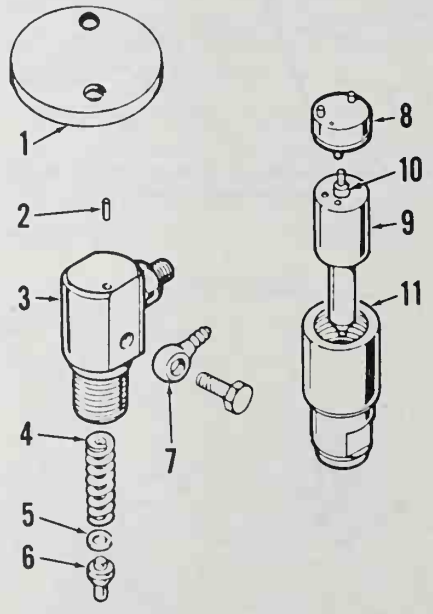


Fig. L4-13–Exploded view of injector.

1. Clamp plate
2. Dowel pin
3. Nozzle body
4. Spring
5. Shim
6. Pressure pin
7. Return line fitting
8. Spacer
9. Nozzle
10. Valve
11. Nozzle holder nut

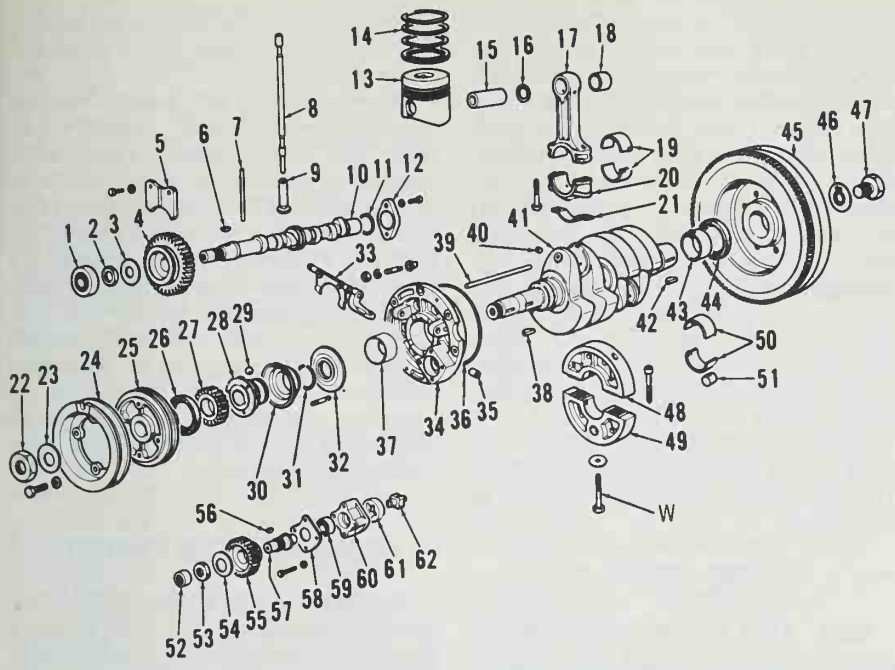


Fig. L4-15—Exploded view of crankshaft, camshaft and oil pump assemblies.

1. Bearing
2. Nut
3. Washer
4. Camshaft gear
5. Retainer
6. Key
7. Fuel pump push rod
8. Push rod
9. Tappet
10. Camshaft
11. "O" ring
12. Cover plate
13. Piston
14. Piston rings
15. Piston pin
16. Snap ring
17. Connecting rod
18. Bushing
19. Rod bearing
20. Rod cap
21. Lockplate
22. Nut
23. Washer
24. Rope pulley
25. Fan pulley
26. Seal
27. Gear
28. Governor hub
29. Balls
30. Governor cup
31. Snap ring
32. Seal
33. Governor arm & shaft
34. End bearing support
35. Bushing
36. "O" ring
37. Main bearing
38. Key
39. Governor rod
40. Plug
41. Crankshaft
42. Key
43. Main bearing
44. Seal
45. Flywheel
46. Lockwasher
47. Cap screw
48. Upper center bearing support
49. Lower center bearing support
50. Center main bearing
51. Round nut
52. Bearing
53. Nut
54. Washer
55. Gear
56. Key
57. Drive shaft
58. Bearing retainer
59. Bearing
60. Oil pump cover
61. Outer rotor
62. Inner rotor
W. Support screw

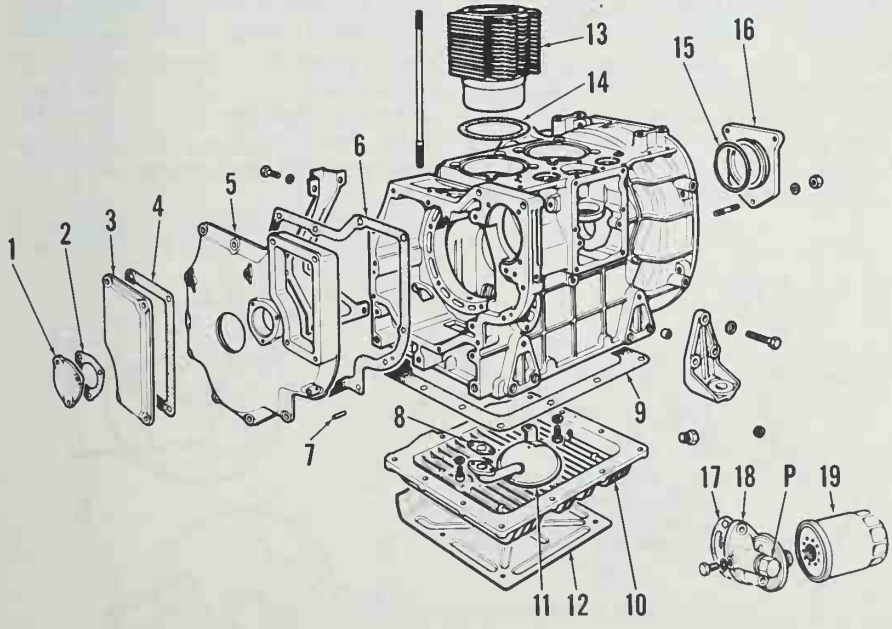


Fig. L4-16—Exploded view of crankcase assembly. Remove plug (P) for access to oil pressure relief valve.

1. Cover
2. Gasket
3. Cover
4. Gasket
5. Timing gear cover
6. Gasket
7. Pin
8. Gasket
9. Gasket
10. Oil pan
11. Oil pickup
12. Air shroud
13. Cylinder
14. Shim gasket
15. "O" ring
16. Cover
17. Gasket
18. Filter adapter
19. Oil filter

When installing pump, engage pin on pump control rack with governor fork. Tighten injection pump screws to 24.5 N·m. If pump is renewed or overhauled, or original shim gaskets are not used, refer to INJECTION PUMP TIMING section and adjust pump timing.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod may be removed after removing cylinder head, oil pan and oil pickup.

When installing piston and rod, note that depression (D – Fig. L4-17) in piston crown is closer to one side of piston. Install piston so depression side of piston is nearer injector. Some pistons also have an arrow embossed on piston. Properly installed, arrow on piston crown will point towards injection pump. Match alignment marks on rod and cap and tighten rod screws to 49 N·m.

Refer to CYLINDER section and measure piston height in cylinder.

PISTON, PIN AND RINGS

The piston is equipped with three compression rings and an oil control ring. Ring end gap is 0.35-0.55 mm for all compression rings and 0.25-0.40 mm for the oil control ring. Piston ring side clearance should be 0.15 mm for top compression ring and 0.10 mm for all other piston rings.

Standard piston diameter measured 2 mm from bottom of skirt, perpendicular to piston pin, is 89.85-89.86 mm for Model 904 and 94.85-94.86 mm for Models 914 and L20. Piston to cylinder clearance should be 0.14-0.17 mm. Pistons and rings are available in standard and oversizes of 0.5 and 1.0 mm. Difference in piston weights must not exceed 6 grams.

Piston pin diameter is 27.995-28.005 mm. Piston pin clearance in rod should

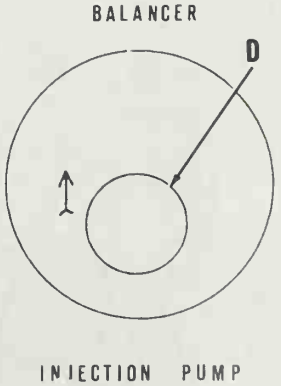


Fig. L4-17—Arrow on piston crown should point towards injection pump and depression (D) should be near injectors.

be 0.015-0.035 mm with a maximum allowable clearance of 0.05 mm.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Clearance between piston pin and rod bushing should be 0.015-0.035 mm with a maximum allowable clearance of 0.05 mm. Bushing inner diameter is 28.020-28.030 mm.

An insert type bearing is used in connecting rod big end. Desired rod bearing clearance is 0.03-0.07 mm with a maximum allowable clearance of 0.10 mm. Big end bearings are available in standard and undersizes.

CYLINDERS

All models are equipped with removable cylinders. Standard cylinder diameter is 90.00-90.02 mm for Model 904 and 95.00-95.02 mm for Models 914 and L20. Maximum allowable taper or out-of-round is 0.1 mm.

With piston at top dead center, top of piston must be even with cylinder top edge. Cylinder height is adjusted using shim gaskets (14 – Fig. L4-16) which are available in thicknesses of 0.1 and 0.3 mm.

TIMING GEARS

REMOVE AND REINSTALL. Remove belt guard and fan belt. Unscrew nut, then using a suitable puller, pull pulley off crankshaft. Remove timing gear cover.

Use a suitable puller to remove gears. Note that retainer (5 – Fig. L4-15) must be removed before pulling off camshaft gear (4). When installing camshaft gear, place gear on shaft so retainer groove is out. Align timing marks (M – Fig. L4-18) on models so equipped, when installing gears. If timing marks are not present on timing gears, proceed as follows: The cylinder head, push rod tube and push rods for number 1 cylinder must be removed. Position number 1 piston at top dead center. If not previously removed, detach camshaft gear from camshaft. Rotate camshaft so number 1 cylinder intake valve tappet is opening (rising) and exhaust valve tappet is closing (going down) then stop rotation when tappets are same height from top surface of crankcase. Without disturbing camshaft position, install camshaft gear. Mark crankshaft, oil pump and camshaft gears for future reference. Reinstall cylinder head.

Tighten camshaft gear nut to 196 N·m and oil pump gear nut to 98 N·m. Tighten timing gear cover screws to 24.5 N·m.

OIL PUMP

R&R AND OVERHAUL. The oil pump is mounted on end main bearing support (34 – Fig. L4-15). To remove pump, remove timing gear cover and oil pump gear (55). Unscrew pump housing screws and disassemble pump.

Refer to Fig. L4-19 and measure clearance between inner and outer rotors (61 and 62). Clearance (A) should be 0.01-0.06 mm with a maximum allowable clearance of 0.10 mm, and clearance (B) should be 0.02-0.10 mm with a maximum allowable clearance of 0.20 mm. Width of inner and outer rotors should be 14.95-14.97 mm and difference in rotor widths must not be greater than 0.02 mm. Outer rotor outer diameter is 40.54-40.57 mm. Pump housing bore is 40.60-40.63 mm. Clearance between outer rotor and pump housing bore should be 0.03-0.09 mm with a maximum allowable clearance of 0.13 mm. With pump cover (60 – Fig. L4-15) and bearing retainer (58) installed and retaining screws torqued, inner rotor end play should be 0.03-0.11 mm. Inspect bearing (52) in timing gear cover and renew if damaged.

To reassemble oil pump, reverse disassembly procedure. Install outer rotor (61) with rounded outer edge towards pump housing. Apply Loctite to outer surface of bearing (59) outer race. Tighten oil pump screws to 24.5 N·m. Refer to TIMING GEARS section and align oil pump gear timing marks. Tighten oil pump gear nut to 98 N·m.

Oil pressure with engine at normal temperature and running at 3000 rpm should be 343-392 kPa. To adjust oil pressure, remove plug (P – Fig. L4-16) and add or remove shims to vary relief valve spring pressure.

CAMSHAFT AND TAPPETS

REMOVE AND REINSTALL. Remove cylinder heads, push rod tubes and push rods. Remove timing gear cover, gear retainer (5 – Fig. L4-15) and camshaft gear (4). Remove fuel injection pump. Using suitable tools, pull valve tappets away from camshaft and secure tappets so they will not fall into crankcase when camshaft is removed. If tappets fall into crankcase, then crankshaft must be removed so tappets can be reinstalled. Withdraw camshaft from crankcase. Remove oil pan for access to tappets.

Inspect bearing (1) in timing gear cover and renew if damaged. Inspect camshaft lobes and bearing journals. Center journal diameter is 40.940-40.960 mm while rear journal diameter is 29.940-29.960 mm. Camshaft journal clearance should be 0.040-0.085 mm with a maximum allowable clearance of 0.10 mm. Maximum runout measured at center journal with camshaft ends supported is 0.10 mm.

Tappet outer diameter is 13.96-13.98 mm while tappet bore in crankcase is

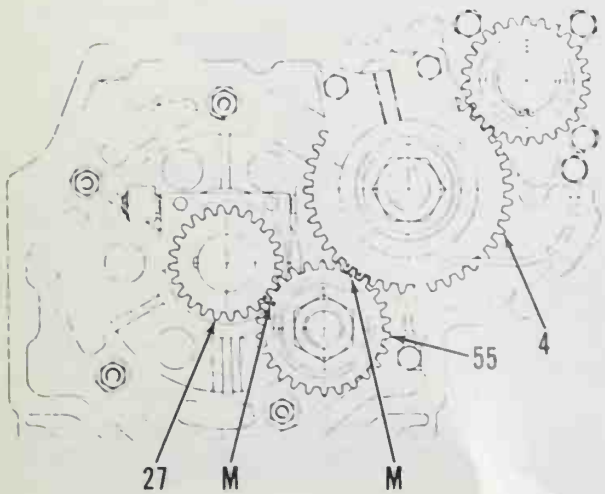


Fig. L4-18 – View showing location of timing marks (M) on camshaft gear (4), crankshaft gear (27) and oil pump gear (55).

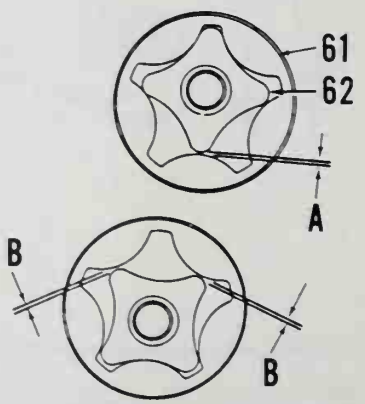


Fig. L4-19 – Refer to text for clearances (A&B) between oil pump outer rotor (61) and inner rotor (62).

14.00-14.02 mm. Clearance should be 0.02-0.06 mm with a maximum allowable clearance of 0.10 mm.

If removed, install tappets. Camshaft end play is controlled by camshaft gear retainer plate (5). Retainer plate thickness is 5.7-5.8 mm while groove in gear (4) is 6.0-6.1 mm. Camshaft end play should be 0.2-0.4 mm. Renew plate (5) and/or gear (4) if end play is incorrect. Refer to TIMING GEARS section for gear installation. Tighten camshaft gear nut to 196 N·m.

GOVERNOR

All models are equipped with a flyball type governor mounted on the crankshaft. As the flyballs (29–Fig. L4-15) move in and out against cup (30), fork and lever assembly (33) forces push rod (39) against pin (1–Fig. L4-20 or L4-21). Pivot flange (4), lever (16) and governor arm (5) are forced to rotate thereby moving fuel injection pump control rack pin (P). Throttle lever (25) operates through pivot arm (12) and governor spring (13) to control engine speed.

Torque control screw (C) on Models 904 and 914 allows additional fuel usage under high torque load. The tip is spring loaded. The tip should recede 0.5-0.6 mm when 470-500 grams force is applied to tip. Torque control screw is available only as an assembly.

Start spring (6) returns the fuel injection pump control rack to maximum fuel position to aid in starting. Spring free length is 29.5-30.5 mm.

Governor spring (13) free length is 69.5-70.5 mm. With a force of 56.84 newtons, spring length should be 82.5-83.5 mm.

To adjust governor, remove cover (24–Fig. L4-20) and on Models 904 and 914, back out torque control screw (C) 5 or 6 turns. With engine stopped, check to be sure start spring (6–Fig. L4-20 and L4-21) has removed slack in governor mechanism. Loosen governor arm screw (8) and move governor arm (5) towards torque control screw (C) until fuel injection pump control rack pin (P) is in maximum fuel position. Tighten screw (8). Install control cover and run engine at high idle speed of 3150 rpm for Models 904 and 914 or 2350 rpm for Model L20. Turn torque control screw (C) in until engine speed just begins to decrease, then turn torque control screw in an additional 1½ turns on Models 904 and 914 or 2.2 turns on Model L20. Tighten torque control screw locknut.

For access to governor flyball assembly, remove timing gear cover and crankshaft gear.

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. The crankshaft rides in sleeve bearings in the crankcase bulkhead and end bearing support (34–Fig. L4-15), and in insert bearings in center support halves (48 and 49).

To remove the crankshaft, remove flywheel, pistons and rods, and governor as previously outlined. Unscrew center support retaining screw (W). Unscrew end support (34) retaining nuts and remove end support. Carefully extract crankshaft and center bearing support from crankcase. Do not lose round nut (51). If necessary, unscrew and separate center support halves (48 and 49).

Standard diameter of center main bearing journal is 55.34-55.35 mm. Standard diameter of outer main bearing journals is 54.94-54.95 mm. Bearing clearance should be 0.05-0.09 mm for center main bearing and 0.05-0.07 mm for outer main bearings with a maximum allowable clearance of 0.12 mm. End main bearings (37 and 43) must be reamed to size. Standard and undersize main bearings are available.

Standard crankpin journal diameter is 49.989-50.000 mm and rod bearing clearance should be 0.03-0.07 mm with a maximum allowable clearance of 0.10 mm. Standard and undersize rod bearings are available.

Serrated parting surfaces of center support halves (48 and 49) must be aligned during assembly. With support screws tightened to 24.5 N·m, center support outside diameter should be 154.980-154.990 mm and inside diameter should be 59.074-59.093 mm. Maximum out-of-round for either diameter is 0.01 mm.

When installing main bearing (37) in end support (34–Fig. L4-22), distance

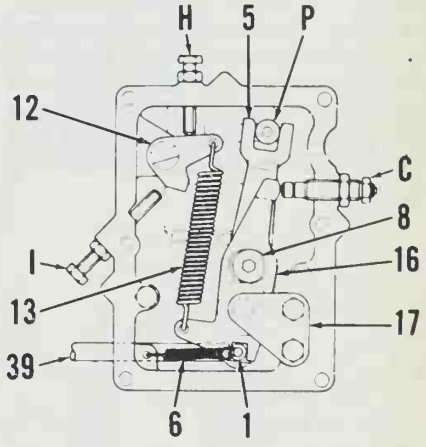


Fig. L4-21–Drawing of governor and throttle control linkage. Refer to Fig. L4-20 for parts identification.

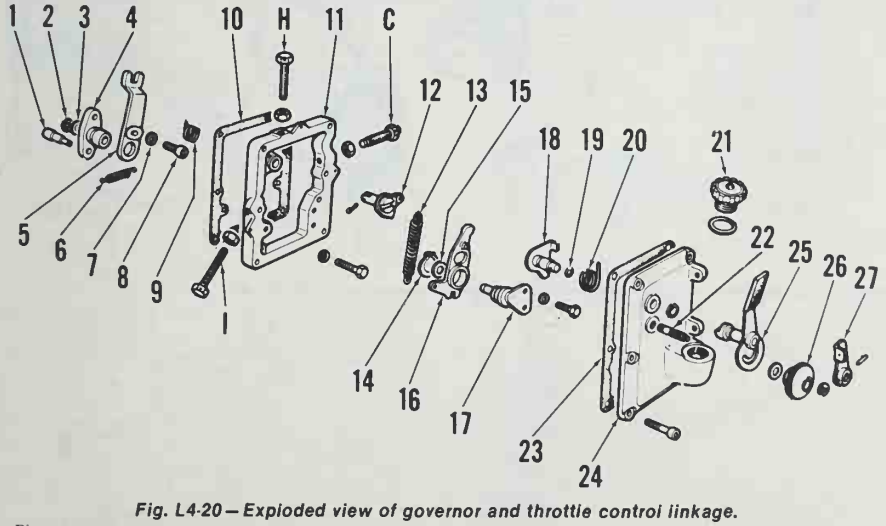


Fig. L4-20–Exploded view of governor and throttle control linkage.

1. Pin
2. Snap ring
3. Washer
4. Pivot flange
5. Governor arm
6. Start spring
7. Washer
8. Allen screw
9. Spring
10. Gasket
11. Plate
12. Pivot arm
13. Governor spring
14. Snap ring
15. Washer
16. Lever
17. Pivot
18. Arm
19. Washer
20. Spring
21. Oil fill cap
22. Stud
23. Gasket
24. Cover
25. Throttle lever
26. Knob
27. Stop lever
C. Torque control screw
H. High idle speed screw
I. Low idle speed screw

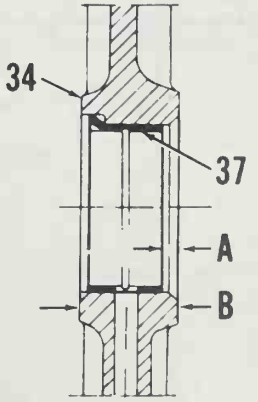


Fig. L4-22–Depth (A) of bearing (37) in end support (34) should be 5 mm. Support width measured at (B) is 33.90-33.95 mm.

(A) from bearing (37) to inside surface of support should be 5 mm.

Crankshaft end play should be 0.15-0.25 mm and is not adjustable. End support (34 – Fig. L4-15) width measured at (B) should be 33.90-33.95 mm. Width of gear end main bearing journal measured from shoulder to thrust face as shown at (C – Fig. L4-23) should be 34.10-34.15 mm. A worn end support or crankshaft will cause excessive end play.

Reassembly is reverse of disassembly. Tighten screws securing center support halves to 24.5 N·m. Tighten end support retaining nuts to 24.5 N·m. Tighten center support retaining screw to 39.2 N·m.

ALTERNATOR AND REGULATOR

Refer to Fig. L4-25 or L4-26 for wiring schematic. Note that circuit in Fig. L4-26 includes an alternator warning light and the voltage regulator is different than the regulator used in circuit in Fig. L4-25. Alternator output may be 14 or 21 amperes as noted on voltage regulator.

The alternator is contained in the fan housing. To check alternator output, disconnect the two yellow leads and the red lead from the voltage regulator. Connect a voltmeter between the red lead and one yellow lead. With engine running, check voltmeter reading and compare with desired values in following table:

Engine RPM	14 Amp Alternator	21 Amp Alternator
1500	18.5-20 Volts	30-32 Volts
2000	24-25 Volts	45-47 Volts
2500	31-32 Volts	57-58 Volts
3000	37-38 Volts	68-69 Volts

Connect voltmeter to red lead and remaining yellow lead and repeat test. If voltage is insufficient, or the difference between tests is greater than 5 volts, then renew alternator. Stator and rotor are available only as a unit assembly.

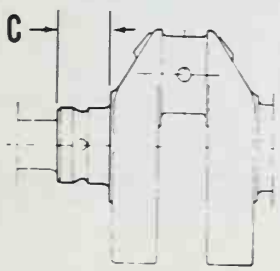


Fig. L4-23 – Gear end main bearing journal width (C) is 34.10-34.15 mm.

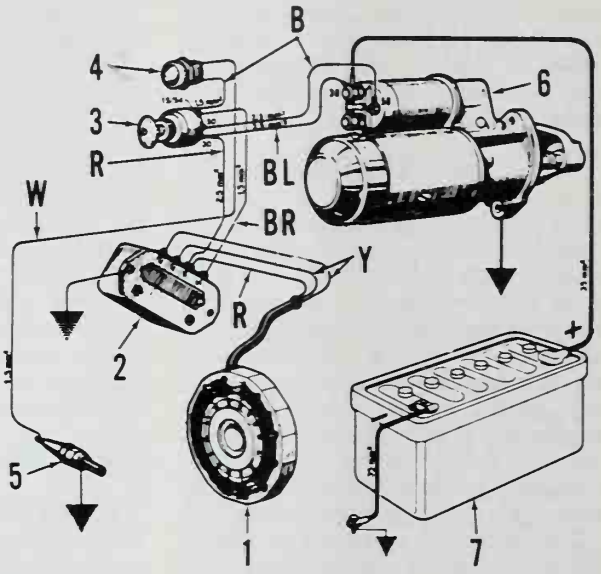


Fig. L4-25 – Wiring schematic of models not equipped with an alternator warning light.

B. Black
BL. Blue
BR. Brown
R. Red
W. White
Y. Yellow
1. Alternator
2. Voltage regulator
3. Switch
4. Oil pressure light
5. Oil pressure sender
6. Starter
7. Battery

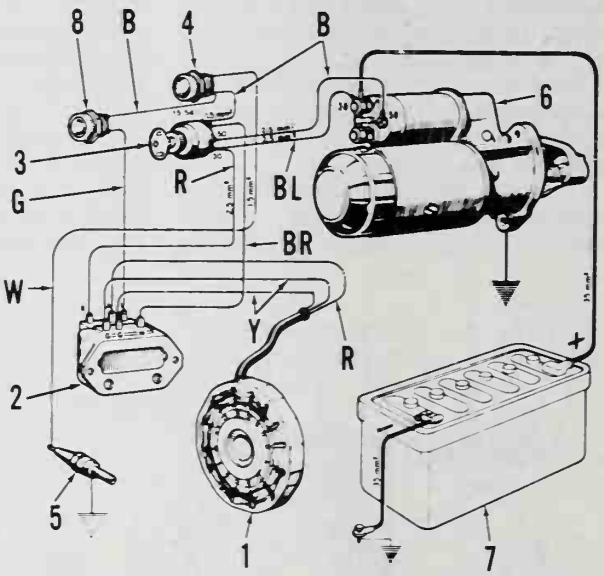


Fig. L4-26 – Wiring schematic of models equipped with an alternator warning light.

B. Black
BL. Blue
BR. Brown
G. Green
R. Red
W. White
Y. Yellow
1. Alternator
2. Voltage regulator
3. Switch
4. Oil pressure light
5. Oil pressure sender
6. Starter
7. Battery
8. Alternator light

LOMBARDINI

Model	No. Cyls.	Bore	Stroke	Displ.
L8	1	85 mm	90 mm	510 cc
L10	1	95 mm	90 mm	638 cc
L14	1	102 mm	100 mm	817 cc
LDA96	1	95 mm	90 mm	638 cc
LDA100	1	100 mm	90 mm	707 cc
LDA450	1	85 mm	80 mm	454 cc
LDA510	1	85 mm	90 mm	510 cc
LDA820	1	102 mm	100 mm	817 cc

All models are four-stroke, single-cylinder, air-cooled diesel engines. Crankshaft rotation is counterclockwise at pto end.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0° C (32° F), SAE 20W for temperatures between 0° C (32° F) and 20° C (68° F), and SAE 40 for temperatures above 20° C (68° F). API classification for oil should be CD. Oil sump capacity is 1.65 liters on Models L8, LDA450 and LDA510 or 2.6 liters on all other models. Manufacturer recommends renewing oil after every 100 hours of operation.

A renewable oil filter is mounted on side of engine crankcase. Manufacturer recommends renewing filter after every 300 hours of operation.

All models are equipped with a pressurized oil system. Refer to OIL PUMP section for service.

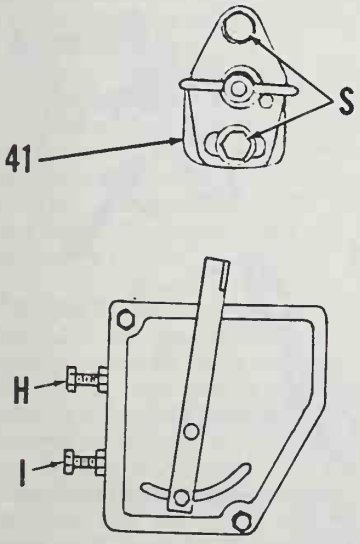


Fig. L5-1—Refer to text for engine speed adjustment.

ENGINE SPEED ADJUSTMENT

Idle speed is adjusted by turning idle speed screw (I—Fig. L5-1). Idle speed should be 1000-1100 rpm. Maximum governed speed is adjusted by turning high speed screw (H). Maximum governed speed under load should be 2200 rpm for Models L8, L10 and L14, 2600 rpm for Models LDA100 and LDA820, and 3000 rpm for Models LDA96, LDA450 and LDA510.

Maximum fuel delivery is adjusted by loosening screws (S) and moving plate (41). Set plate so satisfactory engine pickup is obtained without excessive smoke. Moving plate to left increases fuel delivery.

FUEL SYSTEM

FUEL FILTER. The fuel filter is located inside the fuel tank as shown in Fig. L5-2. Renew fuel filter after every 300 hours of operation or sooner if required.

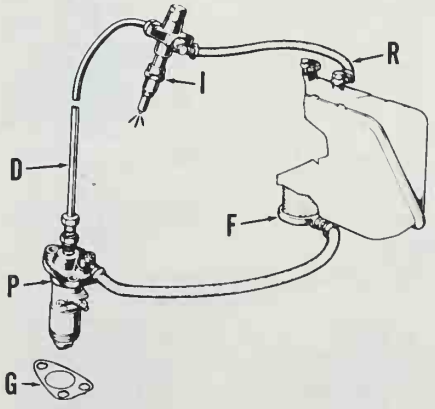


Fig. L5-2—Diagram of fuel system.

D. High pressure delivery line
F. Fuel filter
G. Shim gasket
I. Injector
P. Injection pump
R. Return line

BLEED FUEL SYSTEM. To bleed fuel system, loosen fuel line fitting on fuel pump and allow fuel to flow until air-free, then retighten fitting. Loosen high pressure injection line at injector, then rotate engine crankshaft to operate injection pump until air-free fuel flows from injection line. Retighten injection line.

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G—Fig. L5-2) between pump body and mounting surface on crankcase. To check injection pump timing, unscrew high pressure delivery line (D) fitting from delivery valve holder (1—Fig. L5-3). Unscrew delivery valve holder and remove spring (3) and

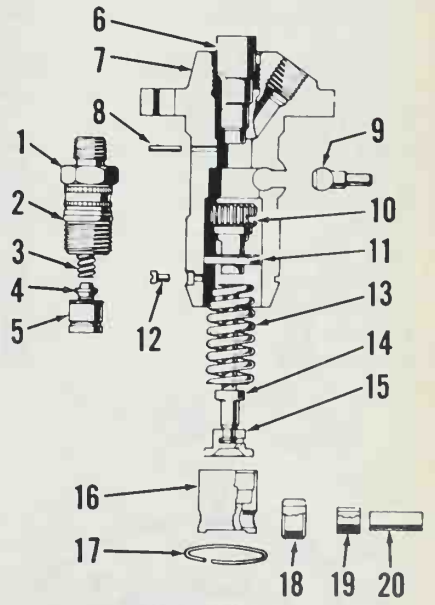


Fig. L5-3—View of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Spring
4. Delivery valve
5. Delivery valve seat
6. Barrel
7. Pump body
8. Pin
9. Control rack
10. Pinion
11. Spring seat
12. Pin
13. Spring
14. Plunger
15. Spring retainer
16. Tappet
17. Circlip
18. Outer roller
19. Inner roller
20. Pin

delivery valve (4) then screw delivery valve holder (1) into pump body. Move throttle control to full speed position. Rotate engine in normal direction (counterclockwise at pto) so piston is on compression stroke. Note fuel in delivery valve holder will spill out. Stop engine rotation at moment fuel ceases to flow out. Timing dot (R – Fig. L5-4) on fan plate should align with injection timing dot (I) on fan shroud. Ignition timing should occur at 22°-23° BTDC on Model L8, 23°45'-25°30' on Models LDA450 and LDA510, and 25°15'-26°45' on all other models.

To advance injection timing, remove shim gaskets (G – Fig. L5-2); install shim gaskets to retard injection timing. Reinstall removed pump components and tighten delivery valve holder to 34.3-39.2 N·m. Tighten injection pump retaining screws to 29.4 N·m.

REPAIRS

TIGHTENING TORQUES

Refer to following table for tightening torques. All values are in newton meters.

Balancer case	49
Balancer cover	49
Connecting rod	
L8, LDA450, LDA510	29.4
All other models	44.1
Cylinder head	
L8, LDA450, LDA510	49
All other models	58.8
Flywheel	
L8, LDA450, LDA510	166.6
All other models	343
Governor shaft nut	
L8, LDA450, LDA510	34.3
All other models	39.2
Injection pump	29.4
Injector	19.6
Main bearing support	
L8, LDA450, L510	29.4
All other models	39.2
Oil pan	24.5
Oil pump	39.2
Oil pump gear	19.6
Pto bearing support	
L8, LDA450, LDA510	24.5
All other models	39.2
Pto flange	225.4
Rope pulley	
L8, LDA450, LDA510	34.3
All other models	39.2

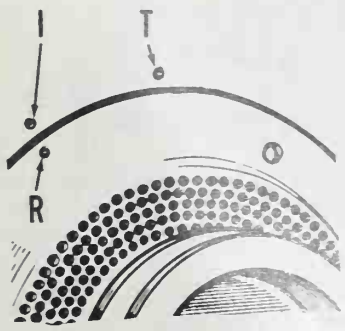


Fig. L5-4 – View of timing marks located on air shroud. Refer to text for injection timing.

VALVE TAPPET GAP

Valve tappet gap may be adjusted after removing rocker arm cover. Valve tappet should be 0.20 mm for both valves with engine cold.

COMPRESSION RELEASE

A manual compression release is located in the rocker arm cover so the exhaust valve can be held open to aid starting. Exhaust valve should be lowered approximately 1 mm from valve seat when compression release is operated. Compression release may be adjusted by varying thickness of rocker arm cover.

CYLINDER HEAD AND VALVE SYSTEM

Do not remove a hot cylinder head as head may deform. To remove rocker arms, unscrew rocker shaft locating pin (21 – Fig. L5-5) on Models L8, LDA450 and LDA510 or shaft locating screw (6) on all other models, then use a suitable puller and withdraw rocker shaft.

Valve face angle is 45 degrees and minimum valve head margin is 0.4 mm. Valve seat angle is 45 degrees with a seat width of 1.4-1.6 mm. Valve seats are renewable and must be installed with head heated to 160°-180° C (320°-356° F). A valve seal is used on the intake valve. Valve stem diameter is 6.98-7.00 mm on Models L8, LDA450 and LDA510 or 7.98-8.00 mm on all other models. Valve guide inside diameter is 7.03-7.05 mm on Models L8, LDA450 and LDA510 or 8.03-8.05 mm on all other models. Desired valve stem clearance for all models is 0.03-0.07 mm. Valve guides are renewable and oversize valve guides are available. Note locating ring (12) around top of each guide. Outside of oversize valve guide must be machined so outer diameter is 0.05-0.06 mm greater than hole in head. The cylinder head should be heated to 160°-180° C (320°-356° F) when installing valve guides.

Valve spring pressure should be 294 newtons at valve spring length of 25.2 mm on Models L8, LDA450 and LDA510 or 25.8 mm on all other models.

The rocker arm shaft on Models L8, L10 and L14 is drilled to allow passage of pressurized oil to rocker arms. Desired clearance on all models between rocker arms and rocker shaft is 0.03-0.06 mm with a maximum clearance of 0.1 mm.

No cylinder head gasket is used.

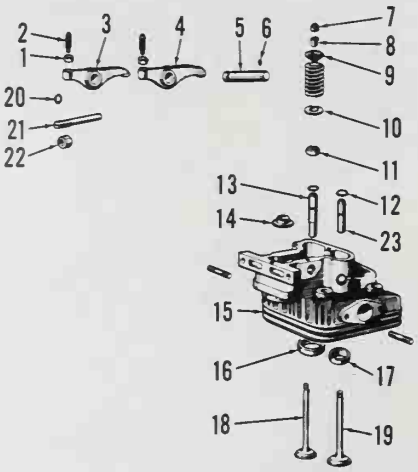


Fig. L5-5 – Exploded view of cylinder head assembly.

1. Locknut
2. Adjuster
3. Intake rocker arm
4. Exhaust rocker arm
5. Rocker arm shaft
6. Set screw
7. Cap
8. Keys
9. Spring retainer
10. Washer
11. Oil seal
12. Circlip
13. Intake valve guide
14. Spring seat
15. Cylinder head
16. Intake valve seat
17. Exhaust valve seat
18. Intake valve
19. Exhaust valve
20. "O" ring
21. Rocker shaft locating pin
22. Locknut
23. Exhaust valve guide

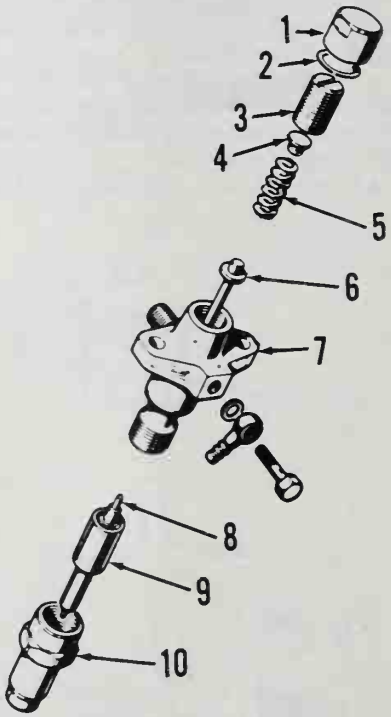


Fig. L5-6 – Exploded view of injector.

1. Nut
2. Gasket
3. Adjuster
4. Spring seat
5. Spring
6. Push rod
7. Body
8. Valve
9. Nozzle
10. Nozzle nut

Cylinder head surface must not be deformed more than 0.30 mm. The cylinder head and cylinder may be lapped together to improve mating surface.

Push rod tube seals should be inspected and discarded if damaged. Push rod nearer cylinder connects to intake rocker arm while outer push rod connects to exhaust rocker arm.

Tighten cylinder head nuts to 49 N·m on Models L8, LDA450 and LDA510 or to 58.8 N·m on all other models.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return and injection lines from injector and immediately cap or plug all openings. Unscrew injector retaining nuts and carefully remove injector from head being careful not to lose shims between injector and head.

Tighten injector retaining nuts to 19.6 N·m. If accessible, measure protrusion of nozzle into combustion chamber. Nozzle tip should extend 2.5-3.0 mm on Model LDA450, 3.0-3.5 mm on Models L8 and LDA510 or 3.5-4.0 mm on all other models. Adjust position of nozzle by installing 0.5 mm shims between injector and cylinder head.

TESTING. WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector operation may be checked. Only clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Opening pressure with a new spring (5–Fig. L5-6) should be 21.6-22.5 MPa while opening pressure with a used spring should be 20.6-21.6 MPa. Opening pressure is adjusted by turning adjuster (3). Valve should not show leakage at orifice spray holes for 10 seconds at 19.1 MPa.

OVERHAUL. Refer to exploded view in Fig. L5-6 and disassemble injector. Thoroughly clean all parts in a suitable solvent. Clean inside orifice end of nozzle tip with a wooden cleaning stick. The orifice spray holes may be cleaned by inserting a 0.28 mm cleaning wire. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle nut (10) to 49 N·m.

INJECTION PUMP

Refer to Fig. L5-3 for view of injection pump. Disassembly and reassembly is evident after inspection of pump and referral to Fig. L5-3. Note that slot in barrel (6) must align with pin (8). Align marks on pinion (10) and rack (9).

The following tests may be used to check injection pump if necessary test equipment is available. With a suitable pressure gage connected to delivery valve holder (1), operate pump. With control rack (18) at mid-point, pump pressure should be at least 29.4 MPa. Pump pressure should be at least 39.2 MPa with control rack in maximum fuel position. To check delivery valve, move control rack (9) to mid-point position and operate pump. After maximum pressure is reached, pressure should drop sharply to a pressure 2940-4900 kPa less than maximum pressure if delivery valve is operating properly. Maximum pump volume at a rate of 1000 pump strokes at 1500 rpm is 27 cc for Model LDA450, 31 cc for Models L8 and LDA510, 36-37 cc for Models L10 and LDA 96, and 51-53 cc for Models L14, LDA100 and LDA820.

Place shim gaskets (G–Fig. L5-2) on pump and engage control rack pin with governor arm during installation. Tighten pump retaining screws to 29.4 N·m. Refer to INJECTION PUMP TIMING section to time injection pump.

PISTON AND ROD UNIT

REMOVE AND REINSTALL. Piston and connecting rod may be removed after removing cylinder head and oil pan.

When installing piston and rod, note that depression in piston crown is closer to one side of piston. Install piston so depression side of piston is nearer exhaust. Some pistons also have an arrow embossed in piston. Install piston so arrow points toward injection pump.

Install cap on connecting rod so bearing tangs are on same side and tighten rod screws to 29.4 N·m on Models L8, LDA450 and LDA510 or 44.1 N·m on all other models.

PISTON, PIN AND RINGS

The piston is equipped with three compression rings and an oil control ring. The top compression ring is chrome plated. Compression ring end gap is 0.35-0.55 mm on Models L14, LDA100 and LDA820 or 0.30-0.45 mm for all other models. Oil control ring end gap is 0.25-0.40 mm for all models.

Refer to following table for standard piston diameter and desired piston clearance. Piston diameter is measured at bottom of skirt perpendicular to piston pin.

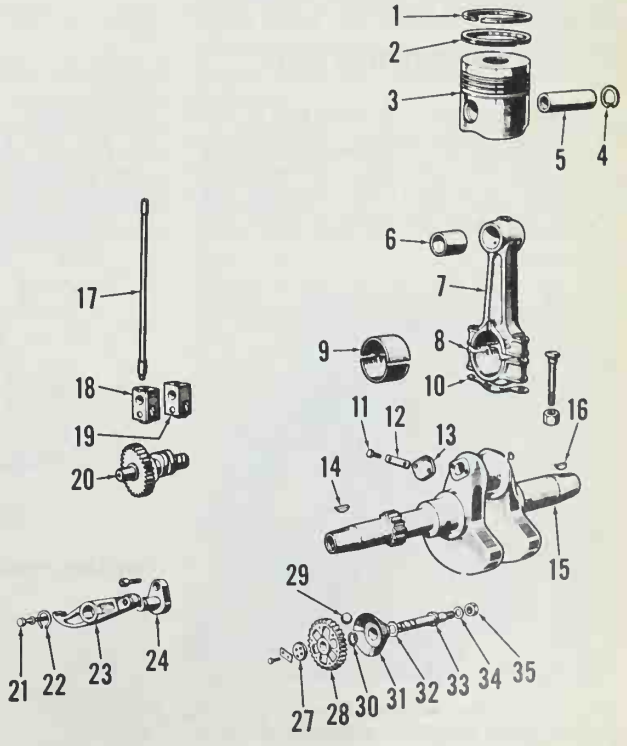


Fig. L5-7—Exploded view of crankshaft, governor and camshaft assemblies. Some models use flyweights instead of flyballs shown.

1. Compression piston rings (3)
2. Oil control ring
3. Piston
4. Snap rings
5. Piston pin
6. Bushing
7. Connecting rod
8. Rod cap
9. Rod bearing
10. Lockplate
11. Screw
12. Lockplate
13. Plate
14. Key
15. Crankshaft
16. Key
17. Push rods
18. Exhaust tappet
19. Intake tappet
20. Camshaft
21. Screw
22. Snap ring
23. Rocker arm
24. Stud
27. Plate
28. Gear
29. Governor balls (6)
30. Snap ring
31. Cup
32. Washer
33. Governor shaft
34. Washer
35. Nut

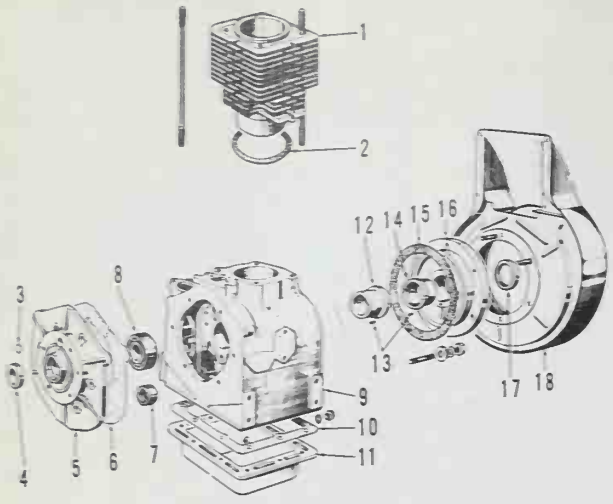


Fig. L5-8 – Exploded view of crankcase.

1. Cylinder
2. Shim gasket
3. Plug
4. Seal
5. Pto bearing support
6. Gasket
7. Bearing
8. Bearing
9. Crankcase
10. Gasket
11. Oil pan
12. Main bearing
13. Dowel pins
14. Main bearing
15. Shim gasket
16. Main bearing support
17. Seal
18. Air shroud

Model	Standard Piston Dia. (mm)	Piston Clearance (mm)
L8	84.88-84.90	0.10-0.14
L10	94.85-94.87	0.13-0.17
L14	101.84-101.86	0.14-0.18
LDA96	94.85-94.87	0.13-0.17
LDA100	99.82-99.83	0.17-0.20
LDA450	84.88-84.90	0.10-0.14
LDA510	84.88-84.90	0.10-0.14
LDA820	101.84-101.86	0.14-0.18

Pistons and rings are available in standard size and oversizes of 0.5 mm and 1.0 mm.

Piston pin diameter is 22.995-23.000 mm on Models L8, LDA450 and LDA510 or 27.995-28.000 mm on all other models. Piston pin clearance in rod bushing should be 0.020-0.035 mm. Maximum allowable clearance is 0.07 mm.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Clearance between piston pin and connecting rod bushing should be 0.015-0.025 mm. Maximum allowable clearance is 0.070 mm.

An insert type bearing is used in connecting rod big end. Desired rod bearing clearance is 0.03-0.06 mm for Models L8, LDA450 and LDA510 or 0.05-0.06 mm for all other models. Maximum allowable clearance for all models is 0.1 mm. Big end bearings are available in standard and undersizes.

CYLINDER

All models are equipped with a removable cylinder. Standard cylinder diameter is 85.00-85.02 mm for Models L8, LDA450 and LDA510, 95.00-95.02 mm for Models L10 and LDA96, 100.00-100.02 mm for Model LDA100, and 102.00-102.02 mm for Models L14 and LDA820. Maximum allowable taper or out-of-round is 0.1 mm.

With piston at top dead center, top of piston should be 0.9-1.0 mm below cylinder top edge. Cylinder height is adjusted by varying shim gaskets (2 – Fig. L5-8).

TIMING GEARS

Gears are accessible after removing pto bearing support (5 – Fig. L5-8). Crankshaft and camshaft gears are embossed with marks (M – Fig. L5-10) which should be aligned as shown. If crankshaft and camshaft gears are not marked, proceed as follows: If not previously removed, remove cylinder head, push rod tube and push rods. Position crankshaft so piston is at top dead center. Intake valve tappet (nearer cylinder) should be opening (rising) and exhaust valve tappet should be closing (going down). Valve tappets should be same height above crankcase when piston is at top dead center. If not, refer to CAMSHAFT section and remove camshaft, then install camshaft so it is correctly timed with crankshaft. Mark crankshaft and camshaft gears for future reference.

CAMSHAFT, TAPPETS AND PUSH RODS

REMOVE AND REINSTALL. To remove camshaft, remove cylinder head, push rod tube, push rods, valve tappets and fuel injection pump. Remove pto bearing support (5 – Fig. L5-8) and withdraw camshaft.

Inspect camshaft for excessive wear

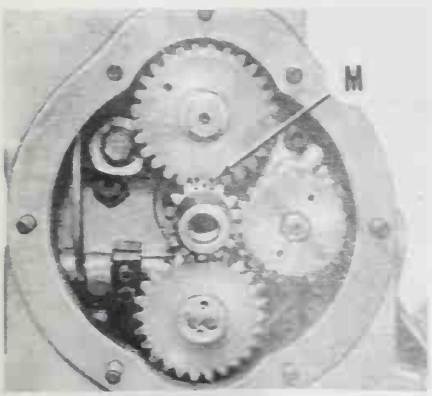


Fig. L5-10 – View showing location of timing marks (M) on crankshaft and camshaft gears.

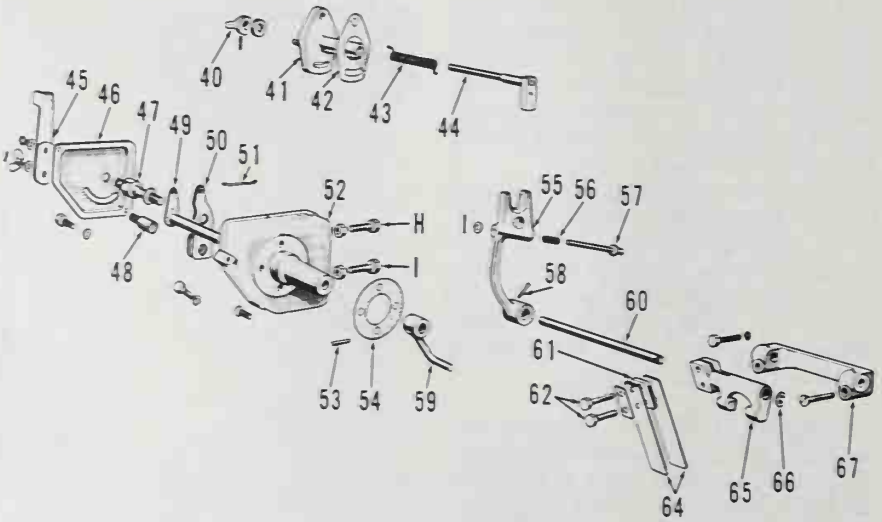


Fig. L5-11 – Exploded view of governor and control linkage. Governor fork (65) contacts governor cup (31 – Fig. L5-7).

40. Stop knob
41. Plate
42. Gasket
43. Spring
44. Stop arm
45. Throttle lever
46. Outer
47. Shaft
48. Pivot screw
49. Arm
50. Lever
51. Link
52. Housing
53. Pin
54. Gasket
55. Arm
56. Spring
57. Torque control rod
58. Pin
59. Arm
60. Shaft
61. Spacer
62. Screws
64. Spring plates
65. Fork
66. "E" ring
67. Bracket
I. Low idle speed screw
H. High speed screw

and damage. Diameter of both camshaft bearing journals is 17.96-17.98 mm. Height of injection pump lobe (lobe nearest gear) should be 33.45-33.55 mm while lobe height for intake and exhaust should be 33.95-34.05 mm.

Reassembly is reverse of disassembly. Refer to TIMING GEARS section to time camshaft and crankshaft. Note that tappets have roller offset to one side and a notched sliding surface on the opposite side. Install tappets so sliding surfaces are together and rollers are on opposite sides. The push rods are contained in a tube and must cross between tappets and rocker arms. Push rod nearer cylinder connects intake tappet and rocker arm while outer push rod connects exhaust cam follower and rocker arm.

GOVERNOR

Most models are equipped with a flyball type governor while some models may be equipped with flyweights. The governor shaft is shown in Fig. L5-7 while governor linkage is shown in Fig. L5-11. The flyball assembly (G – Fig. L5-12) is rotated by the crankshaft. The crankshaft rotates flyball assembly (G – Fig. L5-12) which bears against fork (65 – Fig. L5-11). As the flyballs move, the shaft attached to the fork is rotated thereby moving governor arm (55). Arm (55) mates with fuel injection control rack pin to regulate fuel flow. Throttle lever (45) operates through governor spring plates (64) to control engine speed. One spring plate is used on Models L8, L10 and L14, two spring plates are used on Models LDA96, LDA100 and LDA820, and three spring plates are used on Models LDA450 and LDA510.

To stop engine, stop knob (40) is turned counterclockwise which forces governor arm to move fuel injection pump control rack to no-fuel position. All models except L8, L10 and L14 are equipped with a torque control rod (57) and spring (56) which allows the governor arm (59) additional movement for additional fuel usage under high torque load. By pulling stop knob (40) away from engine, stop arm (44) will slide off tip of torque control rod (57) and allow governor arm to move forward so maximum fuel is delivered during starting.

Governor mechanism is accessible after removing pto bearing support (5 – Fig. L5-8), however, the oil pan must be removed for access to nut (35 – Fig. L5-7) so governor shaft can be withdrawn from crankcase. Inspect governor components and renew any which are damaged or excessively worn. Mechanism must move freely for proper governor operation.

To adjust governor, pto bearing support (5 – Fig. L5-8) and gasket must be removed. Move throttle lever (45 – Fig. L5-11) to full throttle position. Loosen spring plate screws (62) then move governor arm (55) towards crankcase opening and measure distance from pto bearing support mating surface of crankcase to upper part of governor arm. Distance between crankcase surface and governor arm should be 22 mm on Models L8, LDA450 and LDA510 or 28 mm on all other models. Retighten spring plate screws (62).

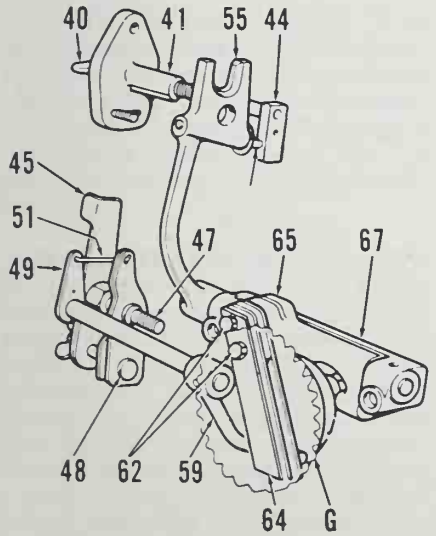


Fig. L5-12 – Diagram of governor mechanism. Refer to text and Fig. L5-11 for parts identification.

OIL PUMP AND RELIEF VALVE

R&R AND OVERHAUL. To remove oil pump, remove pto bearing support (5 – Fig. L5-8) and using a suitable puller remove pump gear (3 – Fig. L5-13). Unscrew pump screws and remove pump from crankcase bulkhead. Maximum clearance between gears and pump body should not exceed 0.15 mm. Maximum clearance between ends of gears and mounting surface of pump body is 0.15 mm.

Apply a thin coating of sealer to mounting surface of pump body. Install pump and tighten mounting screws to 39.2 N·m. Tighten oil pump gear nut to 19.6 N·m. Install timing gear cover.

The oil pressure relief valve is located on inner face of main bearing support (16 – Fig. L5-14). To remove main bearing support, remove crankshaft pulley or crank starter, flywheel and shroud. Unscrew retaining nuts and remove main bearing support. Inspect pressure relief valve components and renew if damaged or excessively worn. Reinstall relief valve by reversing disassembly procedure.

Normal oil pressure with warm oil is 49-98 kPa at idle and 245-392 kPa at full throttle.

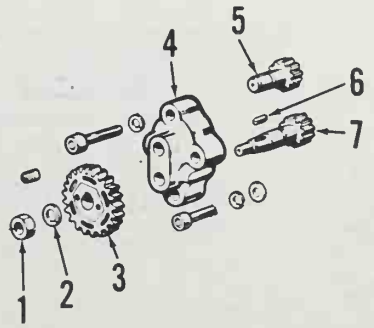


Fig. L5-13 – Exploded view of oil pump.

1. Nut
2. Lockwasher
3. Gear
4. Pump body
5. Driven gear
6. Key
7. Drive gear

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. Remove crankshaft pulley or crank starter then remove flywheel. Remove piston and connecting rod as previously outlined. Remove pto bearing support (5 – Fig. L5-8) and air shroud (18). Remove main bearing support (16) and withdraw crankshaft from crankcase.

Crankshaft main bearing journal standard diameter on Models L8, LDA450 and LDA510 is 41.99-42.00 mm for pto end and 39.99-40.00 mm for flywheel end. Main bearings (12 and 14) on Models L8, LDA450 and LDA510 are available in standard and 1.0 mm undersizes. Main bearings must be reamed to obtain clearance of 0.04-0.06 mm. Maximum allowable bearing clearance is 0.10 mm.

Crankshaft main bearing journal standard diameter on Models L10, L14, LDA96, LDA100 and LDA820 is 44.99-45.00 mm for both main bearings. Main bearings are available in standard and 0.5 mm and 1.0 mm undersizes which should not require reaming. Main bearing clearance should be 0.06-0.08

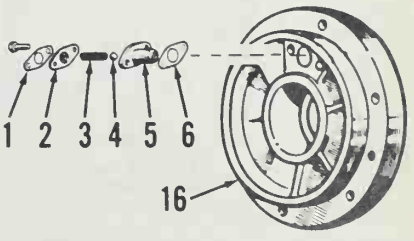


Fig. L5-14 – Exploded view of oil pressure relief valve.

1. Lockplate
2. Cover
3. Spring
4. Ball
5. Body
6. Gasket
16. Main bearing support

mm with a maximum allowable clearance of 0.10 mm.

Reverse disassembly procedure to install crankshaft. Crankshaft end play should be 0.10-0.30 mm and is adjusted by varying thickness of gasket (15 – Fig. L5-8). Tighten main bearing support nuts to 29.4 N·m on Models L8, LDA450 and LDA510 or to 39.2 N·m on all other models.

MANUAL CRANK STARTER

Models L8, L10 and L14 are equipped with a crank type manual starter as shown in Fig. L5-15. Starter repair is evident after inspection of unit.

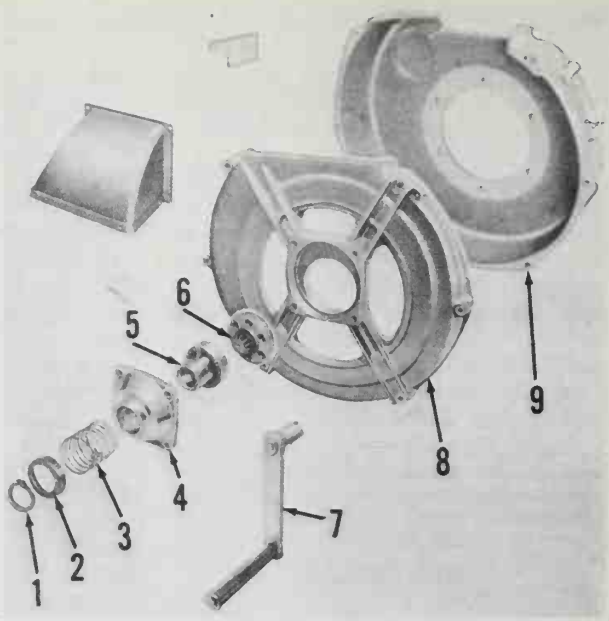


Fig. L5-15 – Exploded view of manual crank starter used on Models L8, L10 and L14.

1. Snap ring
2. Cap
3. Spring
4. Flange
5. Ring gear
6. Pinion
7. Crank
8. Cover
9. Case

ONAN

A DIVISION OF ONAN CORPORATION
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Minneapolis, Minnesota 55432

MODEL	No. Cyls.	Bore (In.)	Stroke (In.)	Displ. (Cu. In.)
DJA	1	3¼	3⅝	30
DJB	2	3¼	3⅝	60
DJBA	2	3¼	3⅝	60
DJC	4	3¼	3⅝	120
DJE	2	3½	3⅝	70
RDJC	4	3¼	3⅝	120
RDJE	2	3½	3⅝	70
RDJEA	2	3½	3⅝	70
RDJF	4	3½	3⅝	140

These ONAN engines make up a "family" of diesel-fueled power units having many features and specifications in common. Models with an "R" prefix, such as Model RDJC, are liquid-cooled while all other models are air-cooled. All models are equipped for electric starting only, with current production engines using a 12-V automotive type starting motor. Some earlier models of DJA engine-generator sets are exciter cranked by switching 12-V battery current through DC windings of direct coupled generator which serves as a starter.

Maintenance and repair procedures pertain to all engines in this group with special attention directed to particular differences among models.

OPERATION

STARTING PROCEDURE. DJA (one cylinder) engines are furnished with an automatic compression release device which works by spring pressure to crack an exhaust valve open to relieve engine compression during starting. See appropriate paragraph in text which follows.

PREHEATING. If engine is cold and air temperature is 55° F or above, preheat for 30 seconds and while holding preheat switch, switch fuel solenoid switch "ON" (two and four cylinder models) and engage starter. Hold starter switch until engine starts and runs. Solenoid contacts can be burned if switch is released too early or if starter is used to bump engine over for service. Longer preheating is necessary in colder temperatures. If temperature fails between 30° and 50° F, preheat for one minute. Below 30° F, preheat engine for two minutes. Oil pressure should indicate at least 20 psi. Relief valve is non-adjustable. Engines are protected by centrifugal and/or oil pressure safety switches and may have an owner/operator installed time delay relay so that a cranking engine can build up sufficient oil pressure (13-15 psi). At about 900 crankshaft rpm, lubricating oil pressure builds up to close these protective switches and current flows thru decompression relay and solenoid (DJA only) to unblock open exhaust valve restoring compression so that engine will fire. If oil pressure actuated switches do not close and engine fails to start, check electrical circuits for continuity and switch controls for proper adjustment.

NOTE: If engine is equipped with centrifugal switch, its oil pressure switch protects the engine by breaking the connection when oil pressure drops below 14 psi. Push reset button before attempting to restart engine. Some DJA models may also have a high temperature safety switch installed in decompressor control circuit. Check wiring diagrams.

MAINTENANCE

LUBRICATION

Recommended oil for crankcase use is API service classification CD/SE or CD/SD. CC level oils may be used for break-in or at temperatures below 32° F. Recommended oil change interval is for every 200 hours operation with filter changed simultaneously. Check oil level daily.

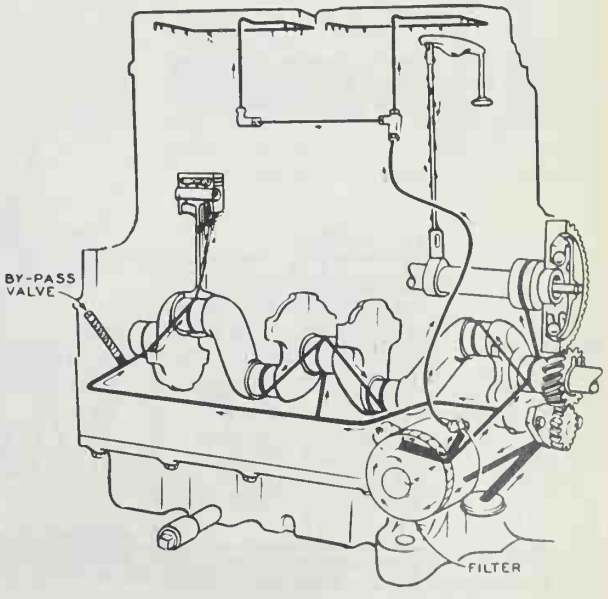


Fig. 0200—View of full-pressure oil system used on ONAN diesel engines. DJC (four cylinder) model shown. By-pass valve is non-adjustable and normally opens at 25 psi. Valve spring, when compressed to 1-3/16 inches, should test at 2.225-2.235 lbs. All models are equipped with full-flow oil filter.

Crankcase capacities are:
DJA ..... 2½ quarts
DJB, DJBA, DJE ..... 3 quarts
RDJE, RDJEA ..... 3 quarts
DJC, RDJC, RDJF ..... 6 quarts
Add ½ quart when filter is changed.

If operating temperatures fall below 0° F, SAE 5W-20 or 5W-30 weight oil should be used. From 0° F to 32° F, use SAE 5W-20, 10W, 5W-30 or 10W-30 weight. Above 32° F, SAE 30 weight oil is called for.

All engines of this section are full pressure lubricated. Refer to Fig. 0200 for cross-section view of lubrication system.

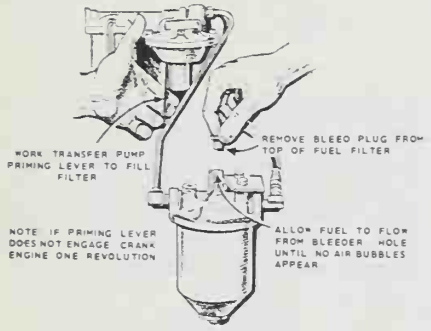


Fig. 0201 — View showing bleeding air on early model fuel systems. Refer to text.

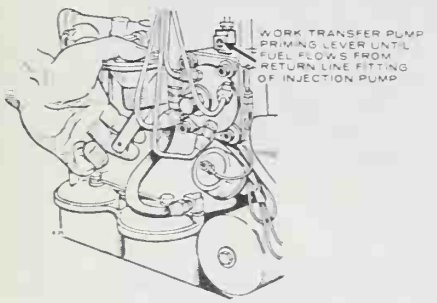


Fig. 0202 — View showing bleeding air on later model fuel system except Model DJE equipped with Bryce or Kiki injection pump.

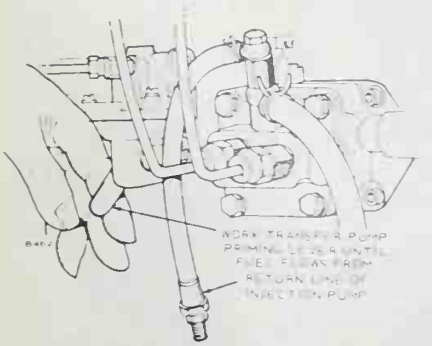


Fig. 0203 — View showing bleeding air on Model DJE equipped with Bryce or Kiki injection pump.

FUEL

No. 2 diesel fuel is recommended for most conditions. No. 1 diesel fuel should be used for light duty or cold weather operation.

BLEED FUEL SYSTEM. The fuel system is essentially self-bleeding except for initial start after unit has been disassembled or opened, as for renewal of filters. Refer to Fig. 0201, 0202 or 0203. To bleed the system, loosen bleed plug on top of secondary fuel filter (early models) or disconnect injection pump fuel return line (late models); then actuate primer lever on primary fuel pump until air-free fuel flows. Return primer lever to normal operating position after bleeding operation is completed.

NOTE: If cam which drives transfer pump is at full lift, priming lever cannot be operated. Turn engine one revolution to release.

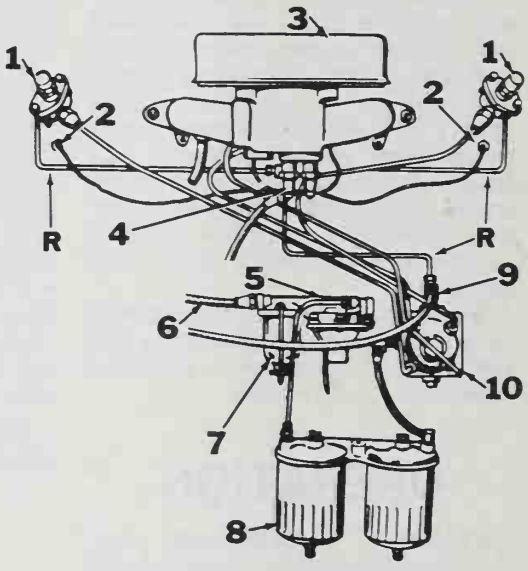


Fig. 0204 — View of ONAN diesel fuel system, typical of later models.
1. Injection nozzles
2. Glow plugs
3. Air cleaner
4. Manifold heater
5. Fuel transfer pump
6. Fuel supply line
7. Primary filter
8. Secondary filters
9. Fuel return point
10. Injection pump

R. Leak-off (return) lines

INJECTION PUMP

Model DJA is equipped with an American Bosch Model PLB injection pump, later Model DJE is equipped with either a Bryce or Kiki injection pump while all other models are equipped with an American Bosch Model PSU injection pump. Refer to following pump sections for injection pump timing:

BOSCH MODEL PLB. On Model DJA equipped with American Bosch PLB injection pump, injection starts at 17° BTDC, corresponding to "PC" (port closing) mark stamped on flywheel. Adjustment is made by changing the number and thickness of a shim pack which is fitted between pump mounting pad on crankcase and pump body mounting flange.

Shut off the fuel and disconnect and remove the injection pump. Cap all connections as they are loosened to prevent

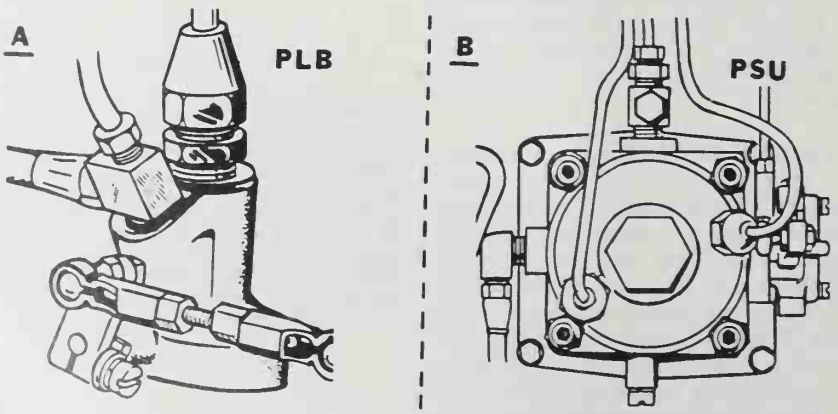


Fig. 0205 — American-Bosch diesel injection pumps used on ONAN engines except later Model DJE equipped with Bryce or Kiki injection pump. Model PLB (view A) is fitted to DJA models and model PSU (view B) is used on all others.

dirt entry into system. Turn crankshaft until cylinder is on compression stroke and "PC" flywheel mark is aligned. Using a depth micrometer, measure the distance from pump tappet to mounting surface of crankcase as shown in Fig. 0206. Subtract 1.670 in. (Port Closing Dimension) from the measured depth to determine shim pack thickness. Shim pack thickness should be 0.006-0.052 inch. If the calculated thickness does not fall within these limits, recheck measurement and/or check for camshaft or tappet wear or improper assembly. Shims are available in an installation shim kit which contains all necessary thicknesses.

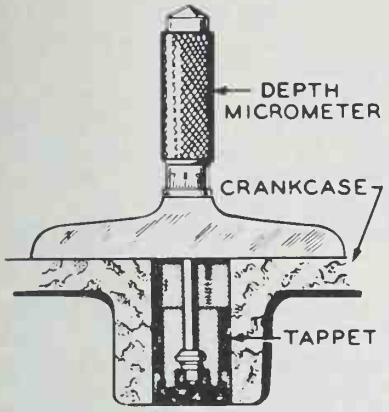


Fig. 0206—Use a depth micrometer as shown to set injection pump timing on model DJA. See text.

BOSCH MODEL PSU. Models DJB, DJBA, DJC, RDJC, RDJE, RDJEA, RDJF and early Model DJE are equipped with an American Bosch Model PSU injection pump. Maximum injection point (full throttle) and stop control are located on injection pump operating lever. Adjust full throttle setting during gradual load increase so that control lever just stops at smoke point. Minimum stop screw should be set to just cut off fuel injection at closed throttle position.

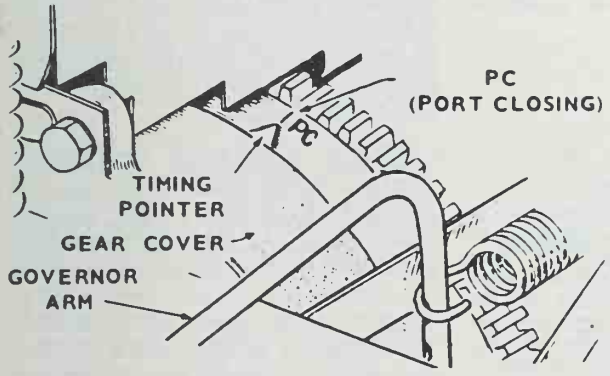


Fig. 0207—Port closing injection timing mark is stamped on margin of diesel engine flywheels. Numerical value in degrees BTDC may be shown. Refer to text.

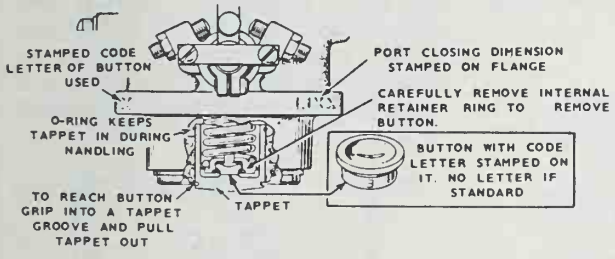


Fig. 0208—Identification of timing button codes and port closing dimensions are stamped on mounting flange of PSU injection pumps. Note placement of timing button under tappet. See text.

Injection timing for PSU pumps calls for insertion of a timing button of proper thickness between pump plunger and tappet. Refer to Fig. 0207. All engines are factory-timed and port closing mark appears at a point on flywheel which may be at 19°, 21° or 25° BTDC depending on production series or specification letter of a particular engine. Coding of timing button and port closing dimension are stamped on pump flange as shown in Fig. 0208.

Two methods for timing injection pumps are used. If pump is renewed, use procedure number one to time new pump to engine. Second method is required if timing dimensions are unavailable or if major parts such as crankcase, crankshaft or flywheel are renewed.

METHOD I. Shut off fuel supply, disconnect all lines, unbolt and remove pump. Protect open lines from dirt and damage. Use the following formula to calculate button thickness:

FORMULA	EXAMPLE
Port closing dimension (old pump)	1.109 in.
Button thickness (old pump)	+ 0.107 in.
Total:	1.216 in.
Now, subtract:	
Port closing dimension (new pump)	– 1.094 in.
Button thickness required for new pump	0.122 in.

Refer to table, Fig. 0209, select button to correspond. In this example case, Code 12 or M, part Number 147A190 will be correct. Install button in place under tappet as in Fig. 0208 and reinstall injection pump as follows:

Rotate engine to align port closing mark with timing pointer as in Fig. 0207. Both valves are closed with rocker arms free from pressure. Remove timing hole screw from mounting flange of pump and insert a ⅛-inch (0.125 in.) soft brass wire into timing hole as shown in Fig. 0210. Then, rotate pump gear until gear locks as tip of wire engages timing recess and reinstall pump body on crank-

OVERSIZE			OVERSIZE			UNDERSIZE		
CODE	PART NO.	SIZE	CODE	PART NO.	SIZE	CODE	PART NO.	SIZE
16 or S	147A186	.134	1 or A	147A147	.119	6 or F	147A152	.101
15 or R	147A187	.131	2 or B	147A148	.116	7 or H	147A153	.098
14 or P	147A188	.128	3 or C	147A149	.113	8 or J	147A154	.095
13 or N	147A189	.125	4 or D	147A150	.110	9 or K	147A155	.092
12 or M	147A190	.122	5 or E	147A151	.107	10 or L	147A156	.089
			11 or STD	147A161	.104			

Fig. 0209—Table of timing button codes and thicknesses. Refer to text for instruction in use of this table.

case. Remove wire and replace plug. IMPORTANT: Do not alter thickness of pump mounting shims. This shim pack controls proper mesh of drive gear on camshaft and driven gear on pump. "O" ring which seals pump body to crankcase should be renewed if defective. Reconnect fuel supply, leakoff and injector lines and throttle linkage. Bleed system as necessary, then start and run engine. Recheck maximum and minimum throttle stops.

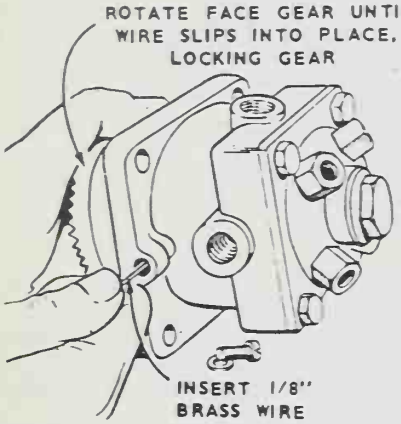


Fig. 0210 – View to illustrate technique for locking PSU injection pump when timing engine.

METHOD II. Begin by installing pump which has been fitted with standard timing button which may be blank (unmarked) or marked No. 11. Refer to Fig. 0211 and remove cap nut from delivery valve and delivery valve holder, then lift out delivery valve spring. Reinstall holder and cap nut. Note that early models do not have a delivery valve holder.

Now, rotate flywheel in counterclockwise direction to a point about 15° before port closing mark in compression stroke of No. 1 cylinder. NOTE: An easy way to measure 15° is to count ring gear teeth or cooling fins on flywheel, divide that number by 24 and lay off resulting number of teeth (or cooling fins) on circumference of flywheel ahead of port closing mark. Mark with chalk.

Place fuel control at wide open and separate injection fuel line from No. 1 nozzle. Observe open end of fuel line, pump priming lever of transfer pump while slowly turning flywheel clockwise until fuel flow from line stops. This is port closing point and injection begins. Check position of mark. If port closing (PC) mark and timing pointer are aligned, the installed timing button is correct. If timing pointer is ahead of port closing mark, then timing is early, and a thinner button is called for. If timing pointer falls between PC and TDC marks, timing is late and a thicker timing button is needed. In order to select a correct button, carefully measure the space between PC mark and timing pointer. Each 1/10-inch (0.1) on flywheel circumference is equivalent to 0.003-inch of button thickness.

EXAMPLE: Button installed in pump for test is standard: 0.104 inch thick. Flow of fuel stops 0.2 inch after PC mark is passed, indicating late timing. Referring to table, Fig. 0209, it will be noted that button of Code 4 or D, Part No. 147A150 is 0.110-inch thick or 0.006 (2 X 0.003) thicker than standard button. Installing this button in place of test button should time injection pump correctly.

Reinstall delivery valve spring which was removed for this procedure. Torque delivery valve holder to 65-70 ft.-lbs. and its cap nut to 55-60 ft.-lbs., then complete injection pump installation and test run the engine.

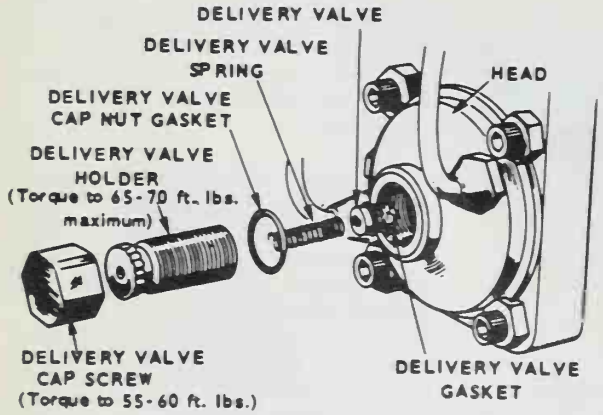


Fig. 0211 – Exploded view of delivery valve assembly of PSU injection pump. Note that only delivery valve spring is removed when using Method II to time two and four cylinder engines. See text for procedure.

BRYCE AND KIKI INJECTION PUMPS. Later Model DJE may be equipped with a Bryce or Kiki injection pump. Bryce and Kiki injection pumps are similar with no difference in servicing. Refer to Fig. 0212 for view of pump. Injection pump timing should occur at 14-22 degrees BTDC. Shims between the injection pump and adapter are used to adjust injection pump timing. If injection pump, adapter or gasket is new, follow procedure in Method I to time injection pump. If pump, adapter or gasket is not renewed or pump timing is to be checked, follow timing procedure in Method II.

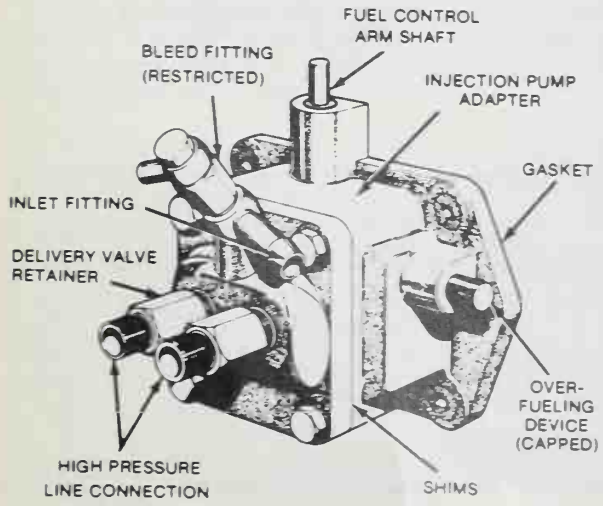


Fig. 0212 – View showing Bryce or Kiki fuel injection pump used on later Model DJE.

METHOD I. To determine thickness

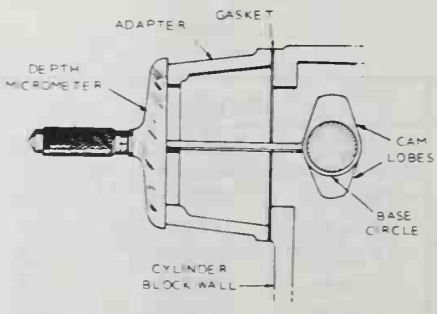


Fig. 0213 – Measure distance from adapter face to base circle of cam lobe to determine shim thickness for correct injection timing. Refer to text.

of shims for correct injection pump timing, install gasket and adapter then secure adapter with capscrews tightened to 20-24 ft.-lbs. Using a depth micrometer, measure distance from adapter face to base circle of either camshaft lobe as shown in Fig. 0213. Subtract this reading from the standard dimension of 3.2598 inches and the result is the required shim thickness between pump and adapter. Note that on early DJE models the standard dimension is 3.2540 inches and "3.2540" is printed adjacent to pump on engine. Shims are available in thicknesses of 0.002, 0.003, 0.006, 0.010, 0.014 and 0.018 inch. Tighten pump mounting screws to 20-24 ft.-lbs.

METHOD II. If pump, adapter or gasket have not been renewed, the following spill timing procedure may be used to check injection pump timing.

Disconnect high pressure fuel line of cylinder being timed from injection pump. Unscrew delivery valve holder (2–Fig. 0214) and remove valve spring (13), volume reducer (3) and delivery valve (4), then reinstall delivery valve holder (2). Attach a spill pipe made of old injector line with a gland nut to delivery valve holder and aim spill pipe at a receptacle to catch discharged fuel. Move fuel control arm toward front of engine to full fuel position while simultaneously holding plunger in on fuel shut-off solenoid. Operate fuel transfer pump while simultaneously rotating flywheel slowly clockwise until fuel just stops flowing from spill pipe. Injection pump port is now closed and PC mark on flywheel and timing pointer should be aligned as shown in Fig. 0207. If PC mark is not present on flywheel, measure around flywheel rim from TC mark. A distance of 0.1 inch equals one degree of crankshaft rotation. Ignition timing is adjusted using shims (See Fig. 0212) installed between pump and adapter. Shims are available in thicknesses of 0.002, 0.003, 0.006, 0.010, 0.014 and 0.018 inch. Tighten pump retaining screws to 20-24 ft.-lbs. Reinstall delivery valve (4–Fig. 0213), volume reducer (3) and valve spring (13) after timing adjustment. Tighten delivery valve holder (2) to 29-33 ft.-lbs. on Bryce pump or to 44-47 ft.-lbs. on Kiki pump.

Injection pump timing for remaining cylinder may be checked using above procedure. Timing differential between cylinders should be 2.5 degrees or less.

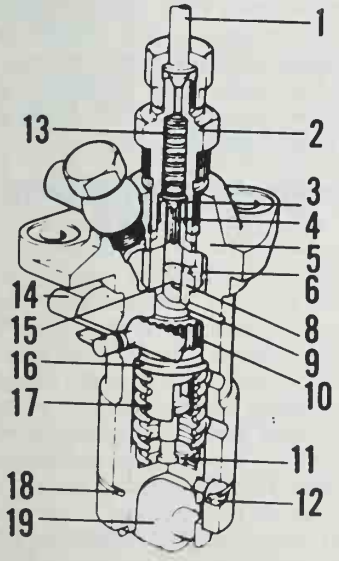


Fig. 0214—Cross sectional view of Bryce or Kiki injection pump.

1. Delivery tube
2. Delivery valve holder
3. Volume reducer
4. Delivery valve
5. Pump housing
6. Suction chamber
8. Plunger barrel
9. Pin
10. Control sleeve
11. Lower spring seat
12. Guide pin
13. Delivery valve spring
14. Control rack
15. Plunger
16. Upper spring seat
17. Plunger spring
18. Snap ring
19. Tappet

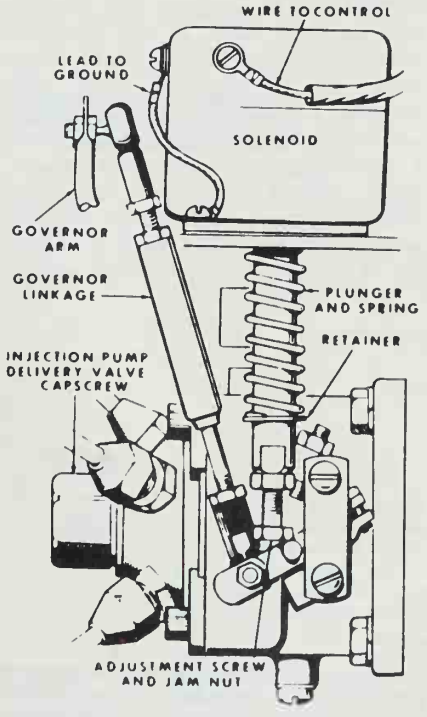


Fig. 0215—Installed view of fuel solenoid. Refer to text.

GOVERNOR (FUEL) SOLENOID. This special-purpose solenoid is an optional item usually associated with two-speed governors furnished on diesel engines. It is referred to as a governor solenoid because it overrides governor control of injection pump throttle lever. See Fig. 0215 for typical mounting arrangement.

When solenoid is energized by current flowing through its windings, plunger is retained within solenoid body and control of throttle is by governor action. When no current is flowing and solenoid de-energizes, then plunger spring forces plunger outward against throttle arm to hold throttle closed.

TESTING. Use a 12-volt input to check operation of solenoid plunger. Series-connected ammeter should indicate about 1 amp through holding coil when plunger is withdrawn into solenoid. If current exceeds 1 amp by a significant amount, then switch contacts for separate retractor winding did not open when plunger was drawn up. Resulting excess current will overheat solenoid. Check for plunger sticking in solenoid recess or for excessive tension on high speed governor spring. Plunger must fully retract to contact this switch, so a thorough check of possible causes of trouble is important. Renew solenoid assembly if defective.

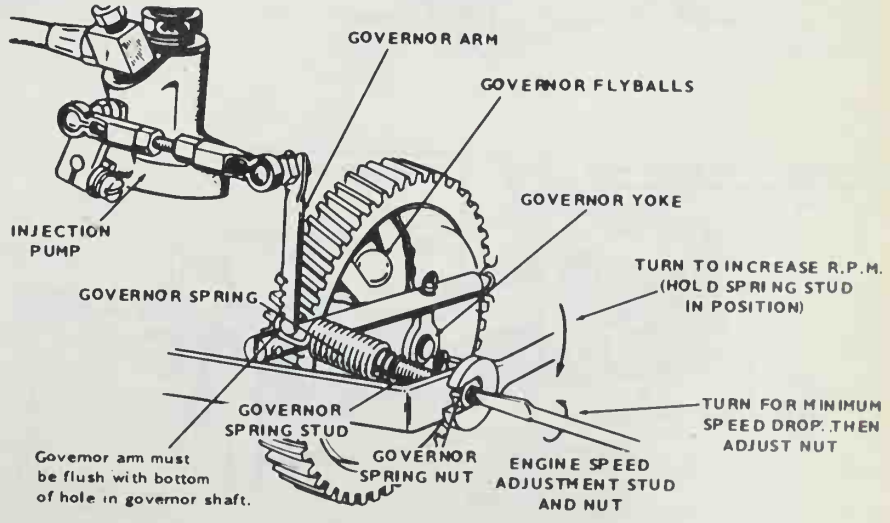


Fig. 0216—View of early governor mechanism to show points of adjustment. Governor shown is typical of constant speed type used on early air-cooled diesel models.

ADJUSTMENT. With current "OFF", solenoid de-energized, loosen jam nut and turn hex cap screw (Fig. 0215) at bottom of plunger in or out so as to completely close throttle. Test action by run-through of an operational start-stop cycle.

GOVERNOR

Flyball type mechanical governors are used on all engines. Governed speeds are 1800 rpm for 60 Cycle AC Generator, and 1500 rpm for 50 Cycle AC Generator, and 1750 rpm for DC Battery Charger. Recommended governed speed is stamped on generator nameplate. It should be possible to adjust governed speed to within 3 cycles (hertz) per second (90 engine rpm) and an adjustment of 2 cps (60 rpm) is usually attainable. For accurate speed adjustment, use of a reed type frequency meter on AC generator output is recommended by manufacturer over use of a mechanical tachometer.

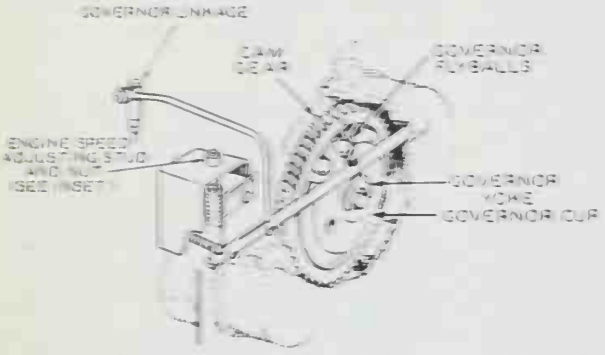
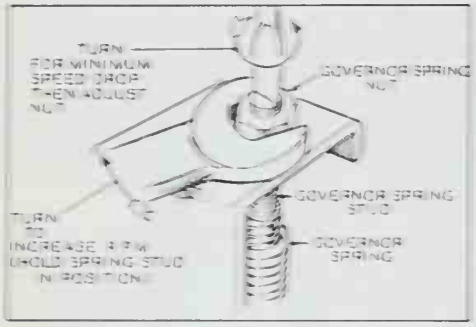


Fig. 0217 – View of governor linkage on early liquid-cooled models.



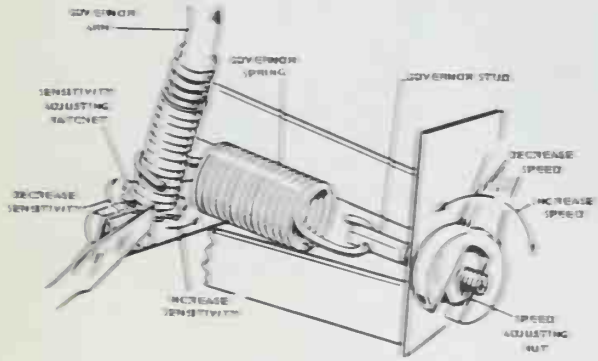


Fig. 0218 – Late governor mechanism showing adjustment on later air-cooled and liquid-cooled models. Refer to text.

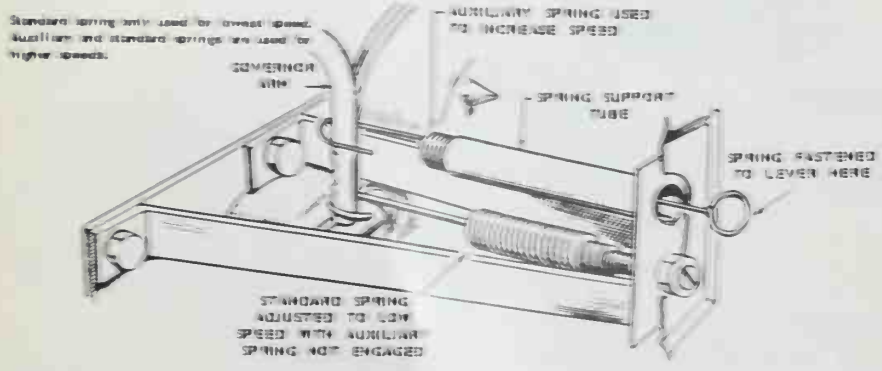


Fig. 0219 – View of variable speed governor auxiliary spring in relation to constant speed governor spring shown in preceding figures. Refer to text.

To adjust governor linkage, proceed as follows: With engine not running, disconnect injection pump throttle link from governor arm and adjust the link if necessary, until link can be reconnected with injection pump throttle arm in wide open position.

Two different types of governor linkage have been used. Refer to Fig. 0216 for linkage on early air-cooled models or to Fig. 0217 for early liquid-cooled models. Sensitivity is adjusted by turning adjustment stud in or out of governor spring, thus regulating the effective length of spring. Engine speed is adjusted by turning governor spring nut while holding stud from turning. On late air-cooled and liquid-cooled models, governor spring nut controls engine speed while sensitivity is adjusted by turning the ratchet nut on governor arm as shown in Fig. 0218.

Two and four cylinder engines (DJB, DJBA, DJC) may be furnished with a variable speed governor as shown in Fig. 0219 instead of constant speed type. Variable speed is controlled by a ratchet locking throttle lever or by a solenoid control attached to auxiliary governor spring (Fig. 0219) to override standard constant speed spring. Basic speed and sensitivity adjustments remain the same with variable higher speeds set at desired levels by throttle control or solenoid position.

COMPRESSION RELEASE MECHANISM

Refer to Fig. 0220 for top and cross-section view of compression release mechanism used on Model DJA (one cylinder) engine. Decompression is obtained by the release arm adjusting screw riding up the ramp of exhaust valve rocker arm, holding exhaust valve slightly open when release mechanism is effective. The compression release arm pivots on its axle pin and is spring actuated to both the RELEASE and RUNNING positions. The coil spring on release arm hub is tensioned to move arm into RUNNING position. A stronger spring located on solenoid plunger moves the arm to RELEASE position when solenoid is NOT energized. When current is routed to solenoid, the plunger is drawn away

from release arm and arm is allowed to move to RUNNING position.

ADJUSTMENT. To adjust the compression release mechanism, first remove decompression solenoid and rocker arm cover. Turn crankshaft until exhaust valve is closed and push rod is loose. Loosen locknut and back out adjusting screw on compression release arm about 2 turns; then check to be sure release arm pivots back and forth easily without binding. Arm should move counterclockwise against spring pressure and should snap back easily to RUNNING position when released. Pivot arm fully counterclockwise against its stop and turn adjusting screw until it just touches rocker arm (rocker arm must be in contact with valve stem). Turn screw ONE additional turn to open valve the specified amount and secure by tightening locknut.

CAUTION: If screw is tightened by more than one turn, valve head might strike piston. Manually move release arm to RUNNING position (clockwise) and check to be sure that some clearance exists between valve rocker arm and set screw.

On models with centrifugal switch, breaker point gap should be adjusted to 0.040 inch.

AIR COOLING SYSTEM

Air cooling systems are used on Models DJA, DJB, DJBA, DJC and DJE to cool engine. Pressure cooling or Vacu-Flo cooling systems are used as outlined in the following sections.

PRESSURE COOLING. On models equipped with pressure cooling, free air is drawn by flywheel rotation into engine sheet metal housing through flywheel grille opening and is forced through cylinder cooling fins and out through a rear or side aperture.

Some engines may be equipped with a thermostat controlled shutter (Vernatherm) which allows engine compartment air to reach 120° F. before opening and becomes wide open at 140° F. for full ventilation of enclosure. Opening temperature of sensing element is not adjustable. To determine if this operating element is in working order, remove two screws which retain it to mounting bracket (note slotted holes for adjusting position) and test it by application of heat. Opening should begin at 120° F. and plunger should be fully extended at 140° F. Total movement should be at least 13/64-inch. Reinstall so that plunger when fully withdrawn into element body just touches roll pin as in Fig. 0221 with shutter completely closed at ambient (free air) temperature.

If shutter operation is unsatisfactory, check for a weak shutter return (closing) spring and examine nylon shutter bearings for dirt or damage. Clean and renew as necessary.

VACU-FLO COOLING. This system is designed for cooling industrial power plants which are installed in a closed compartment. Note in Fig. 0222 that flow of coolant air is drawn through engine shroud and cooling fins and forced out by flywheel blower through a vent or outside duct. Flow is in reverse direction from that of pressure-cooled engines.

IMPORTANT: If flywheel or flywheel blower is renewed, be sure that new part is correct for engine cooling system, whether pressure or Vacu-Flo.

Air volume requirement for proper cooling of these engines, expressed in cubic feet per minute is specified for each engine in factory-furnished operator's manual. Dependent upon engine size, this may range from 300 to 1600 cfm. Duct and vent sizes are detailed for each model and type of cooling system.

HIGH TEMPERATURE CUT-OFF. Some larger engine models were equipped with a high temperature safety switch for protection from overheating.

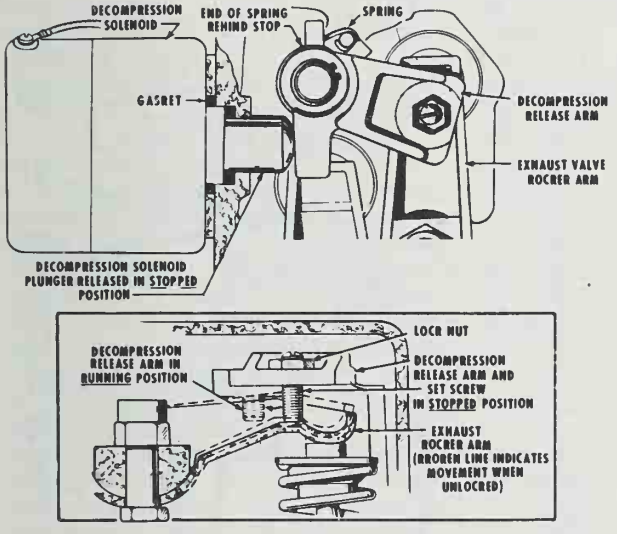


Fig. 0220 – Two-position view of compression release mechanism used on model DJA engine. Upper view is downward, in line with cylinder bore. Lower view shows cross-section with decompression release holding rocker arm down and exhaust valve open as discussed in text.

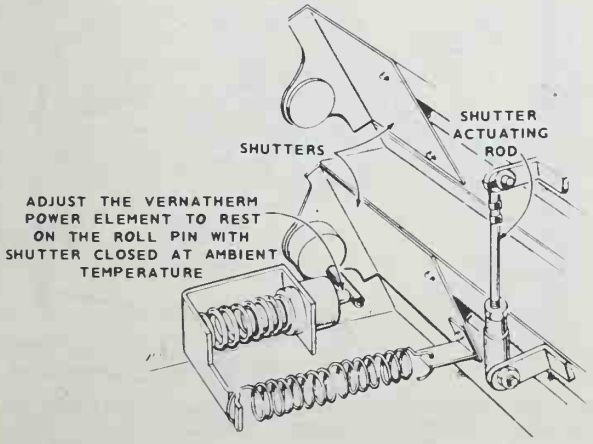


Fig. 0221 – View of thermostat controlled power shutter for pressure-cooled engines. Note adjustment. Refer to text for details.

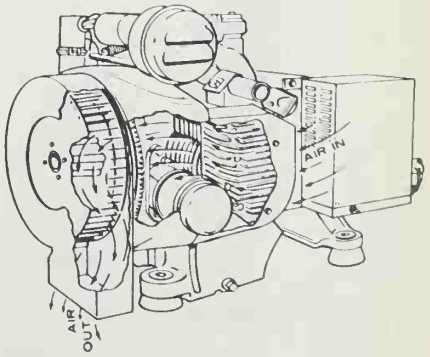


Fig. 0222 – Typical cooling air flow in Vacu-Flo system used for closed compartment installation.

Switch is normally closed, but opens to half engine if compartment air temperature rises to 240° F. due to problem in cooling system caused by blockage or shutter failure to open. When engine compartment temperature drops to about 190° F. switch will automatically close and engine can be re-started.

LIQUID COOLING SYSTEM

Liquid-cooled engines RDJC, RDJE, RDJEA and RDJF use either a radiator or external water source to cool engine. Refer to following sections for servicing.

RADIATOR SYSTEM. An automotive type radiator cooling system is used on some models. Note that cooling fan forces air through radiator and a belt driven water pump is mounted on front of engine. A by-pass line is connected from the water pump to the water outlet on the cylinder head so water is circulated when the thermostat is closed. A 160° F. thermostat is contained inside the cylinder head water outlet.

Radiator capacity for all models is three gallons. Do not use antileak type antifreeze on models equipped with coolant filters. Be sure adequate air circulation is possible around radiator, ducts and vents. Heated air should not be allowed to re-enter cooling air stream. Refer to WATER PUMP section for pump service.

EXTERNAL WATER SYSTEM. Some models may be equipped with a cooling system which routes water supplied from an external source through cooling passages in the engine block. No water pump is used as pressure is supplied at the water source. A solenoid valve shuts off water when the engine is not running while a supply valve controls rate of water flow. Three types of external water systems are used. In the direct flow system, water is routed directly to the engine block then discharged. In the standpipe system shown in Fig. 0223, water circulates through the engine then returns to a standpipe to be mixed with fresh, cool water. The hottest water rises in the standpipe and is drained off. In the wet manifold system shown in Fig. 0224, water is circulated around the exhaust manifold after passing through the engine block. Two 160° F. thermostats contained in housings attached to the cylinder heads must open before water enters the water jacket surrounding the exhaust manifold. A by-pass line circulates water prior to thermostat opening. On all systems, the water discharge line must

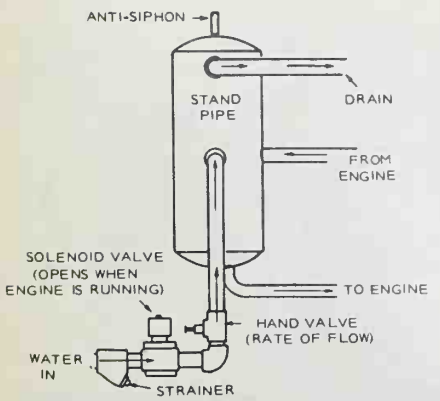


Fig. 0223 — Drawing showing coolant flow to and from standpipe.

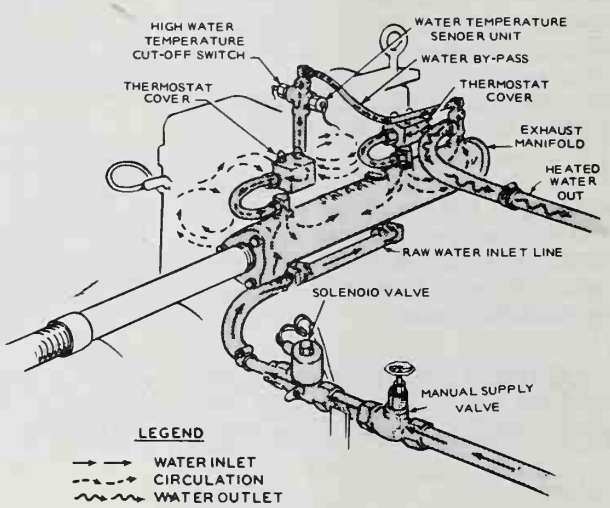


Fig. 0224 — Drawing showing coolant flow on models using external water source routed through the manifold.

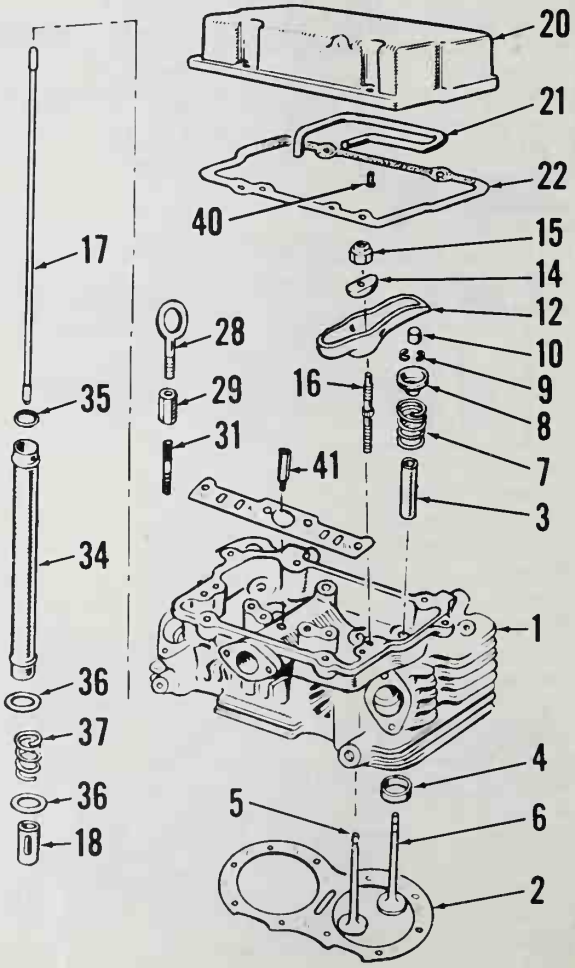


Fig. 0225 — Exploded view of typical cylinder head assembly. Model DJB is shown.

1. Head assembly
2. Head gasket
3. Valve guide
4. Valve seat insert
5. Intake valve
6. Exhaust valve
7. Valve spring
8. Spring retainer
9. Retainer locks
10. Valve stem cap
12. Rocker arm
14. Rocker ball pivot
15. Rocker locknut
16. Rocker arm stud
17. Tappet push rod
18. Tappet
20. Rocker cover
21. Rocker oil line
22. Cover gasket
28. Lifting eye bolt
29. Extension nut
31. Cylinder stud
34. Push rod shield
35. "O" ring
36. Washer
37. Shield spring
40. Oil line screw
41. Crankcase breather

be sufficiently large so water flow is not impeded.

CRANKCASE BREATHER

The crankcase breather is located inside the rocker cover as shown in Fig. 0225. Crankcase breather (41) vents crankcase fumes into the intake port. Inspect breather after every 200 hours of operation.

REPAIRS

TIGHTENING TORQUES

Recommended tightening torques for all models are as follows. Values are in ft.-lbs.

Connecting rod	27-29
Cylinder head	44-46
Exhaust manifold	13-15
Flywheel	65-70
Fuel pump	15-20
Gear case cover	15-20
Glow plug	10-15
Injection nozzle	20-21
Injection pump	18-21
Intake manifold	13-15
Rocker arm cover	8-10
Rocker arm stud	35-40

CYLINDER HEAD

To remove the cylinder head, it is first necessary on liquid-cooled models to drain coolant and disconnect interfering hoses. Remove the decompression solenoid (DJA only), rocker box cover, fuel injector and manifolds. Push rods and push rod tube shields will be loose when head is removed. See Fig. 0225. Both intake and exhaust valve are equipped with release type valve rotator caps. Lift off and identify the caps as head is removed, so they can be reinstalled on the same valves when unit is reassembled. Install cylinder heads with capscrews not tightened. Install intake manifold and torque nuts to specification, then torque cylinder heads to 44-46 ft.-lbs. observing sequence in Fig. 0226. Adjust valve tappet gap and compression release linkage as outlined in appropriate paragraphs. Cylinder head should be retoruqed and valves readjusted after the first 50 hours of engine operation.

VALVE TAPPET GAP

Valve tappet gap should be set cold with piston 10° to 45° past TDC on power stroke. Flywheel can be turned by removing air intake grille and using a socket wrench on flywheel cap screw. Correct valve clearance is 0.011 inch for intake valve and 0.008 inch for exhaust valve on Model DJA. Model DJB, prior to specification D, calls for both intake and exhaust valves to be set to 0.004 inch. Beginning with specification D, intake valve is set to 0.009 inch and exhaust valve to 0.007 inch. Models DJBA and DJC use this 0.009 inch intake and 0.007 inch exhaust valve setting for entire production. Valve clearances are: for Model DJE intake–0.010 inch, exhaust–0.007 inch; for Model RDJC intake–0.011 inch, exhaust–0.016 inch; for Models RDJE, RDJEA and RDJF intake–0.017 inch, exhaust–0.017 inch.

Be sure to move each piston of two cylinder models past TDC on power stroke before adjusting its valve clearance.

For four cylinder models, adjust valves in regular engine firing order (1-2-4-3). To begin, set number one cylinder on power stroke at 10°-45° past TDC as just outlined, and adjust both valves to specification. Then, rotate crankshaft ½ turn (180°) and set valves of number two cylinder. Adjust valves of number four and number three cylinders in that order after turning crankshaft one-half turn before making adjustments. Valves are adjusted by turning the self-locking nut on rocker arm support stud as shown in Fig. 0227.

NOTE: An effort of 4-10 ft.-lbs. should be required to turn the nut. Less torque would indicate a loss of locking ability and nut should be renewed to prevent a change in tappet gap adjustment.

VALVE SYSTEM

All renewable insert type valve seats are stellite, ground to a 45° seat angle. Intake valves, stellite-faced, are machined to a 42° face angle and exhaust valves, also stellite faced, are machine finished to 45°. These angles must be maintained. Manufacturer recommends against handlapping which could blunt sharp contact at seating surface. Width of valve seat band should be 1/32 to 3/64-inch. Valve head margin should be at least 1/32-inch. Renew valves when margin is cut below this minimum.

Hardened valve seats are renewable. To remove old seat, use ONAN tool No. 420A272 mounted in a drill press as shown in Fig. 0228. Set tool for a 1/64-inch cut from inner margin of seat. Rind which remains may be easily peeled from recess. Use care not to damage valve seat counterbore.

In earlier production, exhaust and intake valve seat inserts were interchangeable, however, for current models, intake valve seat counterbore diameter is 1.361-1.362 inches and

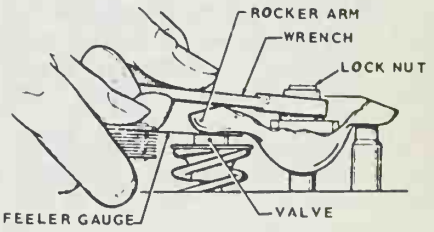


Fig. 0227– Procedure for setting valve clearance of valve-in-head engines. See text for correct valve lash.

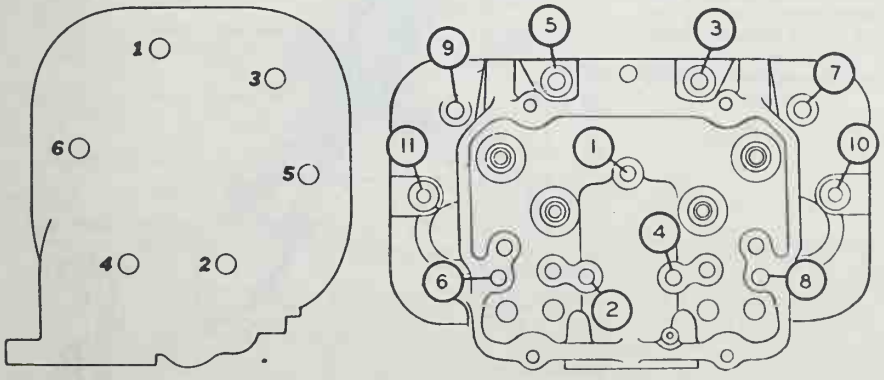


Fig. 0226– Tightening sequence for cylinder head bolts. Left view: Model DJA. Right view: All other models. Refer to torque value table.

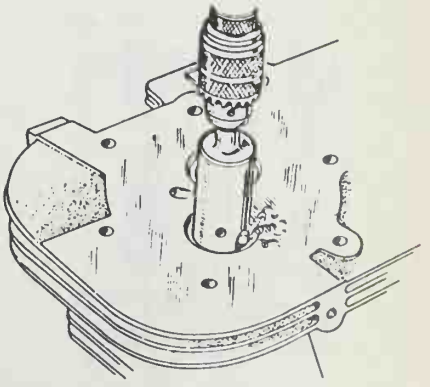


Fig. 0228– Tool set-up for removal of valve seat inserts. Adjust for 1/64-inch cut and take care not to bottom tool in counterbore.

diameter for exhaust valve seat is 1.364-1.365 inches. Renewal seat inserts are available in 0.002, 0.005, 0.010 and 0.025 inch oversizes as well as standard. Hard alloy type must be used for exhaust valves. The seat should have 0.002-0.004 inch interference fit in its bore. When new seats are installed, first clean the counterbore, heat cylinder head to 325° F. in an oven, and chill seats with dry ice. Install immediately. After seat has been renewed and valve and seat have been ground, temporarily install the valve. Lay a straight edge across gasket surface of cylinder head and measure the clearance between straight edge and valve head. Clearance should be at least 0.030 inch; if it is not, valve must be reseated until 0.030 inch clearance exists. Overall flatness of cylinder head should measure under 0.003 inch, checked against straightedge.

Valve stem diameter on all models, is 0.3405-0.3410 inch for intake valve and 0.3405-0.3415 inch for exhaust valve. Recommended stem to guide clearance is 0.0015-0.003 inch for intake valve and 0.003-0.005 for exhaust.

The straight valve guides are interchangeable for intake and exhaust valve, and both must be reamed after installation to provide proper valve stem clearance. Valve guides should extend 11/32-inch above machined spring seat when guide is installed. Ream intake valve guide to 0.3425-0.3435 inch and exhaust valve guide to 0.3445-0.03455 inch after installation.

Valve springs are interchangeable for intake and exhaust valves. Springs have a free length of 1⅞ inches and should test 45-49 lbs. at closed length of 1.528 inches.

When engine has been reassembled, adjust valve clearance and compression release linkage of Model DJA as previously outlined.

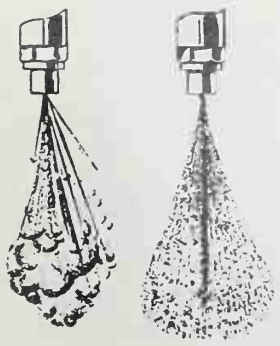


Fig. 0229—Comparison views of poor (left) and good (right) injector spray patterns. See text for details.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing, keep your person clear of the nozzle spray.

All models except later DJE models are equipped with American-Bosch pintle type injector nozzles. Opening pressure is factory adjusted to 1900-1950 psi; pressure will decrease to approximately 1750 psi as the spring takes a set. Later Model DJE is equipped with Diesel Kiki injection nozzles. Opening pressure is factory adjusted to 2130-2200 psi; pressure may decrease to approximately 1950 psi as the spring takes a set.

If engine does not start or does not run properly and the injector is suspected of being at fault, remove and reposition the unit where spray pattern can be observed or attach unit to a nozzle tester. Turn engine over with starter or actuate tester handle. Spray pattern should be conical in shape with a solid core as shown in right hand view, Fig. 0229. If spray pattern is ragged or not symmetrical or if nozzle drips, install a new or rebuilt unit or disassemble, clean and adjust the injector unit. If spray pattern is satisfactory and tester unit is available, adjust opening pressure to pressure specified in preceding paragraph. Pressure is adjusted by turning pressure adjusting screw shown in Fig. 0230. Screw may be turned after unscrewing plug and loosening cover. Tighten cover to 45-50 ft.-lbs. after final screw adjustment and reinstall plug. Unscrew cover (C) and loosen locknut (L) on Kiki and early Bosch injectors to turn adjusting screw. After final screw adjustment, tighten locknut (L) and cover (C) to 45-50 ft.-lbs. Do not disassemble a unit which can be returned to service without disassembly.

NOTE: Do not attempt to disassemble, clean or overhaul an injector unit unless the proper tools are available.

Fig. 0230 shows a cross sectional view of nozzle holder and nozzle valve. Be extremely careful when nozzle unit is handled, not to strike or damage the protruding nozzle valve pintle. Any damage will deform the spray pattern and make the unit unfit for further use. Note assembly order in Fig. 0230.

INJECTION PUMP

Model DJA is equipped with an American Bosch Model PLB injection pump, later Model DJE is equipped with either a Bryce or Kiki injection pump while all other models are equipped with an American Bosch PSU injection pump.

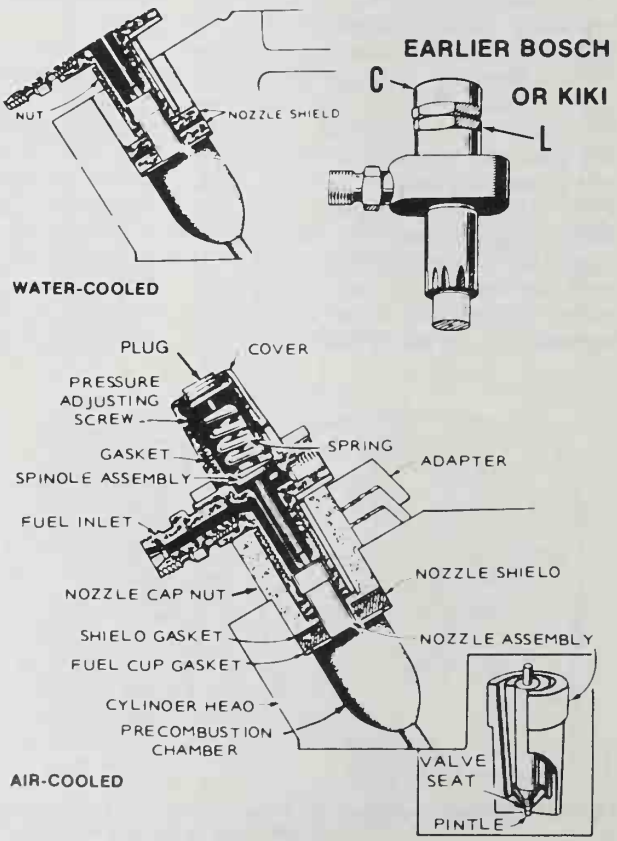


Fig. 0230—Views of injector assemblies. On later Bosch injector, a plug is unscrewed for access to pressure adjusting screw. On Kiki and early Bosch injectors, cover (C) must be removed for access to pressure adjusting screw.

Unless the shop is equipped with the necessary calibration stand and overhaul data, disassembly of pump should not be attempted.

When injection pump is removed, time and bleed the unit during reinstallation, and adjust governor linkage, as outlined in previous MAINTENANCE paragraphs. Tighten injection pump mounting screws alternately and evenly to a torque of 20-24 ft.-lbs. when unit is reinstalled.

WATER PUMP

Models RDJC, RDJE, RDJEA and RDJF equipped with a radiator cooling system use a water pump to circulate coolant. Refer to Fig. 0231 for a view of pump. Note the external by-pass line to circulate coolant while thermostat is closed.

CONNECTING ROD

Connecting rod and piston unit can be removed from above after removing cylinder head and engine oil base. Manufacturer emphasizes that a ridge reamer be used at top of cylinder bore before attempting to remove piston. The forged connecting rod contains renewable, precision bearings which are available in undersizes of 0.002, 0.010, 0.020 or 0.030 inch as well as standard. Upper and lower bearing halves are interchangeable.

Standard crankpin diameter for all models is 2.0597-2.0605 inches with recommended diametral clearance of 0.001-0.003 inch. Two bushings are installed in piston pin end of connecting rod so as to leave an oil groove at center between bushings which is 1/16 to 7/64-inch wide when outer ends of bushings are pressed flush in bore. Drill a 3/16-inch oil hole through bushings at top end of rod before reaming bushings. Final sizing of bushings calls for diametral clearance of 0.0002-0.0007 inch. Standard diameter of piston pin is 0.9899-0.9901 inch with a 0.002 inch oversize available.

When installing assembled piston and connecting rod, notch or "FRONT" mark on piston should face front of engine and witness marks aligned.

NOTE: On diesel engines after specification P, valve relief cut-outs on heads of pistons are faced in same direction as stamped reference numbers on connecting rod, or bearing insert lock recess if no number is imprinted on rod. Tighten connecting rod cap screws to 27-29 ft.-lbs. torque.

PISTON, PIN, RINGS & CYLINDER

Piston is equipped with three compression rings and one expander type oil control ring. Rings are marked "TOP" or otherwise identified. Recommended end gap is 0.010 inch for all piston rings. Ring side clearance should be 0.003-0.005 inch and diesel engine pistons should be renewed if this clearance exceeds 0.006 inch in grooves for chromed top compression rings. End gaps should be staggered equally around piston when installing and gap of ring expander should be opposite (180°) from gap of oil control ring. See Fig. 0232.

Standard cylinder bore diameter is 3.4995-3.5005 inches for Models DJE, RDJE, RDJEA and RDJF. Standard cylinder bore diameter for all other models is 3.2495-3.2505 inches. Some engines are factory equipped with 0.005 inch oversize pistons and rings. These engines are identified by an "E" following the serial number. Pistons and rings are available in oversizes of 0.005, 0.010, 0.020 and 0.030 inch, as well as standard. Recommended piston skirt clear-

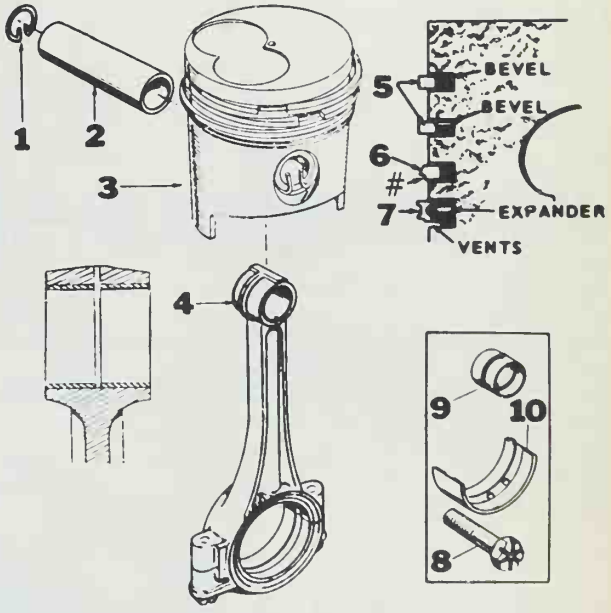


Fig. 0232 — Piston and connecting rod assemblies for diesel engines. Note ring arrangement and refer to text for other details.

1. Piston pin retainer
2. Piston pin
3. Piston
4. Connecting rod
5. Chrome compression rings (note bevel placement)
6. Plain compression ring
7. Oil control ring (cast iron) (note vents at bottom)
8. Rod cap screw
9. Connecting rod bushing
10. Bearing half

#-Scraper recess

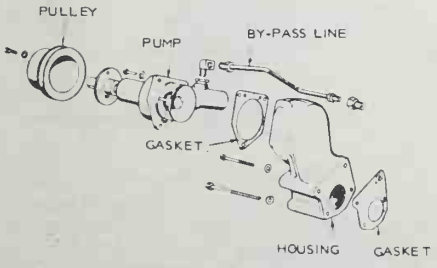


Fig. 0231 — Exploded view of water pump.

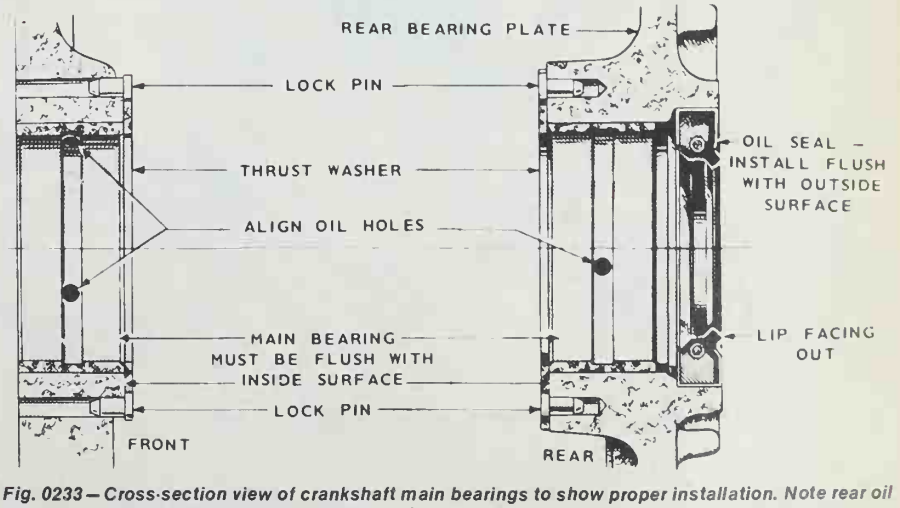


Fig. 0233 — Cross-section view of crankshaft main bearings to show proper installation. Note rear oil seal placement.

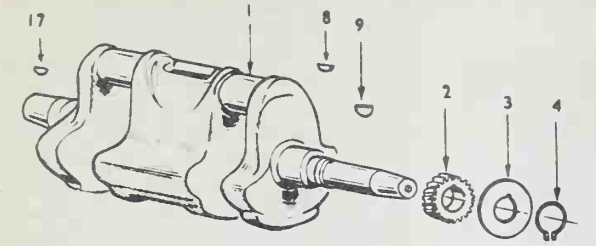
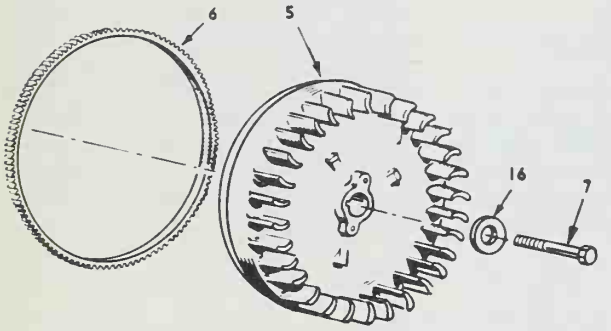


Fig. 0234 – Exploded view of crankshaft and flywheel typical of "J" series. Model DJB shown.

1. Crankshaft
2. Timing gear
3. Retainer washer
4. Lock ring
5. Flywheel
6. Ring gear
7. Flywheel capscrew
8. Timing gear key
9. Flywheel key
16. Flywheel washer
17. Drive gear key



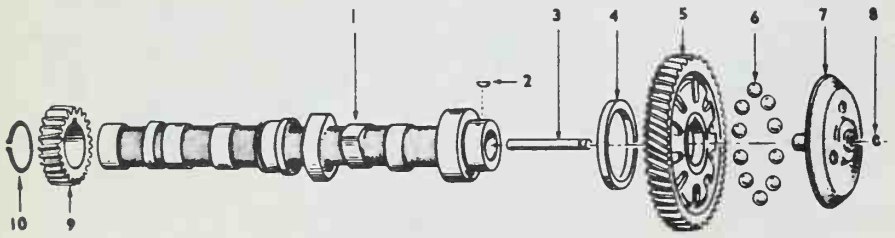


Fig. 0235 – Exploded view of camshaft and governor sensor assemblies. Diesel Model DJB is shown.

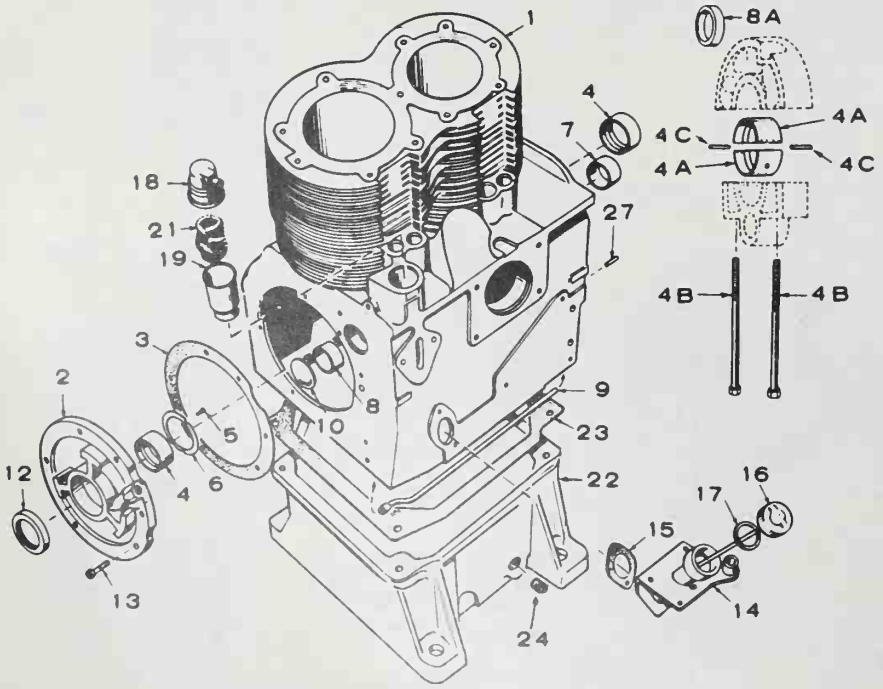
1. Camshaft
2. Cam gear key
3. Center pin
4. Thrust washer
5. Camshaft gear (incl. spacer)
6. Flyballs
7. Governor cup
8. Snap ring
9. Injection pump drive gear
10. Snap ring

ance is 0.0015-0.0075 inch when measured 90° from piston pin. Diameter of standard piston is 3.493-3.494 inches for Models DJE, RDJE, RDJEA and RDJF. Diameter of standard piston for all other models is 3.243-3.244 inches. Diameter is measured just below oil ring groove at right angles to piston pin. Use a hone fitted with 100 grit stones to rebore a tapered or out-of-round cylinder. When cylinder is about 0.002 inch from desired bore size, finish-hone cylinder wall with 300 grit stones to correct inner diameter being sure to leave a "cross-hatch" pattern for satisfactory break in of oversize pistons and rings.

CRANKSHAFT AND BEARINGS

The crankshaft is supported in two lead-bronze sleeve bearings pressed into crankcase and rear bearing plate. Four cylinder engines have an additional split center main bearing. Bearings are precision type and do not require reaming after installation. Oil holes must be aligned when bearings are installed, as shown in Fig. 0233. Crankshaft thrust washers are retained by lock pins as shown.

Crankshaft main journal diameter is 2.2437-2.2445 inches. Crankpin diameter is 2.0597-2.0605 inches. Recommended crankpin bearing clearance is 0.001-0.0033 inch and recommended main bearing clearance is 0.0020-0.0033 for DJA and DJB, 0.0014-0.0052 for DJBA, DJE, RDJE and RDJEA and 0.0024-0.0062 for



1. Block assembly
2. Bearing plate
3. Gasket
4. End main bearings
*4A. Center main bearing
*4B. Bolt, center main
*4C. Pin, center main
5. Thrust washer pin
6. Thrust washer
7. Cam bearing, front
8. Cam bearing, rear
*8A. Cam bearing, center
9. Oil tube
10. Camshaft plug
12. Crank seal, rear
13. Bearing plate bolt
14. Oil fill tube
15. Gasket
16. Cap & gage
17. Cap gasket
18. Breather tube cap
19. Breather tube
21. Baffle
22. Oil base
23. Gasket
24. Drain plug
27. Gear cover dowel
*Four-cylinder models only

Fig. 0236 – Exploded view of cylinder, crankshaft and oil base assemblies typical of this engine series. Model DJBA is shown.

Models DJC, RDJC and RDJF. Main and rod bearings are available in undersizes of 0.002, 0.010, 0.020 and 0.030 inch as well as standard. Crankshaft thrust washers are available in standard thicknesses only, and crankshaft end play of 0.010-0.015 inch is controlled by varying the thickness of gasket pack between rear main bearing plate and crankcase. If more than 0.015 inch total gasket thickness is required, use one or more steel shims to avoid excessive gasket compression.

If crankpin journal must be resized, crankpin fillets must be shot peened to relieve metal stress. Renew crankshaft instead of regrinding if facilities for shot-peening are not available.

Tighten rear bearing plate retaining cap screws to a torque of 40-45 ft.-lbs. when reassembling engine. Tighten oil base mounting screws to 32-38 ft.-lbs.

Refer to Figs. 0234 through 0236 for typical exploded views of engine assemblies.

Front crankshaft oil seal is set into timing gear cover and rear seal is fitted into crankshaft bearing plate. If renewal is required, old seals are driven out from inner side after cover and/or plate have been removed using properly fitted driving tool. New seals are installed with open side facing inward; front seal is driven flush with outer side of gear cover and rear seal should bottom flush with rear surface of bearing end plate. Space between seal lips should be filled with cup or fiber grease before installing over crankshaft ends.

Engines equipped with some types of drive reduction gears do not have a rear oil seal as engine oil also lubricates gear assemblies. See instruction plate on reduction drive housing for details.

CENTER MAIN BEARING. All four cylinder models have a third main bearing. Specifications for center main journal and bearings are the same as for front and rear mains. Refer to Fig. 0237 for details of assembly. Upper bearing half is rotated into position while turning crankshaft. Be sure "FRONT" on bearing housing faces toward crankshaft gear and that oil passages are aligned. After installing position dowels, lower-half bearing insert and center main bearing cap, torque capscrews to 97-102 ft.-lbs.

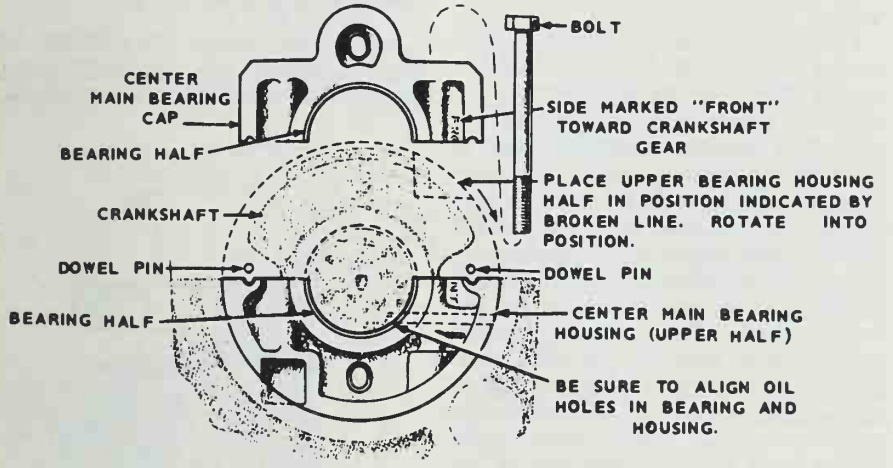


Fig. 0237—Installation of center main bearing used on four-cylinder engines. Refer to procedure in text.

CAMSHAFT & GOVERNOR

The camshaft gear is a press fit on shaft. The assembled unit must be removed from flywheel end of housing after removing flywheel, timing gear cover, injection pump and fuel lift pump. Remove rocker arms and push rods, then lay cylinder block on its side to prevent tappets from dropping. Tappets cannot be withdrawn until after the camshaft is out.

Camshaft bushings are precision type which may be renewed following the procedure shown in Fig. 0238 after camshaft is out. Recommended diametral clearance for both bushings is 0.0012-0.0037 inch. Front journal diameter is 2.500-2.505 inches, rear

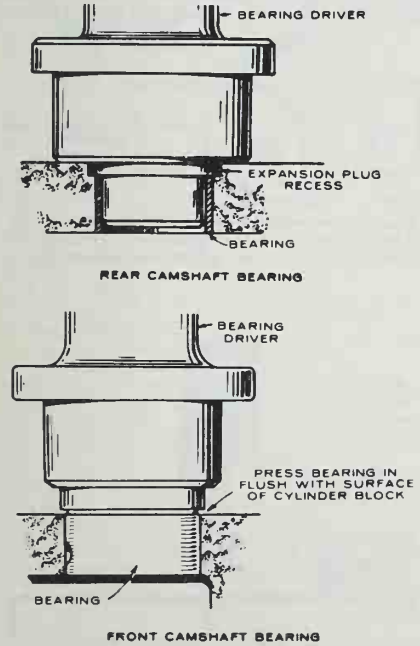


Fig. 0238—Correct placement of front and rear camshaft bearings. These are precision bearings, not to be bored or reamed. Available in standard size only.

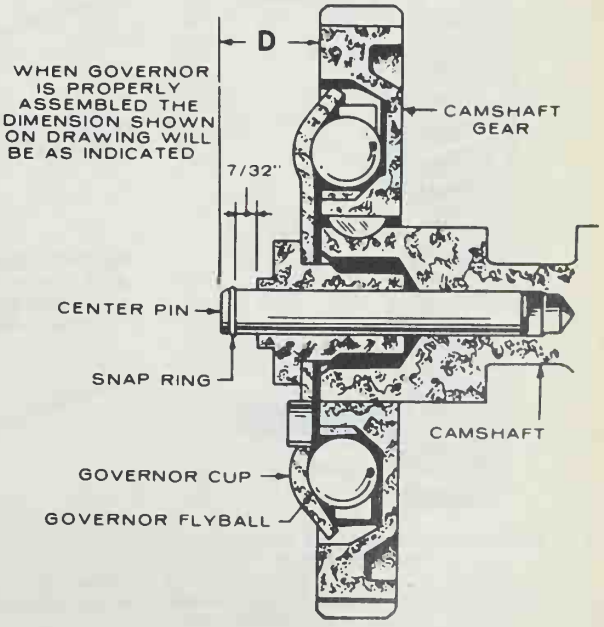


Fig. 0239—Cross-section view of governor mechanism in camshaft gear. In order to limit governor cup movement of 7/32-inch as shown, dimension (D) must be 25/32-inch as described in text.

journal is 1.1875-1.880 inches. Four cylinder engines have a three-bearing camshaft. Center journal diameter is 1.2580-1.2582 inches.

Governor weight unit is mounted on camshaft gear and governor cup rides on a center pin pressed into camshaft as shown in Fig. 0239. Check the distance center pin extends from front face of camshaft gear. Distance must be 25/32-inch as shown to give the proper travel to governor cup. Governor cup must be a free spinning fit on center pin. Renew the cup if race surface is grooved or rough, or if cup is excessively loose on center pin. Renew any flyballs if they have flat spots, grooves, or rust pitting. Center pin must be renewed if removed from camshaft for any reason.

When reinstalling the camshaft, align timing marks as shown in Fig. 0240. Install crankshaft washer and snap ring, then check camshaft end play as shown in Fig. 0241. Clearance (Y) should be 0.007-0.039 inch with camshaft pushed rearward and crankshaft pulled forward. If clearance is excessive, renew spacer washer (1) or crankshaft washer (3).

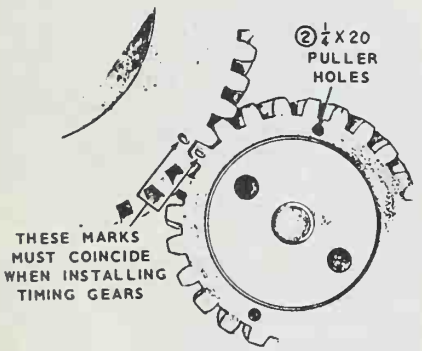


Fig. 0240—Align crankshaft and camshaft timing marks as shown when installing camshaft.

OIL PUMP

The engine is fully pressure lubricated and all oil is circulated through a full flow filter. Oil pressure should be 25 psi or higher with engine at operating speed and temperature.

The gear type oil pump is driven by timing gear and is accessible after removing gear cover and oil base. The by-pass valve is located in rear bearing plate and retained by a socket head pipe plug.

ELECTRIC STARTERS

Two styles of battery-driven electric starter motors are used. Bendix-drive starter shown at A–Fig. 0242 is designed to engage teeth of flywheel ring gear when starter switch is depressed to close circuit causing starter motor to turn. Engagement of starter pinion with ring gear by means of spiral shaft screw within Bendix pinion is cushioned by action of its coiled drive spring so that starting motor can absorb the sudden loading shock of engagement. Engine manufacturer recommends that complete Bendix drive unit be renewed in case of failure, however, if a decision is made to overhaul starter drive by obtaining parts from manufacturer of the starter (Prestolite), be sure that correct drive spring is used. Length of spring is critical to mesh and engagement of starter pinion to flywheel ring gear. There are no procedures for adjustment of this starter.

Service is generally limited to cleaning and careful lubrication, renewal of starting motor brushes (4 used), brush tension springs and starter motor and drive housing bearings. See STARTER MOTOR TESTS for electrical check-out procedures for starter armature and field windings.

Solenoid-shift style starter (B–Fig. 0242) uses a coil solenoid to shift starter pinion into mesh with flywheel ring gear and an over-running (one-way) clutch to ease disengagement of pinion from flywheel as engine starts and runs.

NOTE: Starter clutch will burn out if held in contact with flywheel for overlong periods. Starter switch must be released quickly as engine starts.

All parts of starter are available for service. Solenoid unit and starter clutch are renewed as complete assemblies.

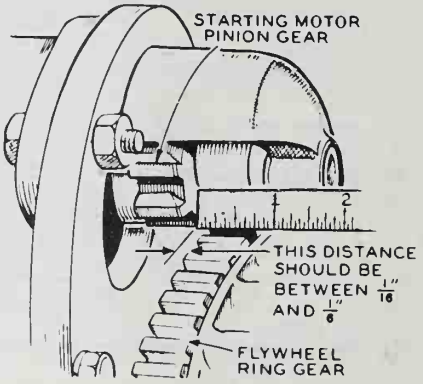


Fig. 0243—Check starter pinion to ring gear clearance as shown. Adjustment details in text.

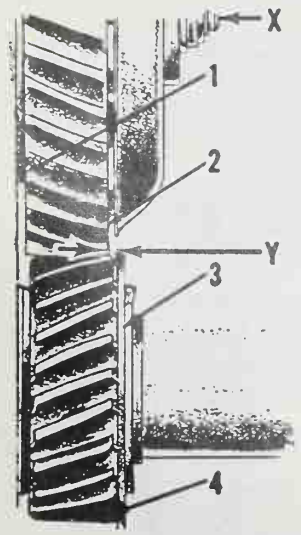


Fig. 0241—Procedure to check camshaft gear end play. See text.

X. Camshaft pushed in
Y. Measure end play here
1. Spacer washers
2. Camshaft gear
3. Crankshaft washer
4. Crankshaft gear

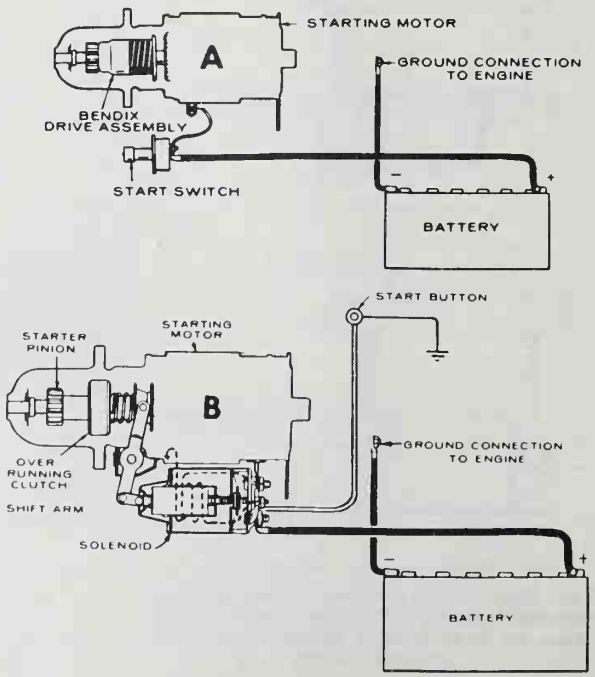


Fig. 0242—Views of Bendix-drive starter and solenoid-shift starter in basic electric circuits. Refer to text.

Refer to Figs. 0243 and 0244 for adjustment check points to measure flywheel ring gear to starter pinion clearance and the gap between pinion and pinion stop on starter shaft. Starter pinion to ring gear clearance (Fig. 0243) is adjusted during starter assembly by proper selection of spacer washers fitted to armature shaft as installed in housing. To adjust pinion clearance against pinion stop (Fig. 0244), remove mounting screws which attach solenoid magnetic coil to front bracket and pinion housing assembly and select a proper thickness of fiber packing gaskets to set required clearance. Be sure that plunger is pressed inward as shown when measuring.

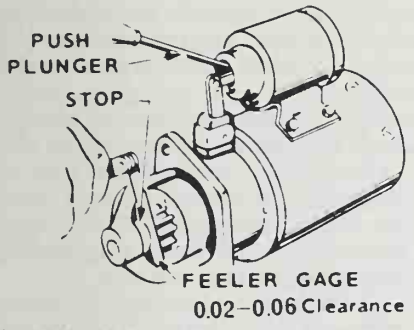


Fig. 0244—Measure clearance between starter pinion and pinion stop with feeler gage as shown.

Starting motor brushes require renewal when worn away by 0.3 inch. Original brush length is 0.55 inches.

Commutator must be clean and free from oil. Use No. 00 sandpaper to clean and lightly polish segments of commutator; never use emery cloth or any abrasive which may have a metallic content. Starter motor commutators do not need to have mica separators between segments undercut. Mica may be flush with surface.

STARTER MOTOR TESTS

ARMATURE SHORT CIRCUIT. Place armature in growler as shown in Fig. 0245 and hold a hack saw blade or similar piece of thin steel stock above and parallel to core. Turn growler "ON". A short circuit is indicated by vibration of blade and attraction to core. If this condition appears, renew armature.

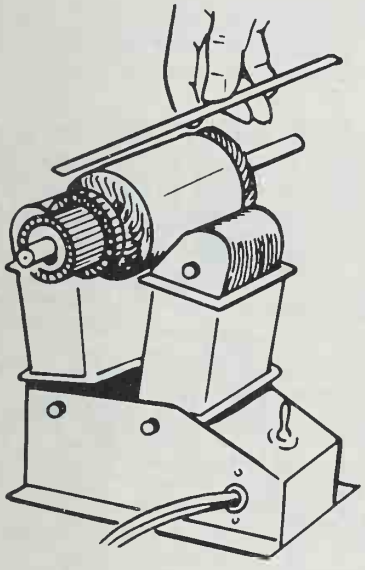


Fig. 0245—Use of growler to check armature for short circuit. Follow procedure in text.

GROUNDED ARMATURE. Check each segment of commutator for grounding to shaft (or core) using ohmmeter setup as shown in Fig. 0246. A low (Rx1 scale) continuity reading indicates that armature is grounded and renewal is necessary.

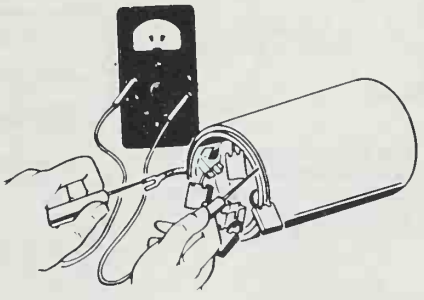


Fig. 0247—Use ohmmeter as shown to check field coil for suspected internal grounding.

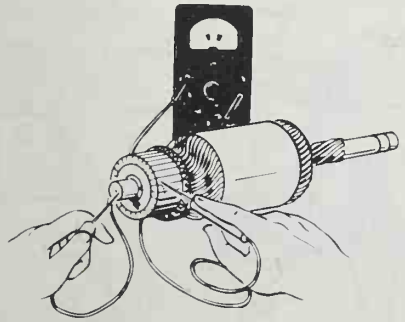


Fig. 0246—Test for grounded armature commutator by placing ohmmeter test probes as shown. Probe shown touching shaft may also be held against core. See text.

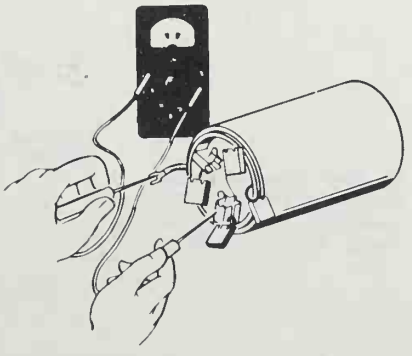


Fig. 0248—Ohmmeter used to check for breaks or opens in field coil windings. Be sure to check lead wires.

It is good procedure to mount armature on a test bench or between lathe centers to check for runout of commutator or shaft. If shaft is worn badly, renewal is recommended. If commutator runout exceeds 0.004 inch, reface by turning.

GROUNDED FIELD COILS. Refer to Fig. 0247 and touch one ohmmeter probe to a clean, unpainted spot on frame and the other to connector as shown, after unsoldering field coil shunt wire. A low range reading (Rx1 scale) indicates grounded coil winding. Be sure to check for possible grounding at connector lead which can be corrected, while grounded field coil cannot be repaired and calls for renewal.

OPEN IN FIELD COILS. Use procedure shown in Fig. 0248 and check all four brush holders for continuity. If there is no continuity or if a high resistance reading appears, renewal is necessary.

NO-LOAD TEST. When starter is considered ready to return to service, connect motor on bench top as shown in Fig. 0249. Acceptable test readings are:

Minimum speed .....3700 rpm
Voltmeter reading .....11.5 volts
Maximum current draw ....60 amperes

If starter motor does not check out as satisfactory on this test, make further checks for:

Weak brush springs.

Brushes not squarely seated.

Dirty commutator.

Poor electrical connections. May be caused by "cold" or corroded solder joints.

Tight armature. Not sufficient end play (should be 0.004-0.020 inch).

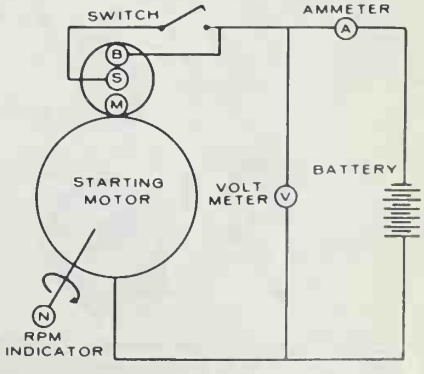


Fig. 0249—Schematic bench test of starting motor. Note that ammeter is connected in series with load and voltmeter is connected "across" the load-in parallel. Refer to text for test values.

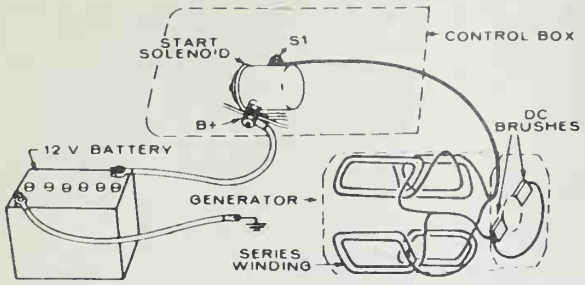


Fig. 0250 – Schematic of DC circuit portion of AC generator used for exciter cranking. Refer to text.

Open or ground in field coil.

Short circuit, open or ground in armature.

EXCITER CRANKING

Exciter cranking, with cranking torque furnished by switching battery current through a separate series winding of generator field coils and the DC brushes, using DC portion of generator armature is wired as shown in Fig. 0250.

This starting procedure may be used on Model DJA. In cases where exciter cranking is inoperative, due to battery failure or other cause, unit may be started by use of a manual rope starter. In some cases, a recoil type "Readi-Pull" starter may be furnished for standby use.

In case exciter cranking system will not operate, isolate starter solenoid switch and battery from DC field windings and perform a routine continuity check of all components by use of a volt-ohmmeter. See Fig. 0250 for possible test points. If problem does not become apparent as caused by battery (low voltage), defective starter solenoid, short or open circuit in lead wires or DC brushes, it will be necessary to check out generator in detail and may involve factory service.

FLYWHEEL ALTERNATOR

This battery charging system is simple and basically trouble-free. Flywheel-mounted permanent magnet rotor provides a rotating magnetic field to induce AC voltage in fixed stator coils. Current is then routed through a two-step mechanical regulator to a full-wave rectifier which converts this regulated alternating current to direct current for battery charging. Later models are equipped with a fuse between negative (–) side of rectifier and ground to protect rectifier from accidental reversal of battery polarity. See schematic, Fig. 0252. Maintenance services are limited to keeping components clean and insuring that wire connections are secure.

TESTING. Check alternator output by connecting an ammeter in series between the positive (+), red terminal of rectifier and ignition switch. Refer to Fig. 0252. At 1800 engine rpm, a discharged battery should cause about 8 amperes to register on a meter so connected. As battery charge builds up, current should decrease. Regulator will switch from high charge to low charge at about 14½ volts with low charge current of about 2 amps. Switch from low charge to high charge occurs at about 13 volts. If output is inadequate, test as follows:

Check rotor magnetism with a piece of steel. Attraction should be strong.

Check stator for grounds after disconnecting by grounding each of the three leads through a 12-V test lamp. If grounding is indicated by lighted test lamp, renew stator assembly.

To check stator for shorts or open circuits, use an ohmmeter of proper scale connected across open leads to check for correct resistance values. Identify leads by reference to schematic.

From lead 7 to lead 8 . . . . . 0.25 ohms
From lead 8 to lead 9 . . . . . 0.95 ohms
From lead 9 to lead 7 . . . . . 1.10 ohms

Variance by over 25% from these values calls for renewal of stator.

RECTIFIER TESTS. Use an ohmmeter connected across a pair of terminals as shown in Fig. 0253. All rectifier leads should be disconnected when

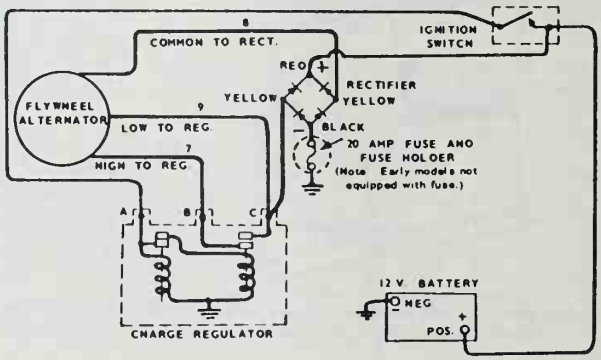


Fig. 0252 – Schematic of flywheel alternator circuits for location of test and check points. Refer to text for procedures.

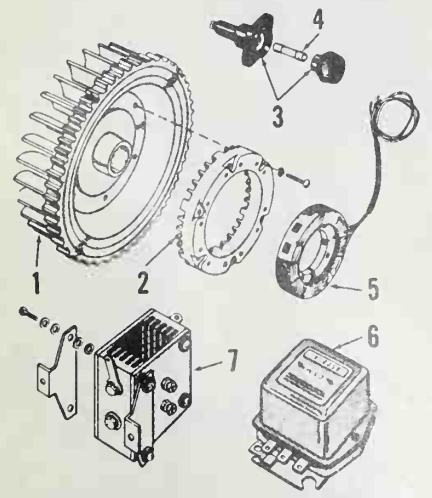


Fig. 0251 – Typical flywheel alternator shown in exploded view. In some models, regulator (6) and rectifier (7) are combined in a single unit.

1. Flywheel
2. Rotor
3. Fuse holder
4. Fuse (20A)
5. Stator & leads
6. Regulator, 2-step
7. Rectifier assembly

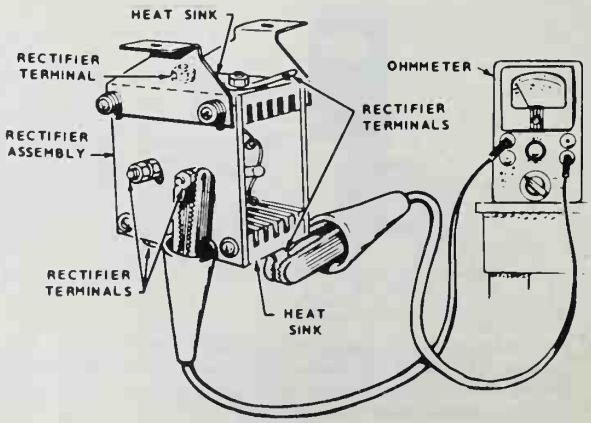


Fig. 0253 – Test each of four diodes in rectifier using Volt-Ohmmeter hook-up as shown. See text for procedure.

testing. Check directional resistance through each of the four diodes by comparing resistance reading when test leads are reversed. One reading should be much higher than the other.

NOTE: Forward-backward ratio of a diode is on the order of several hundred ohms.

If a 12-V test lamp is used instead of an ohmmeter, bulb should light, but dimly. Full bright or no light at all indicates that diode being tested is defective.

Voltage regulator may be checked for high charge rate by installing a jumper lead across regulator terminals (B and C–Fig. 0252). With engine running, battery charge rate should be about 8 amperes. If charge rate is low, then alternator or its wiring is defective.

If charge rate is correct (near 8 amps), defective regulator or its power circuit is indicated. To check, use a 12-V test lamp to check input at regulator terminal (A). If lamp lights, showing adequate input, regulator is defective and should be renewed.

NOTE: Regulator, being mechanical, is sensitive to vibration. Be sure to mount it on bulkhead or firewall separate from engine for protection from shock and pulsating motion.

Engine should not be run with battery disconnected, however, this alternator system will not be damaged if battery terminal should be accidentally separated from binding post.

CLUTCH

When optional Rockford clutches are furnished with these engines, an adapter flange is fitted to engine output shaft for mounting clutch unit and a variety of housings are used dependent upon application and model of engine or clutch used. Refer to Fig. 0254 for guidance in adjustment and proceed as follows:

Remove plate from top of housing and rotate engine manually until lock screw (1–Fig. 0254) is at top of ring (2) as shown. Loosen lock screw and turn adjusting ring clockwise (as facing through clutch toward engine) until toggles cannot be locked over center. Then, turn ring in reverse direction until toggles can just be locked over center by a very firm pull on operating lever. If a new clutch plate has been installed, slip under load to knock off "fuzz" and readjust. Lubricate according to instructions on unit plate.

REDUCTION GEAR ASSEMBLIES

Typical reduction gear unit is shown in Fig. 0255. Ratio of 1:4 is common in industrial applications. Lubrication calls for use of SAE 50 weight motor oil or SAE 90 gear oil. Refer to instructions printed on gear case for guidance. In most cases, a total of six plugs are fitted into case for lubricant fill or level check. Plug openings to be used are determined by positioning of gear box in relation to horizontal or vertical. It is recommended that square plug heads be cut off those plugs not to be used to fill, check or drain so as to eliminate chance of error by overfill or underfill. All parts shown are available for renewal if needed in overhaul.

NOTE: In some installations, no shaft seal is fitted between engine crankcase and reduction gear housing. In these cases, with a common oil supply, engine oil lubricates gears and bearings of reduction gear unit and gear oil is not used. Be sure to check nameplate or operator's manual.

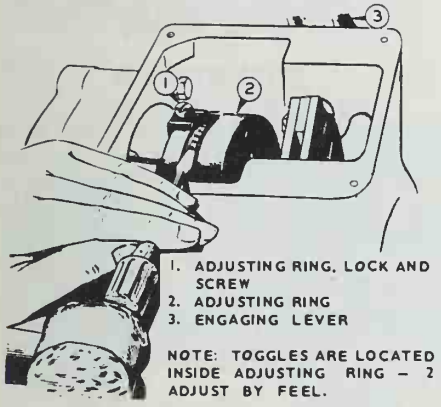


Fig. 0254—Procedure for adjustment of Rockford clutch.

1. Ring lock & screw
2. Adjuster ring
3. Clutch lever

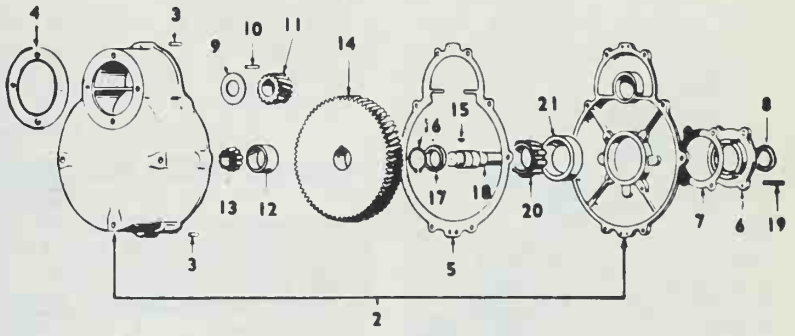


Fig. 0255—Exploded view of typical reduction gear set. See text for service details.

2. Housing & cover
3. Dowel pins (2)
4. Gasket (engine)
5. Cover gasket
6. Bearing retainer
7. Shims
8. Oil seal
9. Pinion washer
10. Pinion key
11. Pinion gear
12. Bearing cup
13. Bearing cone
14. Driven gear
15. Gear key
16. Snap ring
17. Bearing spacer
18. Shaft
19. Key
20. Bearing cone
21. Bearing cup

PEUGEOT

PEUGEOT MOTORS OF AMERICA, INC.
INDUSTRIAL ENGINE DIVISION
One Peugeot Plaza
Lyndhurst, New Jersey 07071

Model	No. Cyls.	Bore	Stroke	Displ.
XDP 4.88	4	88 mm	80 mm	1946 cc
XDP 4.90	4	90 mm	83 mm	2112 cc
XD2P 4.94	4	94 mm	83 mm	2304 cc
XD2PS	4	94 mm	83 mm	2304 cc
XD2PT	4	94 mm	83 mm	2304 cc

Peugeot engines covered in this section are four-stroke, liquid-cooled diesel engines. Models XD2PS and XD2PT are turbocharged. All engines have a cast iron cylinder block and aluminum cylinder head.

Cylinders are numbered 1 through 4 with number 1 cylinder nearest flywheel. Firing order is 1-3-4-2. Crankshaft rotation is counterclockwise at flywheel end.

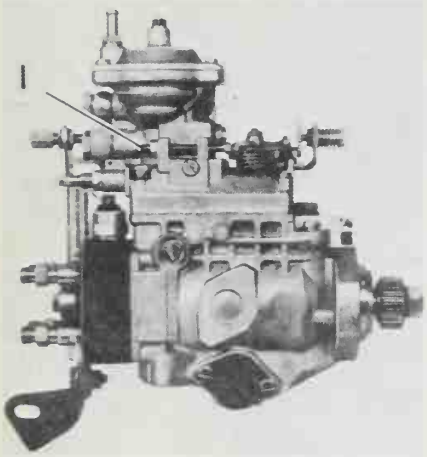


Fig. P1-1—Low idle speed on Bosch fuel injection pump is adjusted by turning screw (I).

MAINTENANCE

LUBRICATION

Recommended oil is API classification CD. Oil viscosity should be SAE 30 for ambient temperatures above 15° C. (59° F.), SAE 20 for ambient temperatures between minus 7° C. (20° F.) and plus 15° C. (59° F.), and SAE 10 for ambient temperatures below minus 7° C. (20° F.).

The engine is equipped with a pressurized oil system. Oil pressure at working speed should be 300 kPa with oil temperature at 80° C. (176° F.).

ENGINE SPEED ADJUSTMENT

Low idle speed should be 700-750 rpm on Models XDP 4.88 and XDP 4.90, 800-850 rpm on Model XD2P 4.94 and 750-800 rpm on Models XD2PS and XD2PT.

Low idle speed on models equipped with Bosch fuel injection pump is adjusted by turning screw (I–Fig. P1-1).

To adjust low idle speed on engines equipped with a Roto Diesel injection pump and variable speed control, be sure idle speed control is set for slow idle speed (not fast idle) and turn adjuster at pump end of idle control cable. To adjust idle speed on fixed speed engines with Roto Diesel injection pump, turn idle speed screw (I–Fig. P1-2). Adjust throttle stop screw so engine decelerates to idle speed without stalling. Note on fixed speed engines that an electrical device stops engine, however, in case electrical stop device malfunctions, idle lever stop (P) may be rotated so idle speed lever will completely close pump fuel circuit thereby stopping engine.

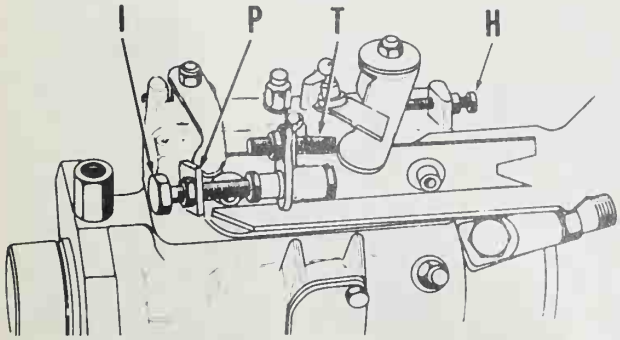


Fig. P1-2—Drawing showing location of idle speed screw (I) and high speed screw (H) on fixed speed engines with Roto Diesel injection pump. Refer to text for adjustment.

FUEL SYSTEM

FUEL FILTER. The fuel filter should be drained after every 50 hours of operation or more often to remove contaminants. Filter element should be renewed after every 200 hours of operation.

BLEED FUEL SYSTEM. To bleed

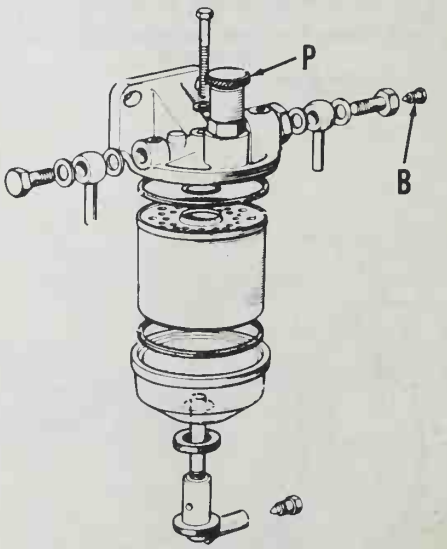


Fig. P1-5—View of fuel filter used on models equipped with Roto Diesel fuel injection pump.

fuel system on engines equipped with Roto Diesel injection pump, open fuel tank valve and fuel filter bleed screw (B – Fig. P1-5). Operate pump handle (P) until air-free fuel flows from bleed screw hole. Close filter bleed screw. Open fuel injection pump bleed screw and operate filter pump handle until air-free fuel exits pump bleed screw hole. Close pump bleed screw. Loosen fuel injection lines at injectors. With throttle open, rotate engine until air-free fuel flows from injection lines, then reconnect lines.

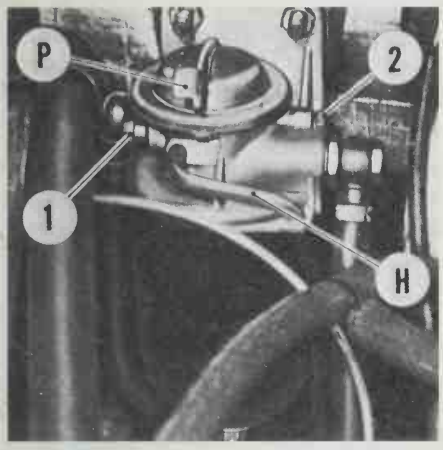


Fig. P1-6 – View of fuel filter used on models equipped with Bosch fuel injection pump.

To bleed fuel system on engines equipped with Bosch injection pump, open fuel tank valve and open bleed screw (1 – Fig. P1-6). Operate filter pump handle (P) until air-free fuel is discharged from hose (H), then close bleed screw (1). Open screw (2) and operate pump handle until resistance is felt, then close screw. Loosen injection pump inlet fitting and allow fuel to flow until air is expelled then tighten fitting. Loosen fuel injection lines at injectors. With throttle open, rotate engine until air-free fuel flows from injection lines, then reconnect lines.

INJECTION PUMP TIMING. Number 4 piston must be placed in firing position to check injection timing or install and time injection pump. To determine piston position, remove valve cover and without dislodging push rod from tappet, disconnect exhaust rocker arm of number 4 cylinder from push rod. Rotate rocker arm away from number 4 cylinder exhaust valve. Using a suitable spring compressor, remove exhaust valve spring. Allow exhaust valve to rest on piston then mount a dial gage so gage contacts valve stem thereby reading piston travel. Be sure valve does not bind in valve guide. Rotate engine so number 4 piston is on compression and locate piston at firing position noted in following table:

Model	Degrees BTDC	Piston Position BTDC
XDP 4.88*	24°	4.29-4.39 mm
XDP 4.90	25°	4.86-4.96 mm
XD2P 4.94	24°	4.49-4.59 mm
XD2PS,XD2PT	.....	0.78-0.82 mm

*Timing specifications in table are for Model XDP 4.88 engines which operate at speeds in excess of 3000 rpm. For Model XDP 4.88 engines operated at 3000 rpm or less, degrees BTDC are 15° and piston position BTDC is 1.67-1.77 mm.

After number 4 piston has been placed in timing position, refer to appropriate following section. Stamp timing marks on engine for future reference.

ROTO DIESEL PUMP. With number 4 piston in firing position as previously outlined, remove pump inspection plate (1 – Fig. P1-8) and note timing groove (2) in pump drive sleeve. If pump is separated from engine, rotate drive gear so groove (2) is aligned with timing pin guide (3). If pump is mounted on engine, groove (2) should be near timing pin guide (3), if not, remove pump and rotate drive gear. Install timing pin (6 – Fig. P1-9) and dial gage as shown in Fig. P1-10. If not installed, mount pump on engine and tighten support plate screws to 19.6-24.5 N·m. Pump retaining nuts must be just loose enough to rotate pump. Install anti-backlash tool (7 – Fig. P1-9) as shown in Fig. P1-10, then rotate pump until maximum dial gage reading is obtained and tighten pump retaining nuts to 14.7-19.6 N·m. Timing marks should be stamped on pump support plate and pump flange for future reference. Remove timing tools and install inspection plate.

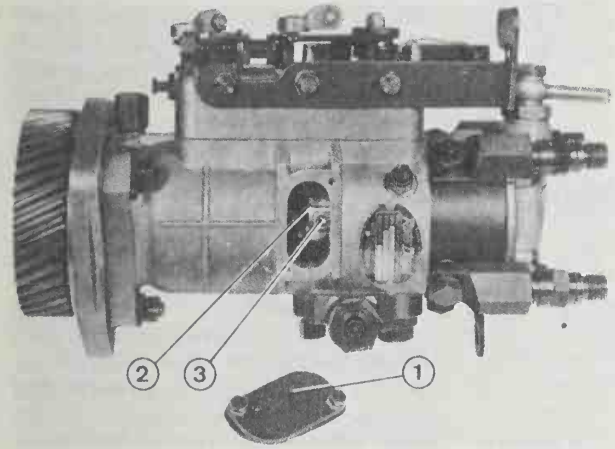


Fig. P1-8 – View of Roto Diesel fuel injection pump with inspection plate (1) removed showing timing groove (2) and timing pin guide (3).

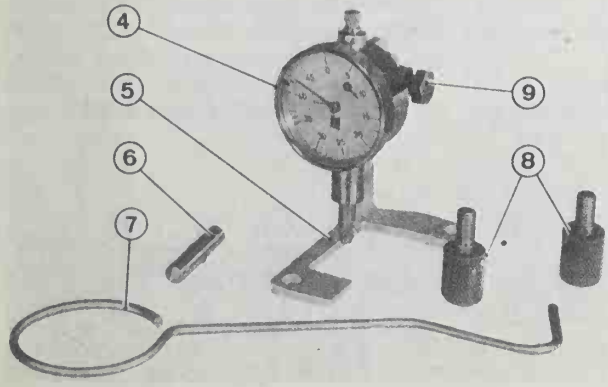


Fig. P1-9 – Use the tools shown to time Roto Diesel fuel injection pump as outlined in text.

4. Dial gage
5. Gage holder
6. Timing pin
7. Anti-backlash tool
8. Holder screws
9. Gage mounting screw

BOSCH PUMP. With number 4 piston in firing position as previously outlined, unscrew plug (2 – Fig. P1-11) and install a dial gage to measure pump plunger travel. If pump is separated from engine, install pump noting drive gear master spline (1). Tighten pump retain-

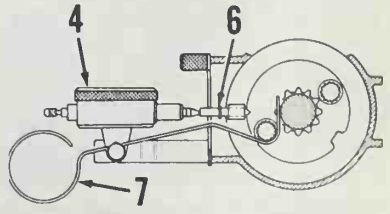


Fig. P1-10 – Install timing tools as shown to time Roto Diesel fuel injection pump.

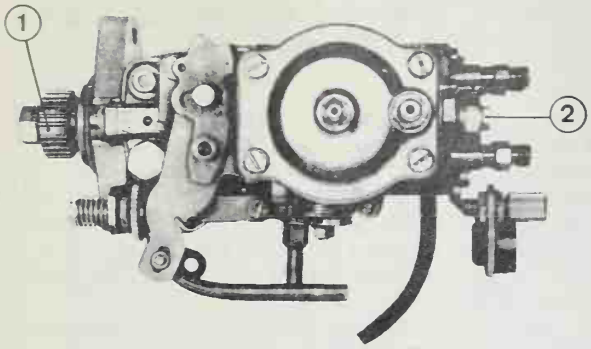


Fig. P1-11—View of Bosch fuel injection pump. Note drive gear master spline (1).

ing screws so pump is secure but rotatable. If not previously marked, stamp marks on block and flywheel or pulley to indicate number 4 piston timing position. Rotate crankshaft and zero dial gage at bottom dead center of pump plunger travel. Rotate crankshaft and return to number 4 piston timing position. Rotate pump so dial gage indicates 0.29-0.31 mm and tighten pump screws to 14.7-19.6 N·m. Timing marks should be stamped on pump support plate and mounting flange for future reference. Remove timing tools.

COOLING SYSTEM

All engines are liquid cooled and equipped with a water pump to circulate coolant. Due to aluminum construction of cylinder head, an ethylene glycol based antifreeze solution or anti-corrosive additive should be used in coolant.

Thermostat opening temperature is 65° C. (149° F.).

REPAIRS

TIGHTENING TORQUES

Refer to following table for tightening torques. All values are in newton meters.

Camshaft retainer	14.7-19.6
Connecting rod	51.5-61.2
Cylinder head	
With flanged injectors	63.7-73.5
With threaded injectors	
XDP 4.88, XDP 4.90	58.8
XD2P 4.94, XD2PS, XD2PT	78.4
Exhaust manifold	19.6-24.5
Flywheel	
XDP 4.88	63.7-68.6
All other models	73.5-78.4
Injection pump	14.7-19.6
Injection pump gear	
Bosch	4.9-7.3
Roto Diesel	21.6-25.4
Injection pump support plate	19.6-24.5
Injector	
Flange type	14.7-19.6
Threaded type	88.2
Intake manifold	19.6-24.5
Main bearing	98-117.6
Oil pan	7.4-12.2
Oil pump cover	4.9-7.3
Rocker shaft	See text
Timing gear cover	7.4-12.2
Water pump	7.4-12.2
Water pump pulley nut	29.4-39.2

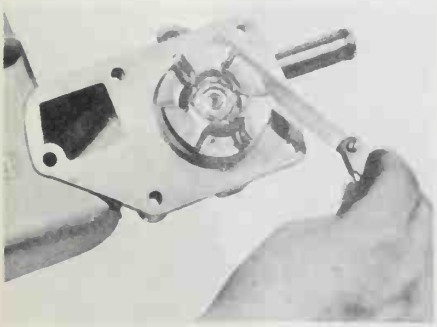


Fig. P1-12—Measure clearance between water pump flange and impeller. Maximum clearance is 1 mm.

COMPRESSION PRESSURE

Compression pressure should be 300-400 kPa with engine temperature approximately 80° C (176° F.) and crankshaft rotated with starter.

WATER PUMP

R&R AND OVERHAUL. To remove water pump, drain coolant, disconnect hoses and remove drive belt. Unbolt and remove water pump. Using a suitable puller, pull impeller off shaft. Disassemble remainder of pump.

When assembling water pump, press impeller on shaft so there is a maximum clearance of 1 mm between impeller and pump flange (Fig. P1-12).

VALVE TAPPET GAP

Valve tappet gap is adjusted with engine cold. Valve tappet gap should be adjusted after 20 to 50 hours operation if head is removed. Refer to following table for recommended tappet gap:

Model	Intake (mm)	Exhaust (mm)
XDP 4.88, XDP 4.90	*0.15-0.20	*0.25-0.30
XD2P 4.94	0.30-0.35	0.30-0.35
XD2PS,XD2PT	0.15	0.25

*Initial adjustment after cylinder head installation on models with flanged injectors is: intake 0.25-0.30 mm; exhaust 0.35-0.40 mm. After 20 to 50 hours operation, readjust to table specifications.

ROCKER ARMS AND SHAFT

R&R AND OVERHAUL. Remove valve cover for access to rocker arm shaft assembly. Unscrew retaining nuts and lift off rocker shaft. Push rods may be removed by carefully separating push rod from tappet so tappet does not leave its bore.

Rocker arms and shaft are lubricated by engine oil routed through an external oil line to cylinder head, then through an oil passageway to oil sleeve (4—Fig. P1-13).

Minimum rocker shaft diameter is 18.96 mm. Rocker arm bushing is renewable.

When assembling rocker shaft assembly, install oil sleeve (4) on shaft so chamfered hole in shaft is aligned with screw hole in sleeve. Place copper washer (6) on oil sleeve locating screw (5) then install and tighten screw to 4.9-7.3 N·m. Note that washers (3) and weak springs (2) are adjacent to oil sleeve. On models with rocker shaft stands at end of shaft, insert a 0.1 mm thick shim between numbers 1 and 4 intake rocker arms and outer shaft stands. Insert push rods then install rocker shaft assembly being sure rubber gasket is installed on oil sleeve nipple. Tighten rocker shaft retaining nuts to 49 N·m,

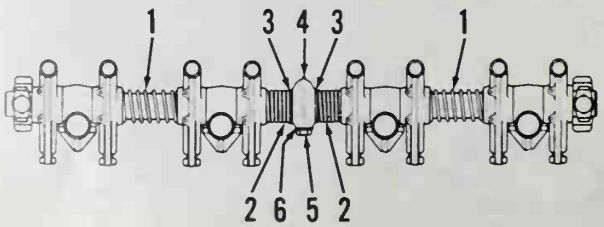


Fig. P1-13—View of rocker shaft assembly on Model XD2P 4.94. Other models are similar.

1. Strong spring
2. Weak spring
3. Washer
4. Oil sleeve
5. Locating screw
6. Copper washer

and on models so equipped, tighten outer rocker shaft stand screws to 19.6 N·m. Remove shims from rocker shaft ends and be sure rocker arms rotate freely.

CYLINDER HEAD

R&R AND OVERHAUL. Drain coolant, then detach coolant hoses and water pump belt. If desired, remove water pump. Disconnect fuel injection lines, remove injectors and cap or plug fuel openings to prevent contamination. Disconnect glow plug wire. Remove intake and exhaust manifolds. Detach external oil line from head. Remove rocker shaft and push rods as previously outlined. Unscrew cylinder head screws and remove head.

Cylinder head surface should be machined if warped more than 0.2 mm or unevenness exceeds 0.1 mm. Minimum cylinder head height is 89.35 mm.

NOTE: Turbulence chambers must be removed from head prior to machining head surface.

Turbulence chamber standout above head surface should be 0.0-0.03 mm. To remove turbulence chamber, insert a malleable punch through injector hole and drive out chamber. Flange thickness (F – Fig. P1-15) should be 3.975-4.025 mm while height of chamber (H) should be 18.50-18.80 mm. Clearance between bottom of bore in head and chamber should be 0.1-0.6 mm. Oversize turbulence chambers are available. Be sure retaining ball is installed in groove when installing turbulence chamber.

Valve seats and guides are renewable with oversizes available. Install valve guide so tip of guide is 27.95-28.05 mm from head mating surface. Ream guide to inner diameter of 8.520-8.542 mm. Intake valve seat angle is 30° on Model XD2P 4.94 and 45° on all other models. Exhaust valve seat angle is 45° for all models.

Three thicknesses of cylinder head gasket are used. Head gasket with thickness of 1.40 mm is used on Models XDP 4.88 and XDP 4.90. To select gasket thickness on all other models, measure piston height above block surface with piston at TDC. If piston standout is lower than 0.84 mm on Model XD2P 4.94 or lower than 0.79 mm on Models XD2PS or XD2PT, install 1.58 mm thick head gasket. If piston standout is higher than 0.84 mm on Model XD2P 4.94 or higher than 0.79 mm on Models XD2PS or XD2PT, install 1.70 mm thick head gasket. Tighten screws in two steps to torque listed in TIGHTENING TORQUES section.

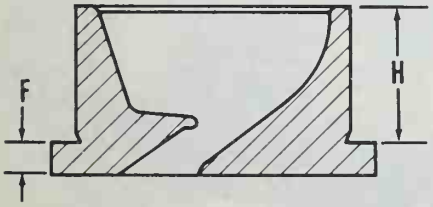


Fig. P1-15 – Turbulence chamber flange thickness (F) is 3.975-4.025 mm while height (H) is 18.50-18.80 mm.

VALVE SYSTEM

Both valves ride in renewable valve guides and seat in renewable seat inserts. Refer to CYLINDER HEAD section for guide and seat installation.

Intake valve face and seat angles are 45 degrees on Models XDP 4.88 and XDP 4.90 and 30 degrees for all other models. Exhaust valve face and seat angles are 45 degrees for all models. Intake and exhaust valve guide inside diameter is 8.520-8.542 mm. Intake valve stem diameter is 8.473-8.495 mm and exhaust valve stem diameter is 8.453-8.475 mm. Distance from top of valve to head surface should be 0.75-1.15 mm.

Inner valve spring free length is 41 mm and outer valve spring free length is 44.6 mm. Inner valve spring pressure is 181 newtons at 21.5-22.5 mm. Outer valve spring pressure is 451 newtons at 25.5-26.5 mm.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

Models XDP 4.88, XDP 4.90 and XD2P 4.94 are equipped with flange type Roto-Diesel injectors. Models XD2PS and XD2PT are equipped with screw type Bosch injectors. Refer to appropriate following section for service.

ROTO DIESEL INJECTORS. Prior to removing injector, thoroughly clean injector, lines and surrounding area using compressed air and a suitable solvent.

TESTING. A complete job of testing and adjusting injectors requires use of special test equipment. Only clean, approved testing oil should be used to test injectors. Injector nozzle should be tested for opening pressure, seat leakage and spray pattern.

When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Before conducting test, operate tester lever until test oil flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, which would indicate that injector may be serviceable without disassembly.

Opening pressure is adjusted by turning adjusting nut (2 – Fig. P1-16). Refer to following table for opening pressure on Roto Diesel injection nozzles:

Injector Type	Opening Pressure (MPa)
RDN OSDC 6577	11.0-12.0
RDN 12 SD 6236	13.5-14.5
RDN 12 SD 6517	12.3-13.3
RDN 45 D 6432	11.5-12.5

The nozzle tip should not leak when injector fluid is pressurized to 2 MPa below opening pressure. Hold pressure for 10 seconds; if drops appear or nozzle tip becomes wet, valve is not seating and injector must be overhauled.

The injector spray pattern should be well atomized, conical and emerge from nozzle tip in a straight axis. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

NOTE: Be sure injector tester is operating properly and connections are tight, especially if similar malfunctions are found in a series of injectors.

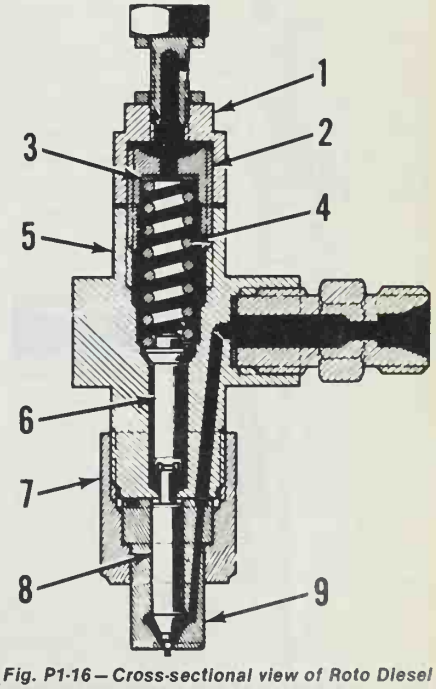


Fig. P1-16 – Cross-sectional view of Roto Diesel injector.

1. Cap nut
2. Adjusting nut
3. Washer
4. Spring
5. Injector body
6. Push rod
7. Nozzle nut
8. Nozzle valve
9. Nozzle

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder. Refer to Fig. P1-16 for a cross-sectional view of injector.

Secure injector body (5) in a soft jawed vise or holding fixture and disassemble injector, being careful not to drop or damage nozzle valve (8). Place all parts in a clean calibrating oil or diesel fuel as they are removed using a compartmented pan and using extra care to keep parts from each injector together and separate from other units.

Clean exterior surfaces with a brass wire brush, soaking in an approved carbon solvent if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces. Tighten nozzle nut (7) to 63.7 N·m.

BOSCH INJECTORS. Prior to removing injector, thoroughly clean injector, lines and surrounding area using compressed air and a suitable solvent.

TESTING. The testing procedure for Bosch injectors is same as Roto Diesel injectors; refer to Roto Diesel section while noting the following.

Opening pressure for Bosch injectors should be 11.0-12.0 MPa (1594-1739 psi) on Models XDP 4.90 and XD2P 4.94, or 12.5-13.5 MPa (1812-1957 psi) on Models XD2PS and XD2PT. Opening pressure is adjusted by varying thickness of shim (2 – Fig. P1-17).

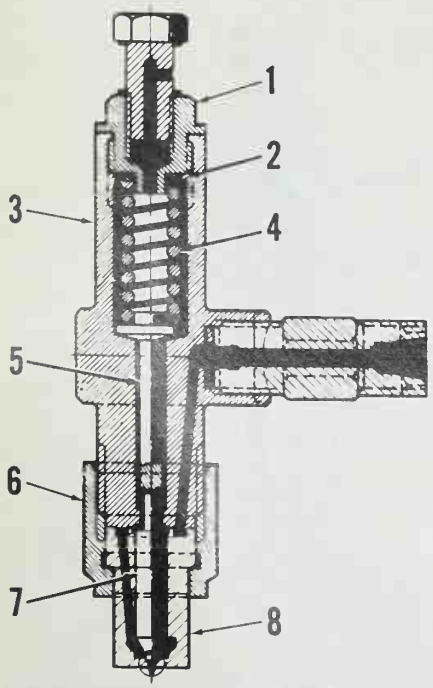


Fig. P1-17 – Cross-sectional view of Bosch injector.

1. Cap nut
2. Shim
3. Body
4. Spring
5. Push rod
6. Nozzle nut
7. Nozzle valve
8. Nozzle

GLOW PLUGS

Each cylinder is equipped with a glow plug. Glow plugs are connected in parallel with each glow plug grounded through mounting threads. Before suspecting a glow plug malfunction, determine that current is reaching glow plugs. To check individual glow plugs, remove electrical strap between glow plugs. With negative battery terminal grounded to engine, connect a test light between positive battery terminal and glow plug electrode. If test light turns on, then glow plug is good. If test light remains off, then glow plug is defective and must be renewed.

INJECTION PUMP

To remove injection pump, disconnect fuel lines and cap openings to prevent contamination. Disconnect control cables and remove rear pump support. On Models XD2PS and XD2PT, unscrew two Allen screws retaining injection pump and separate pump from engine. On all other models, remove screws securing pump support plate and separate pump with plate from engine.

The injection pump should be tested and overhauled by a shop qualified in diesel injection pump repair.

If removed, install gear on gear driven models or splined hub on chain driven models. Refer to INJECTION PUMP TIMING section and install pump. Refer to ENGINE SPEED ADJUSTMENT section if idle or high engine speed requires adjustment.

TURBOCHARGER

Models XD2PS And XD2PT

A Garret AiResearch Model T03 turbocharger is used on Models XD2PS and XD2PT. Refer to Fig. P1-18 for a cutaway drawing of turbocharger. Oil to lubricate and cool turbocharger bearings is provided by pressurized engine oil routed through an external oil line. Return oil is directed to a fitting in side of engine block.

The turbocharger is equipped with an integral wastegate which regulates turbocharger at a maximum pressure of 60 kPa. The wastegate valve (V – Fig. P1-19) is seated in turbine housing by spring (S) with the valve stem attached to diaphragm (D). When pressure in compressor housing (C) reaches 60 kPa, diaphragm (D) overcomes spring pressure and moves the valve off its seat. Exhaust gases bypass the turbocharger turbine thereby reducing turbine and compressor speed which results in reduced pressure in compressor housing. Spring force seats the wastegate valve (V) and the cycle repeats.

REMOVE AND REINSTALL. Removal of unit is apparent with inspection. Turbocharger must be serviced as a

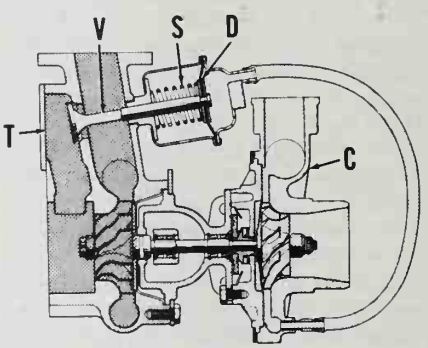


Fig. P1-19 – Cross-sectional view of turbocharger and wastegate used on Models XD2PS and XD2PT.

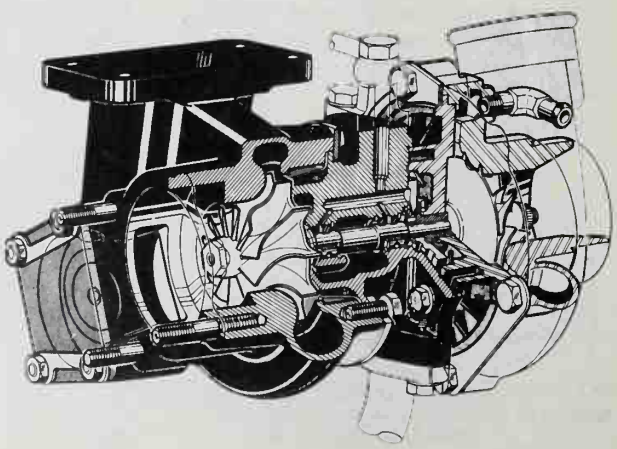


Fig. P1-18 – Cutaway drawing of Garret AiResearch Model T03 turbocharger used on Models XD2PS and XD2PT.

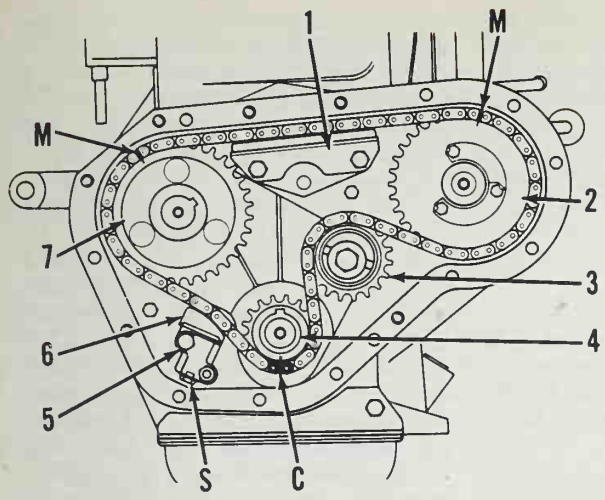


Fig. P1-20—Drawing showing timing chain and sprockets on models so equipped.
1. Rubbing block
2. Injection pump sprocket
3. Idler sprocket
4. Crankshaft sprocket
5. Tensioner
6. Tensioner shoe
7. Camshaft sprocket
C. Copper plated link
M. Timing marks
S. Adjusting screw

unit assembly as overhaul is accomplished at factory. When installing turbocharger, oil cavity of center housing should be filled with oil and oil line from engine should be primed with oil. This procedure is necessary to prevent dry starting of turbocharger and possible early failure of bearings.

TIMING CHAIN AND SPROCKETS

All Models So Equipped

CHAIN TENSION ADJUSTMENT. Chain slack is removed during engine operation by a hydraulically actuated chain tensioner (5—Fig. P1-20) which uses pressurized engine oil to force chain tensioner shoe (6) against the timing chain.

To adjust chain tensioner, loosen idler (3) retaining nut. Turn idler eccentric counterclockwise so gap between chain tensioner body (5) and shoe (6) is 0.5-1.0 mm. Tighten idler retaining nut to 49 N·m. Turn tensioner adjusting screw (S) so shoe (6) bounces against chain. Loosen rubbing block (1) nuts and place a straightedge on chain from camshaft to injection pump sprockets to back up chain. Press rubbing block (1) against chain and tighten nuts.

REMOVE AND REINSTALL. Timing chain and sprockets are accessible after removing chain cover. The injection pump must be removed if chain and sprockets are to be removed. Loosen idler sprocket retaining nut and rotate idler eccentric to loosen chain. Unscrew injection pump sprocket (2—Fig. P1-20) then remove sprocket while disengaging chain. If required, remove camshaft, crankshaft and idler sprockets.

Refer to Fig. P1-21 for a cross-sectional view of injection pump sprocket carrier. If sprocket or carrier assembly is renewed, check clearance between sprocket hub and timing chain cover with gasket installed. Clearance should be 0.06-0.94 mm.

The camshaft sprocket must be heated to 250° C. (482° F.) prior to installation on camshaft end. There must be 0.05-0.15 mm clearance between camshaft sprocket hub and camshaft retainer.

Note in Fig. P1-22 the three timing mark configurations used on the crankshaft sprocket of new engines. Replacement crankshaft sprockets have only one timing mark.

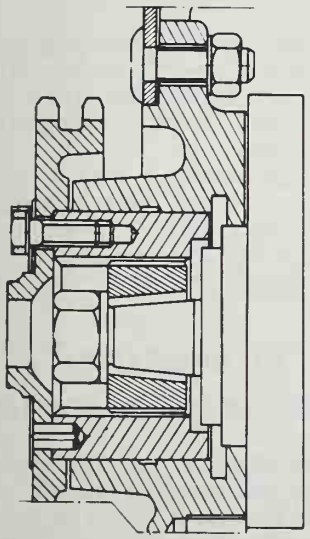


Fig. P1-21—Cross-sectional view of injection pump sprocket carrier on models equipped with a timing chain.

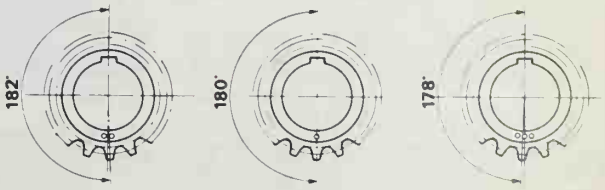


Fig. P1-22—View of crankshaft sprocket timing marks on factory installed sprockets.

To install timing chain, wrap chain around injection pump sprocket so marks (M—Fig. P1-20) on chain and sprocket are aligned. Engage chain with camshaft, crankshaft and idler sprockets so copper plated link (C) is opposite crankshaft sprocket timing mark and marks (M) on chain and camshaft sprocket are aligned. Tighten injection pump sprocket screws to 4.9-7.3 N·m on Bosch pump or 21.6-25.4 N·m on Roto Diesel pump. Refer to CHAIN TENSION ADJUSTMENT section and adjust timing chain tension as outlined. Install injection pump and timing chain cover. Tighten timing cover screws and nuts to 7.4-12.2 N·m.

TIMING GEARS

All Models So Equipped

Crankshaft, camshaft and idler gears are accessible after removing timing gear cover. Remove injection pump to service injection pump drive gear.

To install camshaft gear, heat gear to 250° C. (482° F.) prior to installation on camshaft end. There must be 0.05-0.15 mm clearance between camshaft retainer and gear hub.

End play of idler gear on idler shaft should be 0.05-0.35 mm.

Timing gears are stamped with timing marks which must be aligned during assembly. Tighten timing cover screws and nuts to 7.4-12.2 N·m. Install injection pump as previously outlined.

OIL PUMP

R&R AND OVERHAUL. To remove oil pump, remove oil pan, then unscrew flange screw (F—Fig. P1-25) and taper screw (R). Oil pump is serviced as a unit assembly.

To install pump, insert pump into cylinder block so taper hole in body is aligned with taper screw (R) and install screw with copper washer. Tighten screw to 19.6-24.5 N·m. Install flange screw (F) without a gasket and lightly tighten. Measure gap between flange screw (F) and boss as shown in Fig. P1-25. Select and install a shim 0.05-0.10 mm thicker than measured gap. Tighten flange screw to 79-98 N·m.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod may be removed after removing cylinder head and oil pump. Unscrew rod cap retaining nuts, remove rod cap and extract piston and rod.

Connecting rod marks and indentation in piston crown must be on same side. Install piston and rod so piston crown indentation is towards injection pump side of engine. Tighten rod nuts to 51.5-61.2 N·m

PISTON AND RINGS

Model XDP 4.88 and XDP 4.90 pistons are equipped with three compression rings and an oil control ring. Model XD2P 4.94, XD2PS and XD2PT pistons are equipped with two compression rings and an oil control ring.

Pistons of Models XDP 4.88 and XDP 4.90 are classed "A" or "B" according to piston size. Piston size should be matched with cylinder liner. Refer to CYLINDER LINER section. Piston class letter is stamped on piston crown. Class A piston diameter is 87.700-87.730 mm for Model XDP 4.88 and 89.705-89.735 mm for Model XDP 4.90. Class B piston diameter is 87.720-87.750 mm for Model XDP 4.88 and 89.725-89.755 mm for Model XDP 4.90. Piston diameter is measured perpendicular to piston pin, 74 mm from bottom of piston skirt. Piston clearance should be 0.27-0.32 mm for Model XDP 4.88 or 0.295-0.315 mm for Model XDP 4.90 using piston diameter previously listed.

Pistons of Models XD2P 4.94, XD2PS and XD2PT are classed "A" through 'H" according to piston size. Piston class letter is stamped on piston crown. Class A pistons are standard size while class C, E and G pistons are major oversize pistons. Class B, C, F and H pistons are slightly larger than standard or oversize pistons. For instance, a class C piston is 0.200 mm oversize and a class D piston is 0.215 mm larger than standard. Where possible, the slightly larger piston may be installed without boring to the next oversize. Measure piston diameter perpendicular to piston pin, 76.5 mm from bottom of piston skirt on Model XD2P 4.94 or 73.4 mm from bottom of piston skirt on Models XD2PS and XD2PT. Piston clearance should be 0.34-0.39 mm on Model XD2P 4.94 or 0.37-0.42 mm on Models XD2PS and XD2PT.

Top piston ring end gap should be 0.30-0.45 mm on Model XDP 4.88, 0.38-0.63 mm on Model XDP 4.90, 0.40-0.65 mm on Model XD2P 4.94 and 0.25-0.45 mm on Models XD2PS and XD2PT. Piston ring end gap for middle compression rings should be 0.30-0.45 mm on Model XDP 4.88, 0.38-0.63 mm on Model XDP 4.90, 0.35-0.60 mm on Model XD2P 4.94 and 0.25-0.45 mm on Models XD2PS and XD2PT. Oil control ring end gap should be 0.15-0.30 mm on Models XD2P 4.94, XD2PS and XD2PT. Oil control ring on Models XDP 4.88 and XDP 4.90 must not be altered.

PISTON PIN

A full floating piston pin is used in all models. Piston pin diameter is 30.000-30.006 mm for Models XD2PS and XD2PT or 28.000-28.006 mm for all other models.

CONNECTING ROD AND BEARINGS

Connecting rods are equipped with a renewable bushing in the small end and insert type bearings in the big end. Bushing inner diameter is 30.007-30.020 mm on Models XD2PS and XD2PT or 28.007-28.020 mm on all other models. Clearance between big end bearing and crankpin should be 0.040-0.092 mm on all models. Rod side play should be 0.010-0.025 mm.

Connecting rods are graded according to weight and stamped with a number (1 through 5) or letter (A through H). Renew rod with one of same weight grade.

CAMSHAFT AND TAPPETS

R&R AND OVERHAUL. To remove camshaft, remove valve cover and push rods. Remove tappet cover and extract tappets. Remove oil pan and oil pump. Detach timing chain or gear cover, and on models so equipped, remove timing chain. Unscrew camshaft retainer plate screws and withdraw camshaft.

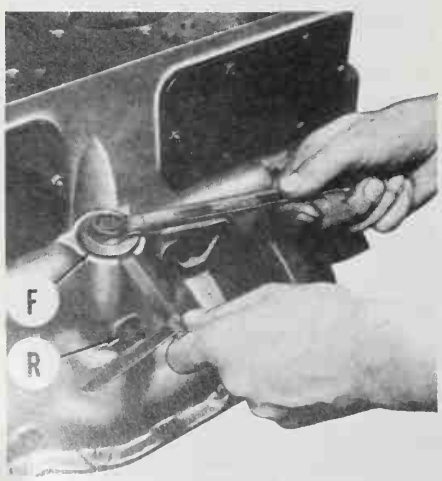


Fig. P1-25—Measure clearance between flange screw (F) and boss as outlined in text. Taper screw (R) holds oil pump in block.

Camshaft journal diameter is 41.925-49.950 mm. Camshaft bearing clearance should be 0.05-0.11 mm. Standard tappet diameter is 23.95-23.96 mm. Oversize tappets with a diameter of 24.15-24.16 mm are available. Tappet clearance should be 0.04-0.08 mm.

To install camshaft, reverse removal procedure. Be sure camshaft journals and lobes are adequately lubricated. Refer to TIMING GEARS AND SPROCKETS or TIMING GEARS section to install camshaft sprocket or gear. Be sure camshaft journals and lobes are adequately lubricated. Align gear timing marks on models so equipped. Tighten camshaft retainer plate screws to 14.7-19.6 N·m. On models equipped with a timing chain, refer to TIMING CHAIN AND SPROCKETS section and install chain. Refer to OIL PUMP section for pump installation.

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove flywheel and timing gear or chain cover. Remove timing chain on models so equipped. Remove pistons and rods. The crankshaft can be removed after detaching main bearing caps.

Standard main journal diameter is 54.994-55.021 mm. Main bearing clearance should be 0.040-0.098 mm for all journals. Undersize main bearings are available.

Crankshaft end play is controlled by thrust washers attached to center main bearing. Crankshaft end play should be 0.08-0.29 mm. Thrust washers are available in thicknesses of 2.30-2.33 and 2.50-2.53 mm. Install thrust washers with smooth side towards main bearings.

Crankpin standard journal diameter is 54.994-55.021 mm on Models XD2PS and XD2PT, and 49.984-50.011 on all other models. Rod bearing undersizes are available.

To install crankshaft, reverse removal procedure. Tighten main bearing cap screws to 98-117.6 N·m. Rolling torque necessary to turn crankshaft with pistons installed should not exceed 58.8 N·m.

CYLINDER LINER

Models XDP 4.88 and XDP 4.90

Models XDP 4.88 and XDP 4.90 are equipped with wet type cylinder liners. Cylinder liner lower end is sealed by a rubber ring. Cylinder liner standout above block surface should be

0.025-0.085 mm.

Cylinder liners are classed according to bore size to match with pistons. Refer to PISTON AND RINGS section. The liner is marked on the outer edge at bottom of bore with one or two notches. Class "A" cylinder liners have one notch and class "B" cylinder liners have two notches. Cylinder liner bore diameter of class A liners is 88.00-88.02 mm for Model XDP 4.88 or 90.00-90.02 mm for Model XDP 4.90. Cylinder liner bore diameter of class B liners is 88.02-88.04 mm for Model XDP 4.88 or 90.02-90.04 mm for Model XDP 4.90.

VOLKSWAGEN

VOLKSWAGEN INDUSTRIAL ENGINES
3737 Lake-Cook Road
Deerfield, Illinois 60015

Model	No. Cyls.	Bore	Stroke	Displ.
068.2	4	76.5 mm	80 mm	1471 cc

The Volkswagen Model 068.2 engine is a four-stroke, liquid-cooled diesel. The cylinder block is cast iron and the cylinder head is aluminum.

Cylinders are numbered 1 through 4 with number 1 cylinder nearest crankshaft pulley. Firing order is 1-3-4-2. Crankshaft rotation is counterclockwise at flywheel end.

MAINTENANCE

LUBRICATION

Recommended oil is API classification CC or CD. Oil weight should be SAE 40 for ambient temperatures above 20° C. (68° F.), SAE 30 for ambient temperatures between 20° C. (68° F.) and 0° C. (32° F.), SAE 20W20 for ambient temperatures between 0° C. (32° F.) and minus 10° C. (14° F.) and SAE 10W for ambient temperatures below minus 10° C. (14° F.). Crankcase capacity with filter is 3.5 liters. A renewable oil filter is mounted on side of cylinder block.

The engine is equipped with a pressurized oil system. Oil pressure should be 196 kPa with engine running at 2000 rpm and engine temperature at 80° C. (176° F.).

ENGINE SPEED ADJUSTMENT

Low and high idle speeds are adjusted using screws (I and H – Fig. V1-1) on injection pump. Low idle speed screw (I) is on engine side of pump. With engine at normal operating temperature, turn low idle speed screw (I) to obtain a low idle speed of 850-950 rpm. Turn high idle speed screw (H) so maximum engine speed does not exceed 4000 rpm on continuous duty engines or 5000-5500 rpm for intermittently loaded engines.

FUEL SYSTEM

FUEL FILTER. On models so equipped, inspect and periodically renew filter element. Drain water each time engine is started.

BLEED FUEL SYSTEM. If air enters fuel system, the following procedure may be used to bleed air from fuel system: Loosen fuel fitting or bleed screw at fuel filter and allow fuel to flow until air is expelled, then retighten fitting or bleed screw. Loosen inlet fuel line fitting on injection pump and allow fuel to flow until air is expelled, then retighten fitting. Disconnect high pressure fuel lines from injectors. Rotate engine to operate fuel injection pump, then reconnect fuel lines when air-free fuel flows from fuel lines.

INJECTION PUMP TIMING. Injection pump timing is correct when mark (M – Fig. V1-1) on pump flange and notch (N) on mounting plate are aligned. If marks are unuseable or believed inaccurate, refer to following procedure to time pump.

NOTE: Timing belt tension and valve timing affect injection pump timing. If belt tension is incorrect or belt has slipped over gear teeth, refer to TIMING BELT section.

Install VW tool 2068 (T – Fig. V1-2) on flywheel end of cylinder block (B) as shown. Rotate flywheel so number 1 piston is on compression and TDC mark (M) is aligned with tip of timing tool (T). Remove plug from rear of injection pump and install a dial gage as shown in Fig. V1-3. Preload gage so dial reading is 3 mm. Turn flywheel clockwise until dial needle just stops, then zero dial gage. Turn flywheel counterclockwise until dial gage reads 0.83 mm. Flywheel TDC mark (M – Fig. V1-2) should be aligned with pointer of timing tool (T). If not, rotate flywheel so TDC mark aligns with timing tool point. Loosen injection pump mounting screws and carefully rotate injection pump so dial gage reads 0.83 mm. Retighten pump mounting screws to 24.5 N·m. If necessary, construct new timing marks on pump mounting flange and pump mounting plate. Remove dial gage and install plug.

COOLING SYSTEM

The engine is liquid cooled and equipped with a water pump to circulate coolant. Due to aluminum construction of cylinder head, antifreeze with anti-corrosion additives should be used to prevent corrosion.

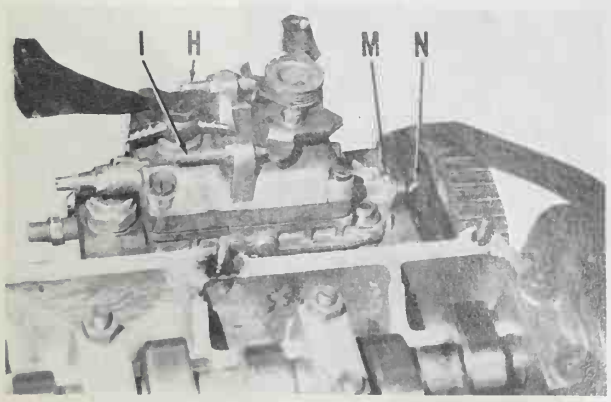


Fig. V1-1 – View of fuel injection pump showing location of idle (I) and high (H) speed adjusting screws. Note location of injection pump timing mark (M) and timing notch (N) on mounting plate.

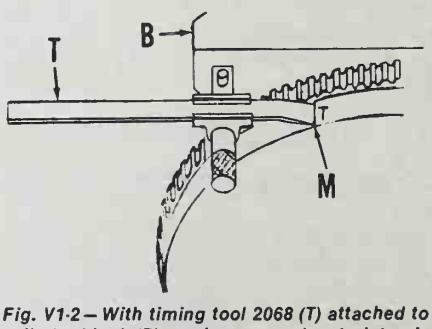


Fig. V1-2 – With timing tool 2068 (T) attached to cylinder block (B) as shown, number 1 piston is at TDC when TDC mark (M) aligns with tool point.

Water pump belt tension is adjusted by removing pump pulley and adding or removing spacers between pulley halves. Belt tension is correct if thumb pressure deflects belt approximately 10 mm.

Thermostat opening temperature is 80° C. (176° F.) and full flow temperature is 94° C. (201° F.).

REPAIRS

TIGHTENING TORQUES

Refer to following table for tightening torques. All values are in newton meters.

Camshaft cap nuts	19.6
Camshaft sprocket	78.4
Connecting rod	44.1
Crankshaft sprocket	78.4
Cylinder head	see text
Flywheel	73.5
Injection pump	24.5
Injection pump sprocket	44.1
Injector nozzle nut	68.6
Intermediate shaft seal carrier	24.5
Intermediate shaft sprocket	78.4
Main bearing	63.7
Oil pan	19.6
Oil pump base	9.8
Oil pump mounting screws	19.6
Timing belt tension pulley	44.1

COMPRESSION PRESSURE

Compression pressure should be 333 kPa with a minimum allowable compression pressure of 275 kPa. Compression pressure difference between cylinders should be less than 49 kPa.

TIMING BELT AND VALVE TIMING

A rubber composition timing belt is used to drive camshaft, injection pump and intermediate shaft. Belt tension is adjusted by loosening tensioner pulley nut and rotating pulley against belt. Use VW tool 210 or other similar tool and adjust belt tension so a reading of 12 or 13 is obtained on tool scale.

Use the following procedure for correct valve timing when installing timing belt: Rotate crankshaft so number 1 piston is on compression and top dead center mark (M – Fig. V1-2) on flywheel is aligned with pointer of Volkswagen timing tool 2068 (T). Camshaft sprocket must be loose on camshaft taper, if not, loosen sprocket retaining screw approximately one-half turn and tap sprocket loose. Loosen and rotate tensioner pulley to maximum slack position. Remove camshaft cover. Note slot (S – Fig. V1-4) in rear of camshaft and turn camshaft so both cam lobes for number 1 cylinder are pointing up. Install Volkswagen tool bar 2065 (B – Fig. V1-5) in camshaft slot to position slot parallel with head surface. Rotate injection pump sprocket and insert tool 2064 (T – Fig. V1-6) through sprocket hole and hole in injection pump mounting plate. Refer to Fig. V1-7 and install timing belt over sprockets and pulleys. Adjust belt tension by rotating tensioner pulley so timing belt tension between camshaft and injection pump sprockets is 12-13 mm on scale of Volkswagen tension tool 210. Tighten tensioner pulley screw to 44.1 N·m. Tighten camshaft sprocket retaining screw to 78.4 N·m. Remove timing tools, rotate crankshaft several turns and recheck belt tension.

VALVE TAPPET GAP

The camshaft is located in the cylinder head directly above the valves. Gap between camshaft lobe and tappet is adjusted by varying thickness of shim (S – Fig. V1-8) which sits in recess of tappet.

Valve tappet gap should be measured with engine coolant temperature at approximately 35° C. (95° F.). Desired tappet gap is 0.20-0.30 mm for intake valve and 0.40-0.50 mm for exhaust valve. The valve tappet must be depressed using a suitable tool to remove

Fig. V1-3 – View showing installation of dial gage in injection pump for injection timing. Injection lines may remain connected.

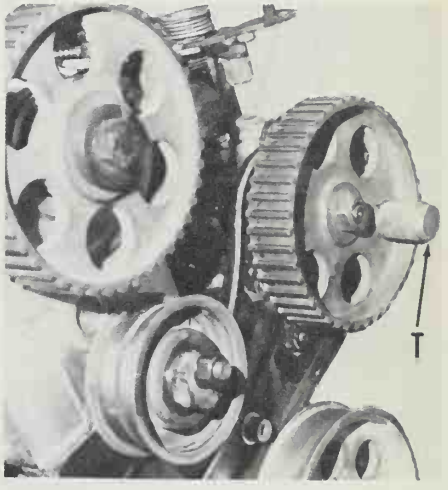


Fig. V1-6 – Insert tool 2064 (T) through holes in injection pump sprocket and pump mounting plate.

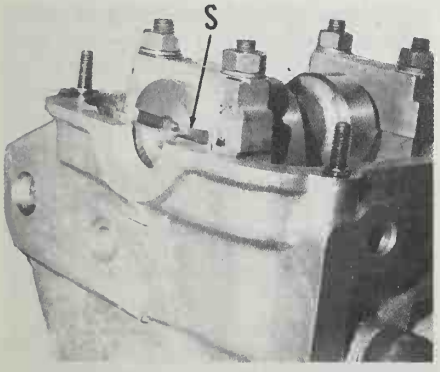
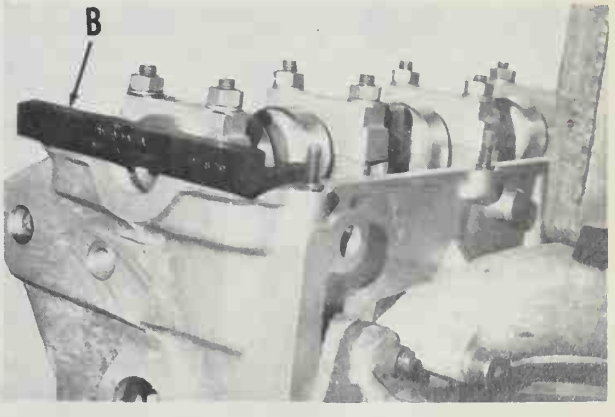


Fig. V1-4 – View of slot (S) in camshaft rear.

Fig. V1-5 – View of camshaft locking tool 2065 (B) engaged in slot (S – Fig. V1-4). Number 1 cylinder camshaft lobes point up when slot (S) is correctly positioned to accept tool (B).



or install shim (S).

CAUTION: Piston of cylinder requiring adjustment must be at least 90 degrees from top dead center to prevent contact between piston and valves.

Install shim (S) so side marked with shim thickness is against valve tappet.

CAMSHAFT

REMOVE AND REINSTALL. The camshaft is located in cylinder head and rides directly in aluminum of head and five caps which secure camshaft.

To remove camshaft, remove air cleaner and timing belt cover. Loosen timing belt tensioner and slide belt off camshaft sprocket. If necessary, remove camshaft sprocket. Remove cylinder head cover and note that camshaft retaining caps are numbered 1 through 5 with number 1 cap nearest camshaft sprocket end. Remove bearing caps 1, 3 and 5, then using alternate turns in a diagonal pattern, unscrew nuts securing caps 2 and 4 until valve spring pressure is released and camshaft can be removed.

Inspect camshaft, head and caps for excessive wear and damage. Maximum camshaft runout is 0.01 mm measured at center of camshaft with camshaft supported at ends.

Lubricate camshaft journals and bearing surfaces of head and caps prior to assembly. Install camshaft on cylinder head, then place caps numbered 2 and 4 on camshaft but do not tighten nuts.

NOTE: Bearing surface in camshaft retaining caps is offset; be sure cap is installed correctly. Cap numbers – 1 through 5 – may not be on same side of camshaft.

Alternately tighten in a diagonal pattern nuts securing caps 2 and 4. Install caps 1, 3 and 5 and tighten nuts for all caps to 19.6 N·m. Camshaft end play should not exceed 0.15 mm. Install camshaft sprocket and refer to TIMING BELT AND VALVE TIMING section. Install cylinder head cover, timing belt cover and air cleaner.

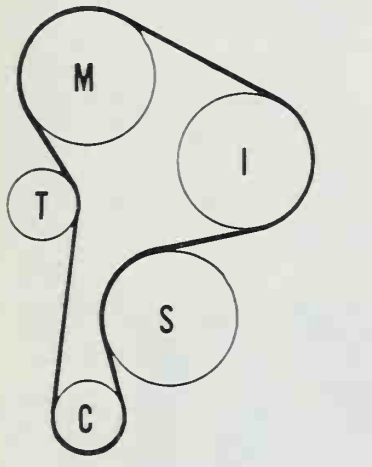


Fig. V1-7 – Install timing belt as shown in diagram.

C. Crankshaft sprocket
I. Injection pump sprocket
M. Camshaft sprocket
S. Intermediate shaft pulley
T. Tensioner pulley

CYLINDER HEAD

R&R AND OVERHAUL. Drain coolant and detach coolant hoses from cylinder head. Detach timing belt cover, loosen belt tension pulley and remove belt from camshaft sprocket. Remove air cleaner, then disconnect and cap fuel injection lines. Remove cylinder head cover and unscrew cylinder head screws using reverse of sequence shown in Fig. V1-9. Remove camshaft as previously outlined for access to valve components. Volkswagen tool VW541 or other suitable tool is used to depress valve spring so valve can be unlocked and removed.

Cylinder head surface must not be warped more than 0.1 mm. Cylinder head must be discarded if head surface distortion is excessive as manufacturer does not recommend machining head surface.

Valve guides are renewable. Press guides out towards camshaft side of head. Cylinder head should be cold and guide lubricated with oil for installation. Press new guide in from camshaft side of head until guide is seated. Do not use excessive force. Ream valve guide to inner diameter of 8.00 mm.

To select proper cylinder head gasket thickness and obtain desired valve-to-piston clearance, measure height of piston above cylinder block surface with piston at TDC. Refer to following table and install listed gasket:

Piston Height	Gasket Thickness
0.43-0.63 mm	1.3 mm
0.63-0.82 mm	1.4 mm
0.82-0.92 mm	1.5 mm
0.92-1.023 mm	1.6 mm

Note that some head gaskets are marked "OBEN" to indicate top or surface next to cylinder head.

When installing cylinder head, tighten cylinder head screws to 83.3 N·m with engine cold or to 93.1 N·m with engine warm. Follow tightening sequence in Fig. V1-9. Refer to CAMSHAFT, VALVE TAPPET GAP and TIMING BELT AND TIMING GEARS sections during reassembly.

VALVE SYSTEM

Remove cylinder head and camshaft as previously outlined for access to valve system components. Volkswagen tool VW541 or other suitable tool is used to depress valve spring so valve can be un-

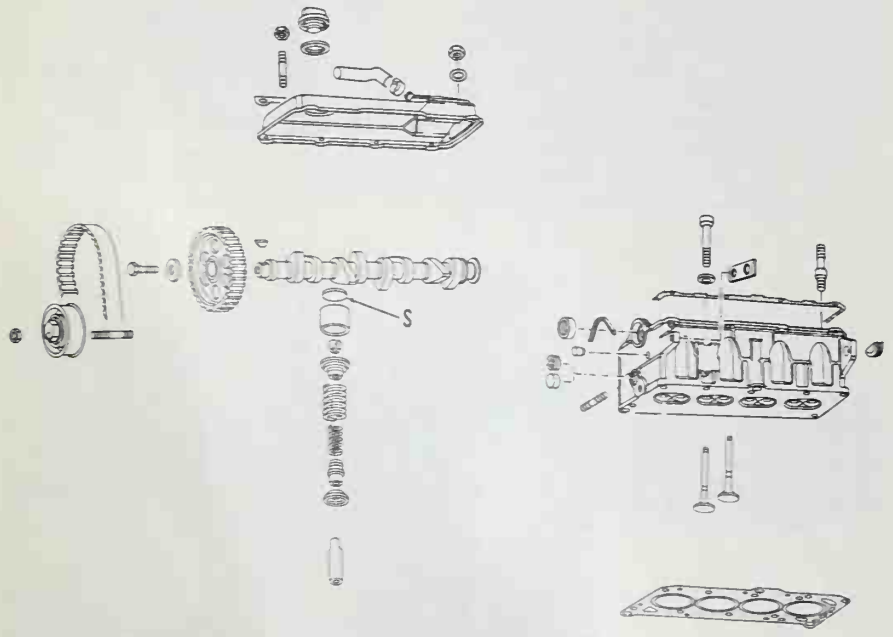


Fig. V1-8 – Exploded view of cylinder head assembly. Shim (S) adjusts valve tappet gap.

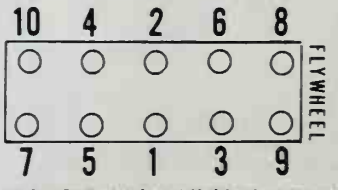


Fig. V1-9 – Cylinder head tightening sequence.

locked and removed.

Valves ride in guides pressed in cylinder head. Refer to CYLINDER HEAD section for renewal. Valve stem diameter is 7.97 mm on intake valve or 7.95 mm on exhaust valve.

Valves seat on non-renewable inserts in cylinder head. Valve seat angle is 45 degrees for both valves. Valve seat width should be 2.0 mm for intake valve or 2.4 mm for exhaust valve. Valve face angle is 45 degrees for both valves and valve margin should not be less than 0.5 mm.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE AND REINSTALL. Before removing an injector or loosening injector lines, thoroughly clean injector, lines and adjacent area with a suitable solvent and compressed air. Disconnect high pressure and by-pass lines from injector, then cap lines to prevent contamination. Unscrew injector from cylinder head, then remove and discard heat shield (9–Fig. V1-10).

Before installing injector, be sure injector bore and seating surface in head are clean and free of carbon. Install heat shield (9) with concave side towards combustion chamber as shown in Fig. V1-11. Install injector and tighten to 68.6 N·m. Reconnect injector lines.

TESTING. A complete job of testing and adjusting injectors requires use of special test equipment. Only clean, approved testing oil should be used to test injectors. Injector nozzle should be tested for opening pressure, seat leakage and spray pattern.

When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Before conducting test, operate tester lever until test oil flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, which would indicate that injector may be serviceable without disassembly.

OPENING PRESSURE. Open valve to tester gage and operate tester lever slowly while observing gage reading. Opening pressure should be 11.8-12.8 MPa (1700-1850 psi).

Opening pressure is adjusted by varying thickness of shim (2–Fig. V1-10). Increasing or decreasing shim thickness by 0.5 mm will change opening pressure approximately 490 kPa (70 psi).

SEAT LEAKAGE. Injector nozzle tip should not leak at a pressure less than 10.8 MPa (1560 psi). To check for leakage, actuate tester lever slowly and as gage needle approaches suggested test pressure, observe nozzle tip. Hold pressure for 10 seconds; if drops appear or nozzle tip becomes wet, valve is not seating and injector must be disassembled and overhauled as later outlined.

NOTE: Leakage of tester check valve or connections will cause a false reading, showing up in this test as fast leakback. If a series of injectors fail to pass this test, the tester rather than injector units should be suspected.

SPRAY PATTERN. Spray pattern should be well atomized and slightly conical, emerging in a straight axis from nozzle tip. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder assembly. Refer to Fig. V1-10 for exploded view and proceed as follows:

Secure injector body (1) in a soft jawed vise or holding fixture and remove nozzle nut (8). Place all parts in clean calibrating oil or diesel fuel as they are removed, using a compartmented pan and using extra care to keep parts from each injector together and separate from other units.

Clean exterior surfaces with a brass wire brush, soaking in an approved carbon solvent if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces. Tighten nozzle nut (8) to 68.6 N·m when installing on injector body (1).

GLOW PLUGS

Each cylinder is equipped with a glow plug. Glow plugs are connected in parallel with each glow plug grounded through mounting threads. Before suspecting a glow plug malfunction, determine that current is reaching glow plugs. To check individual glow plugs, remove electrical strap between glow plugs. With negative battery terminal grounded to engine, connect a test light between positive battery terminal and glow plug electrode. If test light turns on, then glow plug is good. If test light remains off, then glow plug is defective and must be renewed.

INJECTION PUMP

Refer to Fig. V1-1 for view of injection pump. The injection pump should be tested and overhauled by a shop qualified in diesel injection pump repair.

To remove injection pump, disconnect fuel lines and cap openings to prevent contamination. Disconnect control cables. Detach timing belt cover, loosen belt tensioner pulley and slide timing

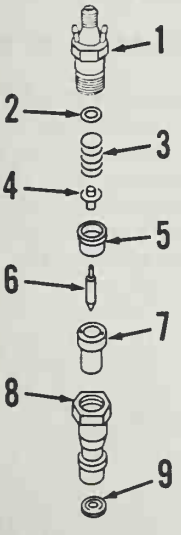


Fig. V1-10–Exploded view of fuel injection nozzle.

1. Body
2. Shim
3. Spring
4. Pressure pin
5. Spacer
6. Valve
7. Nozzle
8. Nozzle nut
9. Heat shield

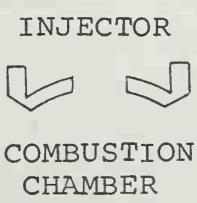


Fig. V1-11–Install heat shield so concave side is towards combustion chamber.

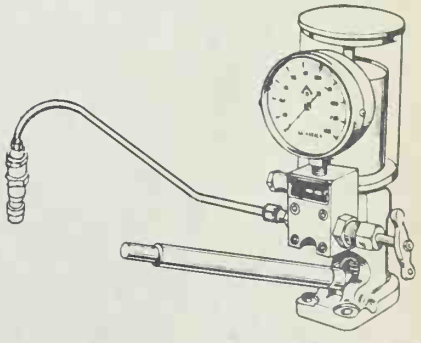


Fig. V1-12–View of typical fuel injection nozzle tester.

belt off injection pump sprocket. Using a suitable puller, remove sprocket from pump shaft. Remove pump retaining screws and remove pump.

When installing pump, tighten pump retaining screws to 24.5 N·m and sprocket nut to 44.1 N·m. Refer to TIMING BELT AND VALVE TIMING section to install timing belt and to INJECTION PUMP TIMING section for pump timing. Refer to ENGINE SPEED ADJUSTMENT section if idle or high engine speed requires adjustment.

OIL PUMP

R&R AND OVERHAUL. The oil pump is driven by intermediate shaft (8–Fig. V1-13) gear and a gear coupled to oil pump drive shaft (14). To remove oil pump, remove oil pan and unscrew oil pump mounting screws.

Remove oil pump base and pickup (17). Backlash between pump gears should be 0.05-0.2 mm. Place a straightedge across face of body and measure gap between straightedge and ends of gears. Maximum allowable gap is 0.15 mm.

Tighten oil pump base screws to 9.8 N·m. Install pump and tighten pump mounting screws to 19.6 N·m.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod are removed as a unit after removing cylinder head and oil pump. Unscrew rod cap retaining nuts, detach rod cap and extract piston and rod.

Marks (M–Fig. V1-15) cast in rod and cap must be on same side when installing cap on rod. Install piston and rod units so marks (M) are nearer intermediate shaft side of engine and arrow on piston crown points towards crankshaft pulley end. Tighten rod cap nuts to 44.1 N·m. If new pistons or rods are installed, refer to CYLINDER HEAD section and determine head gasket thickness.

PISTON AND RINGS

All pistons are equipped with two compression rings and an oil control ring. Oversize pistons and rings are available.

Clearance between piston and cylinder bore should be 0.03 mm. Measure piston diameter approximately 15 mm from bottom of piston skirt and perpendicular to piston pin.

Piston ring end gap is 0.3-0.5 mm for compression rings and 0.25-0.40 mm for oil ring. Maximum allowable end gap is 1.0 mm for any ring. Side clearance is 0.06-0.09 mm for top compression ring, 0.05-0.08 mm for second compression ring and 0.03-0.06 mm for oil ring. Maximum allowable side clearance is 0.2 mm for compression rings and 0.15 mm for oil ring.

PISTON PIN

Piston pin is full floating and retained by circlips in piston. Piston pin removal and installation is eased if piston is heated to approximately 60° C. (140° F.).

CONNECTING ROD AND BEARINGS

Connecting rod is equipped with a renewable bushing in the small end and insert type bearings in the big end. Clearance between rod bearing and crankpin should be 0.028-0.088 mm. Maximum bearing clearance is 0.12 mm. Maximum rod side play is 0.37 mm.

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, drain coolant then remove water pump and, if so equipped, alternator and starter. Remove fuel injection pump, cylinder head and piston and rod units. Remove crankshaft V-belt pulley and timing belt sprocket. Remove fly-

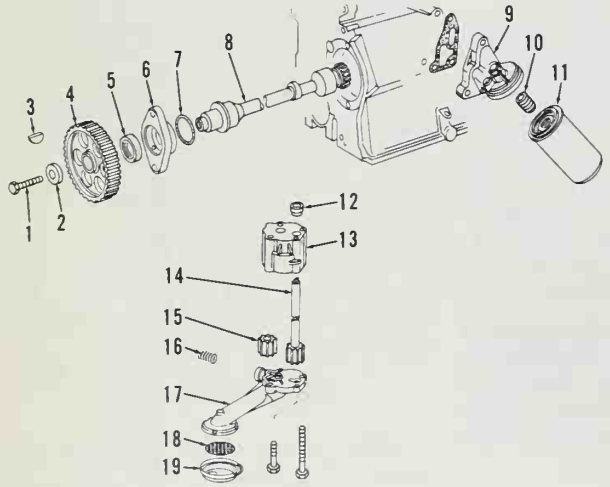


Fig. V1-13—Exploded view of intermediate shaft and oil pump assemblies.

1. Screw
2. Washer
3. Key
4. Sprocket
5. Seal
6. Carrier
7. "O" ring
8. Intermediate shaft
9. Filter mount
10. Nipple
11. Oil filter
12. Bushing
13. Pump body
14. Drive shaft & gear
15. Driven gear
16. Relief spring
17. Pickup
18. Screen
19. Cap

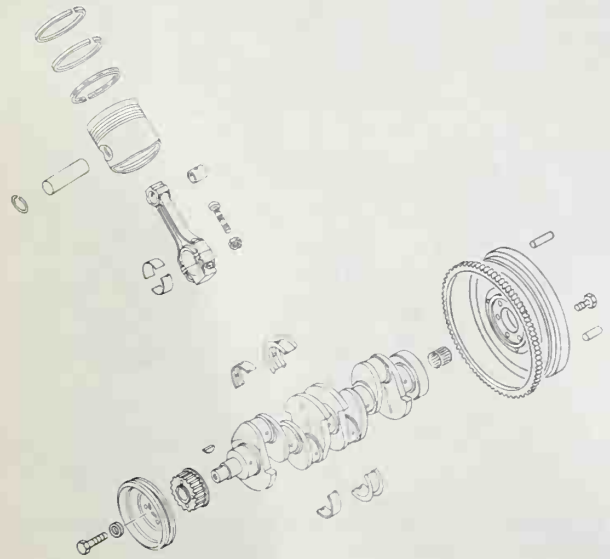


Fig. V1-14—Exploded view of crankshaft, piston and rod assemblies.

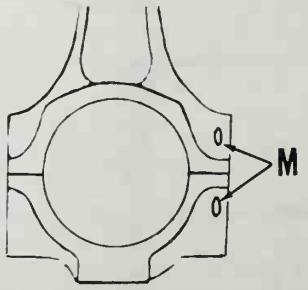


Fig. V1-15—Connecting rod marks (M) must be on same side as shown.

wheel and seal carriers at both ends of crankshaft. The crankshaft can be removed after detaching main bearing caps.

Main bearing clearance is 0.03-0.08 mm with a maximum limit of 0.17 mm. Crankshaft end play is 0.07-0.17 mm with a maximum limit of 0.37 mm. Crankshaft end play is controlled by center main bearing.

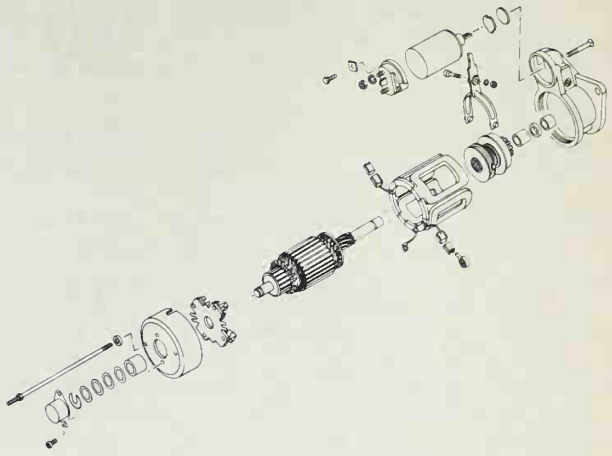


Fig. V1-16—Exploded view of starter.

CRANKSHAFT SEALS

Crankshaft seals are located in seal carriers which are attached to front and rear of cylinder block. Seals may be renewed without detaching seal carriers, however, if seal carriers must be removed, note that two screws in each end of oil pan are threaded into seal carriers.

WISCONSIN

TELEDYNE WISCONSIN MOTOR
Milwaukee, Wisconsin 53219

Model	No. Cyls.	Bore	Stroke	Displ.
WD1-340	1	75 mm	78 mm	345 cc
WD1-350	1	75 mm	78 mm	345 cc
WD1-430	1	84 mm	78 mm	432 cc
WD1-660	1	95 mm	95 mm	673 cc
WD1-670	1	95 mm	95 mm	673 cc
WD1-750	1	100 mm	95 mm	746 cc

Engines covered in this section are air-cooled, single-cylinder, four-stroke diesel engines. Crankshaft rotation is counterclockwise at pto end.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0° C. (32° F.), SAE 20 for temperatures between 0° C. (32° F.) and 20° C. (68° F.), and SAE 40 for temperatures above 20° C. (68° F.). API oil classification should be CD. Oil sump capacity is 0.95 liters on Models WD1-340, WD1-350 and WD1-430 or 2.8 liters on all other models. Manufacturer recommends renewing oil after first 25 hours of operation and after every 100 hours of operation thereafter.

A renewable oil filter is located on the oil pickup tube of all models. Remove screws securing oil pickup (P–Fig. W1-1) and withdraw pickup from crankcase. Oil pickup filter should be renewed after every other oil change.

Models WD1-660, WD1-670 and WD1-750 are equipped with a renewable external oil filter. Renew filter after first 25 hours of operation then after every other oil change.

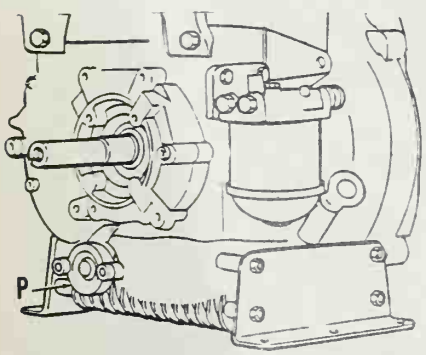


Fig. W1-1—Remove oil pickup (P) for access to internal oil filter.

ENGINE SPEED ADJUSTMENT

Idle speed is adjusted by turning idle speed screw (I–Fig. W1-2) and high speed is adjusted by turning high speed screw (H). Idle speed should be 1500-1800 rpm while maximum governed speed under load may be 2200 or 3000 rpm depending on engine application.

FUEL SYSTEM

FUEL FILTERS. A fuel filter is located in the fuel tank on all models and some engines may be equipped with an external fuel filter. Renew fuel filters after every 200 hours of operation or sooner if required.

BLEED FUEL SYSTEM. On gravity-feed fuel systems, a fuel return line and check valve are connected to the fuel injection pump as well as the fuel supply line. Fuel supply line should bleed air automatically up to fuel injection pump on gravity flow systems. To bleed high pressure injection line, loosen fitting for high pressure line at injector, then rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection line. Retighten injection line.

On engines equipped with a fuel transfer pump, loosen fuel supply line fitting on injection pump, then rotate engine crankshaft to operate fuel transfer pump until air-free fuel flows from fuel line. Retighten fuel supply line and loosen fitting for high pressure injection line at injector. Rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection line. Retighten injection line.

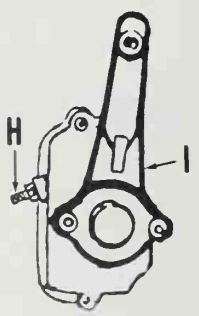


Fig. W1-2—View showing location of high speed adjusting screw (H). Idle speed screw is located behind speed control lever at (I).

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G–Fig. W1-3) between pump body and mounting surface of crankcase. Refer to INJECTION PUMP section for pump removal and installation.

To check injection pump timing, un-

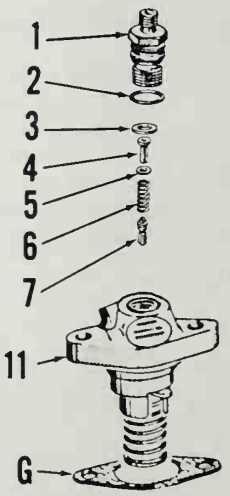


Fig. W1-3—Partial exploded view of fuel injection pump. Injection timing is adjusted using shim gaskets (G).

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Shim
6. Spring
7. Delivery valve
11. Fuel injection pump

screw high pressure injection line from injection pump delivery valve holder (1). Unscrew delivery valve holder (1) and remove spring (6), shim (5), spring guide (4) and delivery valve (7), then screw delivery valve holder (1) back into pump. Move throttle control to full speed position. Rotate engine in normal direction (counterclockwise at pto) so piston is on compression stroke. Fuel will flow out of delivery valve holder – it may be necessary to connect a gravity-flow fuel tank to injection pump if engine is not so equipped. Stop engine rotation at moment fuel ceases to flow. Timing mark (R – Fig. W1-4) should be within 3 mm of injection timing mark (N) on crankcase. To advance injection timing, remove shim gaskets (G – Fig. W1-3); install shim gaskets to retard injection timing. Reinstall removed pump parts after checking timing.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques. All values are in newton meters.

Models WD1-340, WD1-350 And WD1-430

Connecting rod	34.3
Crankcase	29.4
Cylinder head	44.1
Fan	15.7
Flywheel	176.4
Gear cover	24.5
Injection pump	24.5
Injector retainer plate	9.8

Models WD1-660, WD1-670 And WD1-750

Connecting rod	49
Crankcase	
M8	29.4
M12	68.6
Cylinder head	68.6
Fan	15.7
Flywheel	588
Gear cover	24.5
Injection pump	29.4
Injector retainer plate	9.8

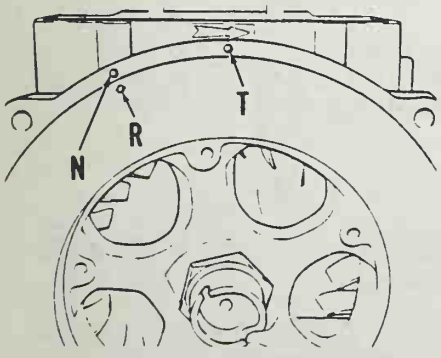


Fig. W1-4 – Fuel injection should occur when flywheel reference mark (R) is aligned with crankcase mark (N). The piston is at top dead center when flywheel mark (R) is aligned with crankcase mark (T).

VALVE TAPPET GAP

Valve tappet gap may be adjusted after removing rocker arm cover. Valve tappet gap with engine cold should be 0.15 mm for exhaust valve (1 – Fig. W1-5) and 0.10 mm for intake valve (5) on Models WD1-340, WD1-350 and WD1-430, or 0.20 mm for both valves on Models WD1-660, WD1-670 and WD1-750.

CYLINDER HEAD AND VALVE SYSTEM

R&R AND OVERHAUL. To remove cylinder head, disconnect high pressure and return fuel injection lines then immediately cap fuel lines. Remove muffler, air cleaner, exhaust and intake manifolds. Remove rocker arm cover, unscrew cylinder head retaining nuts and remove cylinder head.

Valve face angle for both valves is 45½ degrees and valve seat angle is 45 degrees. Valve seats are renewable and must be installed with head heated to 200° C. (392° F.).

Intake valve stem diameter is 36.095-36.120 mm for Models WD1-340, WD1-350 and WD1-430 or 44.143-44.159 mm for all other models. Exhaust valve stem diameter is 32.095-32.120 mm for Models WD1-340, WD1-350 and WD1-430 or 43.143-43.159 mm for all other models. Valve stem clearance should be 0.040-0.070 mm on Models WD1-340, WD1-350 and WD1-430 or 0.070-0.100 mm on all other models.

Valve guides are renewable. Heat cylinder head to 200° C. (392° F.) when removing or installing valve guides. To remove valve guide, press guide out top of cylinder head. When installing valve guide note that guide may have a locating flange or a circlip (10 – Fig. W1-6). Press guide into head from rocker arm side of head so guide flange bottoms or circlip seats in groove.

Reassemble by reversing disassembly procedure. Install new "O" rings on compression release shaft. Install new upper seals on push rod tubes. Tighten cylinder head nuts to 68.6 N·m.

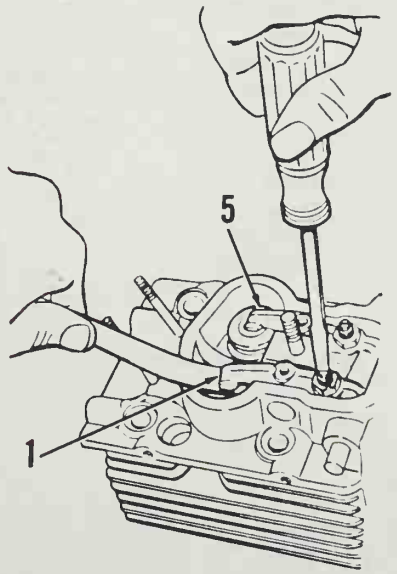


Fig. W1-5 – Refer to text for adjustment of exhaust (1) and intake (5) valve tappet gap.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and high pressure injection line and immediately cap or plug all openings. Unscrew retainer plate and remove injector and copper washer.

Reverse removal procedure to reinstall injector. Install a new copper washer (9 – Fig. W1-7). Tighten injector retaining plate nuts to 9.8 N·m.

TESTING. WARNING: Fuel leaves the injection nozzle with sufficient force to

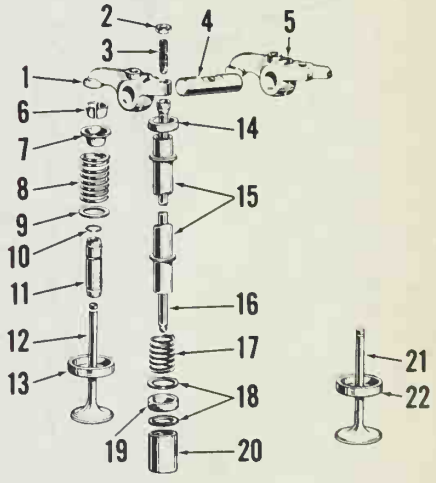


Fig. W1-6 – Exploded view of valve train. On Models WD1-660, WD1-670 and WD1-750, an inner spring is located inside valve spring (8) and circlip (10) is not used.

1. Exhaust rocker arm
2. Locknut
3. Adjuster
4. Rocker arm shaft
5. Intake rocker arm
6. Keys
7. Spring retainer
8. Valve spring
9. Washer
10. Circlip
11. Valve guide
12. Exhaust valve
13. Exhaust valve seat
14. Seal
15. Push rod tube
16. Push rod
17. Spring
18. Washer
19. Seal
20. Tappet
21. Intake valve
22. Intake valve seat

penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector operation may be checked. Only clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Opening pressure on Models WD1-340, WD1-350 and WD1-430 should be 20.1-21.1 MPa. Opening pressure on Models WD1-660, WD1-670 and WD1-750 should be 24.0-25.0 MPa. Opening pressure is adjusted by varying number and thickness of shims (2–Fig. W1-7). Valve should not show leakage at orifice for 10 seconds at 17.6 MPa.

OVERHAUL. Clamp injector body (1–Fig. W1-7) in a vise with nozzle pointing upward, unscrew nozzle holder nut (8) then remove injector components shown in Fig. W1-7. Thoroughly clean all parts in a suitable solvent. Clean inside orifice of nozzle tip with a wooden cleaning stick. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle holder nut (8) to 49 N·m.

INJECTION PUMP

R&R AND OVERHAUL. To remove fuel injection pump, disconnect fuel lines and immediately cap all openings. Refer to GOVERNOR section and detach side control cover. Unscrew pump retaining screws and remove fuel injection pump. Do not lose shim gaskets (G–Fig. W1-3). Pump components (17 through 22–Fig. W1-8) will remain in crankcase. If tappet assembly must be removed, reach inside side cover opening and place a magnet against guide pin (21). Detach clip (22) and use magnet to remove guide pin (21). Slide tappet (18) out of crankcase.

Refer to Fig. W1-8 for an exploded view of fuel injection pump. The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

Reverse removal procedure to reinstall pump. Tighten pump retaining screws to 24.5 N·m on Models WD1-340, WD1-350 and WD1-430 or to 29.5 N·m on all other models. If pump is renewed or overhauled, or original shim gaskets are not used, refer to INJECTION PUMP TIMING section and adjust pump timing.

PISTON, PIN, RINGS AND CYLINDER

R&R AND OVERHAUL. Remove cylinder head as previously outlined. If piston and cylinder do not require service but only removal, proceed as follows: Rotate crankshaft so piston is at top dead center. Lift cylinder up until piston pin is exposed, remove piston pin retainer, withdraw piston pin and remove cylinder and piston as a unit. If piston, rings or cylinder requires service, lift cylinder off crankcase, remove piston pin retainer, withdraw piston pin and remove piston.

Standard size pistons and cylinders are color-coded red, yellow, blue or green. A paint dot is located on inside of piston and on outside of cylinder. Piston diameter is measured 12 mm from bottom of piston skirt on Models WD1-340, WD1-350 and WD1-430 or 18 mm from bottom of piston skirt on all other models. Refer to following table for standard piston and cylinder sizes (all dimensions are in millimeters):

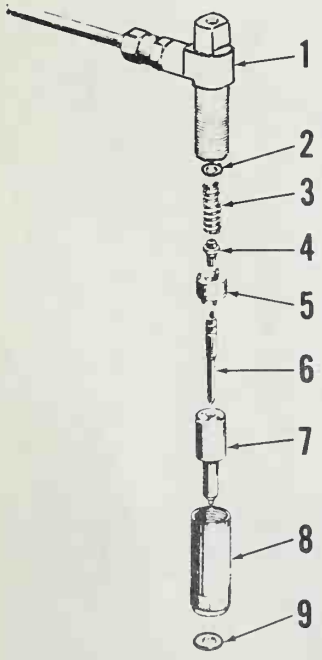


Fig. W1-7–Exploded view of injector.

1. Body
2. Shim
3. Spring
4. Push piece
5. Spacer
6. Valve
7. Nozzle
8. Nozzle holder
9. Gasket

Standard Piston/Cylinder Diameter

	Red or Yellow	Blue or Green
WD1-340, WD1-350		
Piston	74.930-74.940	74.940-74.950
Cylinder	75.000-75.010	75.010-75.020
Clearance	0.06-0.08	0.06-0.08
WD1-430		
Piston	83.925-83.935	83.935-83.945
Cylinder	84.000-84.011	84.011-84.022
Clearance	0.065-0.086	0.066-0.087
WD1-660, WD1-670		
Piston	94.920-94.930	94.930-94.940
Cylinder	95.000-95.011	95.011-95.022
Clearance	0.070-0.091	0.071-0.092
WD1-750		
Piston	99.890-99.900	99.900-99.910
Cylinder	100.000-100.011	100.011-100.022
Clearance	0.100-0.121	0.101-0.122

Maximum allowable piston clearance is 0.2 mm. Refer to following table for piston ring clearances (all clearances are in millimeters).

Piston pin clearance in rod bushing should be 0.02-0.04 mm with a maximum clearance of 0.10 mm. Piston pin clearance in piston should be 0.002-0.011 mm with a maximum clearance of 0.060 mm.

Reverse disassembly procedure for reassembly. Arrow (A–Fig. W1-10) on piston crown must point towards flywheel end of engine. With piston at top dead center, clearance between piston crown and top edge of cylinder should be 0.8-0.9 mm. Install cylinder shim gaskets (32–Fig. W1-11) as required to obtain desired clearance.

Piston Ring Clearances

	End Gap	Side Clearance
WD1-350, WD1-360, WD1-430		
Top ring	0.25-0.40	0.050-0.082
Second ring	0.30-0.45	0.050-0.082
Oil ring	0.25-0.40	0.040-0.072
WD1-660, WD1-670, WD1-750		
Top Ring	0.35-0.55	0.072-0.100
Second ring	0.35-0.55	0.072-0.100
Oil ring	0.25-0.40	0.040-0.072

GOVERNOR

REMOVE AND REINSTALL. Refer to Fig. W1-12 for an exploded view of governor linkage. To remove or inspect governor linkage, unbolt side cover (68), rotate cover 90 degrees clockwise to disengage governor spring (60) and remove side cover assembly. Remove gear cover (83) if easier access to governor is desired. Pull shaft (65) from crankcase to remove lever (56) and pivot (58) being careful not to drop spacer (57)

Fig. W1-10–Arrow (A) on piston crown must point towards flywheel.

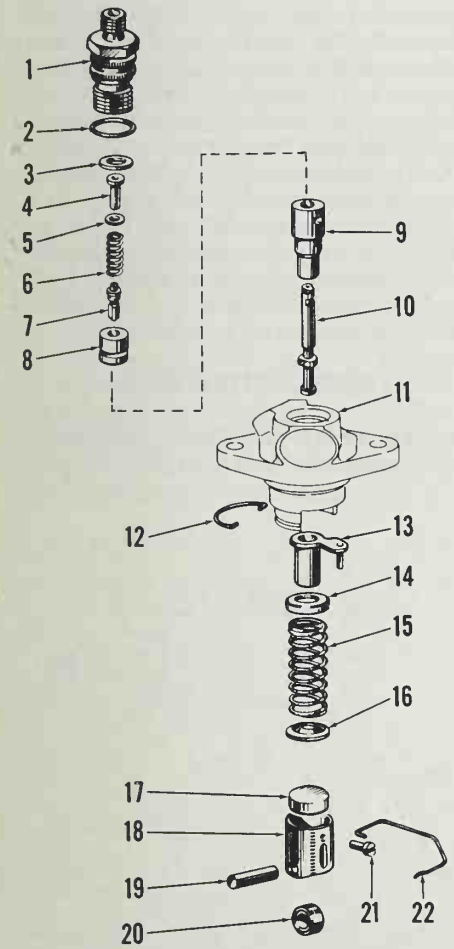


Fig. W1-8–Exploded view of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Shim
6. Spring
7. Delivery valve
8. Delivery valve seat
9. Barrel
10. Plunger
11. Body
12. Clip
13. Control sleeve
14. Spring seat
15. Spring
16. Spring retainer
17. Spacer
18. Tappet
19. Pin
20. Roller
21. Pin
22. Clip

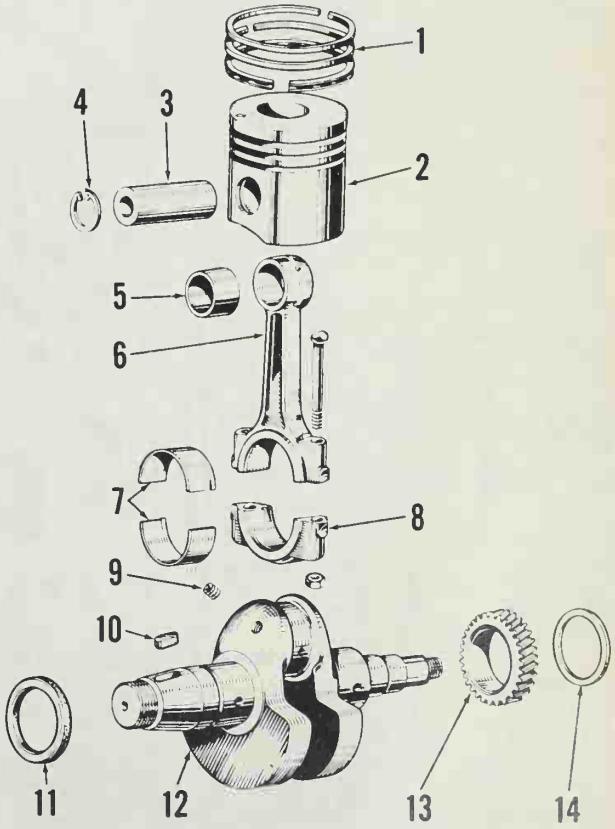


Fig. W1-9–Exploded view of crankshaft assembly.

1. Piston rings
2. Piston
3. Piston pin
4. Snap ring
5. Bushing
6. Connecting rod
7. Bearing
8. Rod cap
9. Plug
10. Key
11. Rubber ring
12. Crankshaft
13. Gear
14. Thrust washer

into crankcase. Do not lose spacer (57) which must be installed in original position. Refer to OIL PUMP section if flyweight assembly (46–Fig. W1-11) must be removed.

Two different governor springs (60–Fig. W1-12) are used. Maximum governed speed is limited to 2200 rpm or 3000 rpm depending on governor spring used. Long end of pivot spring (59) is connected to pivot (58).

Maximum fuel delivery screw (84) is located in gear cover (83) and should be adjusted to provide acceptable power without excessive smoke. With engine warm and under no load, accelerate engine quickly. If smoke is excessive turn screw (84) clockwise. If additional fuel is needed turn screw counterclockwise. Carefully turn screw in 1/8-turn or less increments.

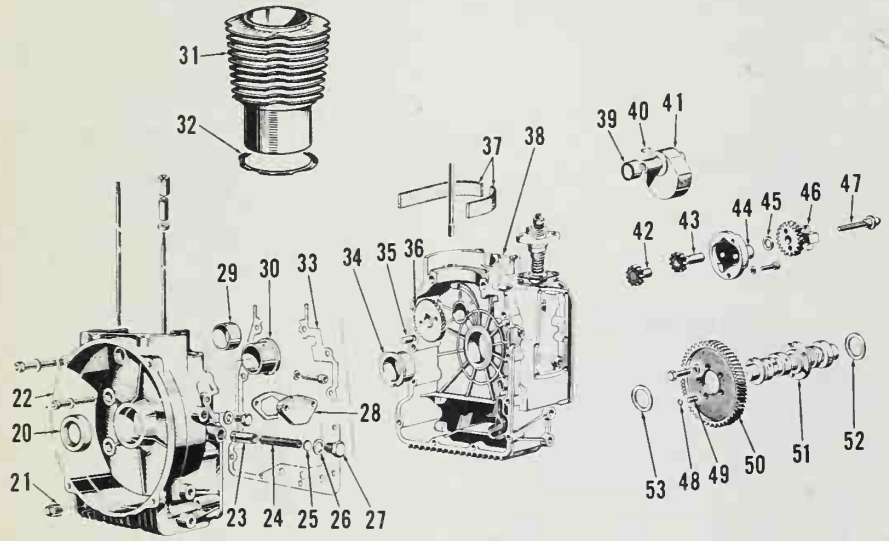


Fig. W1-11–Typical exploded view of crankcase. Balancer (41) is not used on Models WD1-340, WD1-350 and WD1-430.

20. Oil seal
21. Oil drain plug
22. Crankcase half
23. Oil pressure relief valve
24. Spring
25. Shim
26. Washer
27. Plug
28. Cover
29. Camshaft bushing
30. Main bearing
31. Cylinder
32. Shim gasket
33. Gasket
34. Main bearing
35. Dowel
36. Balancer gear
37. Felt
38. Crankcase half
39. Bushing
40. Key
41. Balancer
42. Driven gear
43. Drive gear & shaft
44. Oil pump body
45. Thrust washer
46. Balancer assy.
47. Push rod
48. Circlip
49. Pin
50. Camshaft gear
51. Camshaft
52. Shims
53. Thrust washer

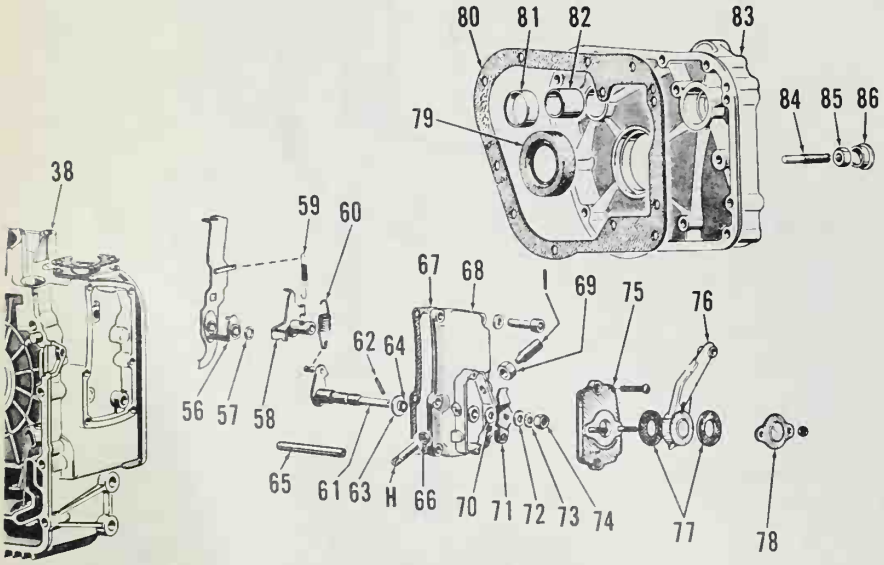


Fig. W1-12–Exploded view of governor linkage.

38. Crankcase half
56. Lever
57. Spacer
58. Pivot
59. Spring
60. Governor spring
61. Control shaft
62. Pin
63. Washer
64. "O" ring
65. Pivot shaft
66. Locknut
67. Gasket
68. Side cover
69. Locknut
70. Washer
71. Lever
72. Washer
73. Lockwasher
74. Nut
75. Cover
76. Control lever
77. Friction discs
78. Retainer
79. Seal
80. Gasket
81. Balancer bushing
82. Camshaft bushing
83. Gear cover
84. Max. fuel delivery screw
85. Nut
86. Plug

OIL PUMP

R&R AND OVERHAUL. Refer to GOVERNOR section and remove governor and control linkage. Remove gear cover if not previously detached. Unbolt and remove oil pump and governor assembly. Press gear and governor assembly (46–Fig. W1-11) off oil pump gear shaft (43). Inspect oil pump gears and housing and renew if damaged or worn excessively. Maximum gear backlash is 0.30 mm. Maximum gear depth (D–Fig. W1-13) is 0.10 mm. Maximum radial clearance (C) between side of gear and housing is 0.15 mm. Reverse disassembly procedure to assemble oil pump. Be sure thrust washer (45–Fig. W1-11) is on oil pump shaft before pressing governor assembly onto shaft.

The oil pressure relief valve (23–Fig. W1-11) is located in side of crankcase. Oil pressure is adjusted by removing or adding shims (25). Refer to LUBRICATION section for oil pressure testing.

CONNECTING ROD

R&R AND OVERHAUL. To remove connecting rod, drain engine oil and

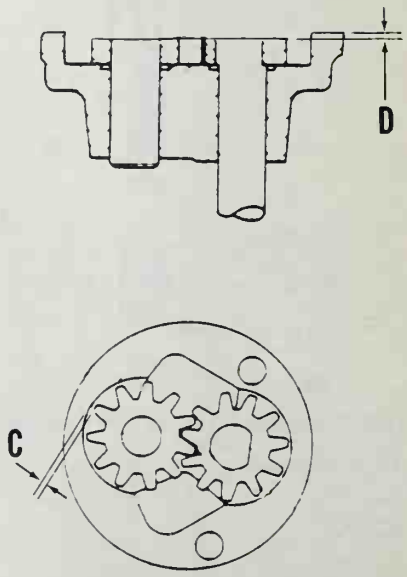


Fig. W1-13–Maximum oil pump gear side clearance (C) is 0.15 mm and maximum gear depth (D) is 0.10 mm.

detach flywheel. Remove piston and cylinder as previously outlined. Unscrew crankcase screws (eleven screws on Models WD1-340, WD1-350 and WD1-430; twelve screws on all other models) and position crankcase with gear cover (83–Fig. W1-12) down. Lift off flywheel side crankcase half (22–Fig. W1-11) and remove connecting rod.

Inspect connecting rod and crankpin. If crankshaft must be removed, refer to CRANKSHAFT AND CRANKCASE section.

Crankpin diameter should be 48.221-48.237 mm on Models WD1-340, WD1-350 and WD1-430, or 59.981-60.000 mm on all other models. Rod bearing clearance on Models WD1-340, WD1-350 and WD1-430 should be 0.030-0.072 mm with a maximum clearance of 0.10 mm. Rod bearing clearance on Models WD1-660, WD1-670 and WD1-750 should be 0.040-0.10 mm with a maximum clearance of 0.12 mm. Rod bearings are available in standard and 0.25 and 0.50 mm undersizes.

The small end rod bushing is renewable; refer to PISTON, PIN, RINGS AND CYLINDER section.

Reverse removal procedure to install connecting rod. Tighten rod nuts to 34.3 N·m on Models WD1-340, WD1-350 and WD1-430, or 49 N·m on all other models. Be sure thrust washer (53–Fig. W1-11) is on camshaft end. Tighten eleven crankcase screws on Models WD1-340, WD1-350 and WD1-430 to 29.4 N·m. On Models WD1-660, WD1-670 and WD1-750, tighten ten M8 crankcase screws to 29.4 N·m and two M12 crankcase screws to 68.6 N·m.

CRANKSHAFT AND CRANKCASE

R&R AND OVERHAUL. To remove crankshaft, drain engine oil and detach flywheel. Unbolt side cover (68–Fig. W1-12), rotate cover 90 degrees clockwise to disengage governor spring (60) and remove side cover assembly. Remove fuel injection pump, piston and cylinder as previously outlined. Remove cover (28–Fig. W1-11) or transfer fuel pump, if so equipped. Unscrew crankcase screws (eleven screws on Models WD1-340, WD1-350 and WD1-430; twelve screws on all other models) and position crankcase with gear cover (83–Fig. W1-12) down. Lift off flywheel side crankcase half (22–Fig. W1-11).

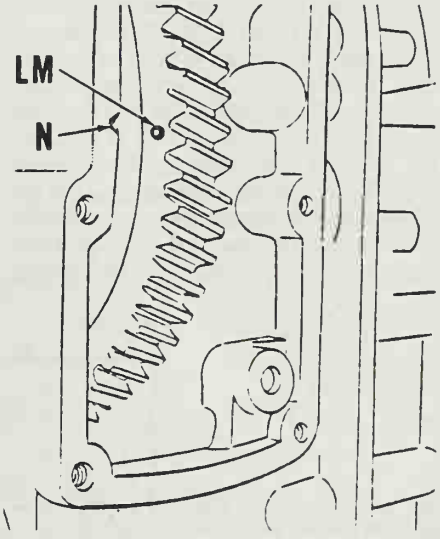


Fig. W1-15–View of large camshaft gear timing mark (LM) and crankcase notch (N) on Models WD1-660, WD1-670 and WD1-750.

Withdraw crankshaft and rod assembly then remove rod if desired.

Crankshaft main bearing journal diameter should be 45.984-46.000 mm on Models WD1-340, WD1-350 and WD1-430, or 55.981-56,000 mm on all other models. Main bearing clearance should be 0.054-0.095 mm on Models WD1-340, WD1-350 and WD1-430. Main bearing clearance on Models WD1-660, WD1-670 and WD1-750 should be 0.04-0.08 mm. Maximum main bearing clearance for all models is 0.12 mm. Main bearings (30 and 34–Fig. W1-11) are available in standard and 0.25 and 0.50 undersizes. If main bearings must be renewed, remove any components in crankcase which may be damaged by heat. Heat crankcase to 150° C. (300° F.), then using a suitable press remove and install main bearings.

If camshaft bushing (29) must be renewed, heat crankcase half (22) to 150 ° C. (300° F.) prior to removal and installation.

If removed, install connecting rod on crankshaft and tighten rod nuts to 34.3 N·m on Models WD1-340, WD1-350 and WD1-430, or 49 N·m on all other models.

To install crankshaft on Models WD1-340, WD1-350 and WD1-430, rotate camshaft so timing mark (M–Fig. W1-14) on camshaft gear is aligned with arrow (A) on crankcase. Insert crankshaft into pto crankcase half (38–Fig. W1-11) so crankpin is at top dead center. Recheck camshaft gear timing mark. With crankpin at top dead center, timing marks (M and A–Fig. W1-14) should be aligned.

To install crankshaft on Models WD1-660, WD1-670 and WD1-750, rotate camshaft so large timing mark

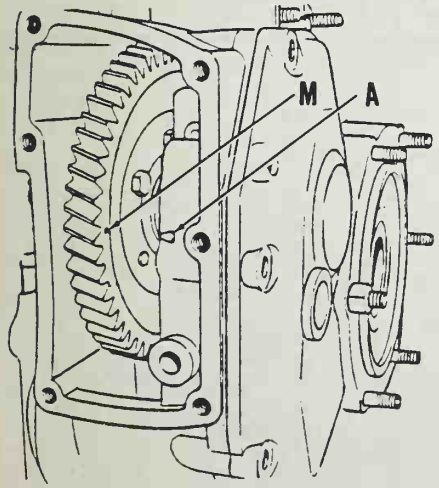
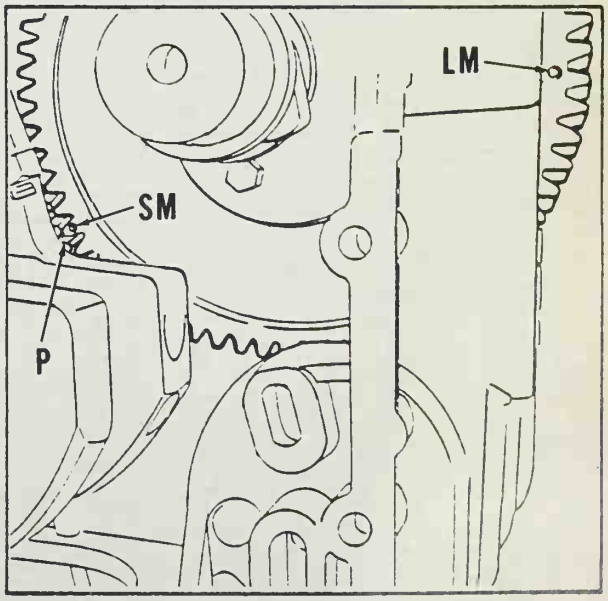


Fig. W1-14–View of camshaft gear timing mark (M) and crankcase mark (A) on Models WD1-340, WD1-350 and WD1-430.

Fig. W1-16–View of large (LM) and small (SM) camshaft timing marks and red paint mark (P) on crankshaft gear of Models WD1-660, WD1-670 and WD1-750.



(LM – Fig. W1-15) is aligned with notch (N) in crankcase. Insert crankshaft into pto crankcase half (38 – Fig. W1-11) so red paint mark (P – Fig. W1-16) is aligned with small camshaft gear timing mark (SM). Rotate crankshaft until red paint mark (P – Fig. W1-17) on crankshaft gear is adjacent to balancer gear. Red paint mark (P) must align with balancer gear mark (M). If marks (P and M) do not align, hold camshaft gear in place, withdraw crankshaft, rotate balancer so marks (P and M) will be aligned then reinsert crankshaft into crankcase. When properly mated, balancer gear mark (M) and red paint mark (P) will align on each crankshaft rotation, and red paint mark (P – Fig. W1-16) will align with small camshaft timing mark (SM) when large camshaft timing mark (LM – Fig. W1-15) is aligned with crankcase notch (N).

On all models, install rubber ring (11 – Fig. W1-9) and oil seal (20 – Fig. W1-11) with seal lip inward. Be sure thrust washer (53) is on camshaft end. Install crankcase half (22) but do not apply sealant to gasket or crankcase. Tighten eleven crankcase screws on Models WD1-340, WD1-350 and WD1-430 to 29.4 N·m. On Models WD1-660, WD1-670 and WD1-750, tighten ten M8 crankcase screws to 29.4 N·m and two M12 crankcase screws to 68.6 N·m.

Crankshaft end play should be 0.10-0.35 mm on Models WD1-340, WD1-350 and WD1-430, or 0.20-0.40 mm on all other models. If end play is excessive, remove crankshaft and install thicker thrust washer (14 – Fig. W1-9).

Complete remainder of assembly by reversing disassembly procedure.

CAMSHAFT

R&R AND OVERHAUL. To remove camshaft, refer to previous section and disassemble crankcase but do not remove crankshaft. Remove gear cover (83 – Fig. W1-12) and governor linkage. Set aside camshaft shims (52 – Fig. W1-11) for future use. Detach gear (50) from camshaft (51) and withdraw camshaft from crankcase. Remove gear through side cover opening.

The camshaft is supported by bushings in the crankcase and gear cover. Maximum allowable camshaft journal clearance is 0.15 mm. If the crankcase bushing (29 – Fig. W1-11) requires renewal, refer to following section as crankcase must be disassembled and heated for bushing installation. To renew bushing (81 – Fig. W1-12), heat gear cover (83) to 150° C. (300° F.) before removal or installation. Be sure crankshaft seal (79) is not damaged by heat. Camshaft bushings are available in standard size and 0.25 and 0.50 mm undersizes.

Intake and exhaust cam lobe heights should be 32.775-33.025 mm on Models WD1-340, WD1-350 and WD1-430. Intake cam lobe height on Models WD1-660, WD1-670 and WD1-750 should be 39.966-40.216 mm and exhaust cam lobe height should be 39.966-40.216 mm. Fuel injection cam lobe height should be 34.925-35.075 mm on Models WD1-340, WD1-350 and WD1-430 or 40.857-41.107 mm on all other models.

To install camshaft, insert gear (50 – Fig. W1-11) into crankcase through side cover opening and mate gear with crankshaft gear. On Models WD1-340, WD1-350 and WD1-430 with crankpin at top dead center, camshaft timing gear mark (M – Fig. W1-14) must be aligned with arrow (A) on crankcase. On Models WD1-660, WD1-670 and WD1-750, red paint mark (P – Fig. W1-16) on crankshaft gear must align with small camshaft gear timing mark (SM) while large camshaft gear timing mark (LM – Fig. W1-15) must align with crankcase notch (N). While holding camshaft gear in mesh with crankshaft gear, insert camshaft into crankcase and through camshaft gear. Rotate camshaft so locating pin (49 – Fig. W1-11) in gear enters notch in camshaft flange. Install camshaft gear screws. Place original shims (52) on camshaft and install governor linkage and gear cover. Tighten gear cover screws to 24.5 N·m. Complete remainder of assembly by reversing disassembly procedure, but do not install side cover.

Check camshaft end play which should be 0.10-0.30 mm on Models WD1-340, WD1-350 and WD1-430 or 0.20-0.40 on all other models. Install or remove shims (52) as needed to obtain desired end play. Attach governor spring (60 – Fig. W1-12) and install side cover (68).

BALANCER

Models WD1-660, WD1-670 And WD1-750

REMOVE AND REINSTALL. Models WD1-660, WD1-670 and WD1-750 are equipped with a balancer (41 – Fig. W1-11) which is driven by gear (36) which meshes with the crankshaft gear.

To remove balancer, remove crankshaft as previously outlined then remove gear cover being careful not to lose camshaft shims (52). Use a suitable puller to

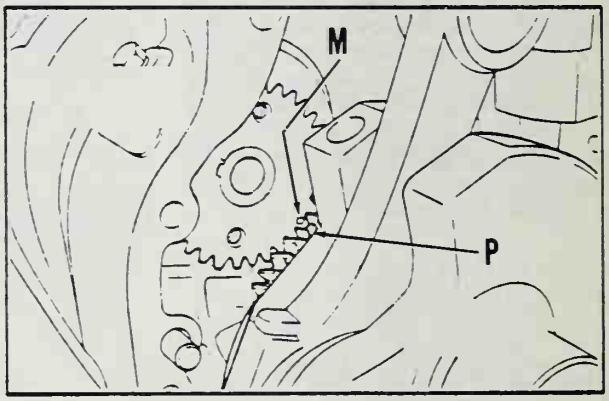


Fig. W1-17 – Balancer gear mark (M) and red paint mark (P) on crankshaft gear should be aligned on Models WD1-660, WD1-670 and WD1-750.

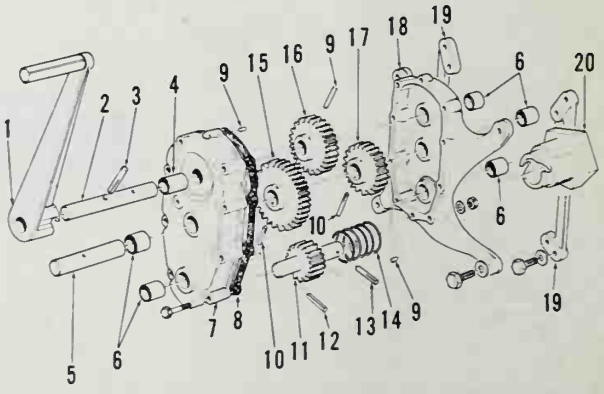


Fig. W1-18 – Exploded view of crank type manual starter used on some models. Adapter (19) is used on Models WD1-660, WD1-670 and WD1-750.

1. Crank
2. Shaft
3. Pin
4. Bushing
5. Shaft
6. Bushings
7. Housing half
8. Gasket
9. Dowel
10. Pin
11. Output gear & shaft
12. Pin
13. Pin
14. Spring
15. Gear (29 teeth)
16. Gear (23 teeth)
17. Gear (21 teeth)
18. Housing half
19. Adapter
20. Crank jaw

remove gear (36) from balancer shaft.

Inspect balancer, gear and bushings (39–Fig. W1-11 and 82–Fig. W1-12). Renew if damaged or excessively worn. Crankcase or gear cover must be heated to 150° C. (300° F.) when removing or installing bushings. Remove any components which may be damaged by heat.

To install balancer, insert balancer into crankcase then use a suitable press to install gear (36–Fig. W1-11) onto balancer shaft with timing gear mark (M–Fig. W1-17) out. Install gear cover being sure to install camshaft shims (52–Fig. W1-11). Refer to CRANKSHAFT AND CRANKCASE section for crankshaft installation and reassembly.

MANUAL STARTER

R&R AND OVERHAUL. Refer to Fig. W1-18 for an exploded view of crank type manual starter used on some models. Unscrew housing mounting screws to remove starter from engine. Unscrew housing screws and separate housing halves (7 and 18) for access to starter components.

Inspect starter components for damage and excessive wear. Heat housing halves to 150° C. (300° F.) before removing and installing bushings. Manufacturer recommends renewing both bushings for a particular shaft.

When assembling starter, adequately grease all internal components. Be sure starter operates properly after assembly without binding or sticking. Manufacturer recommends filing down area (R–Fig. W1-19) of crank jaw so starter pin disengages easier. With starter mounted on engine, starter pin (13–Fig. W1-18) must be at least 1/16-inch from crank jaw as shown in Fig. W1-20. Install shims (S) between starter and engine to obtain desired clearance.

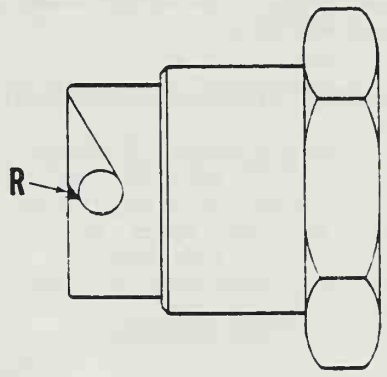


Fig. W1-19–File away area (R) on crank jaw to dimensions shown for easier disengagement.

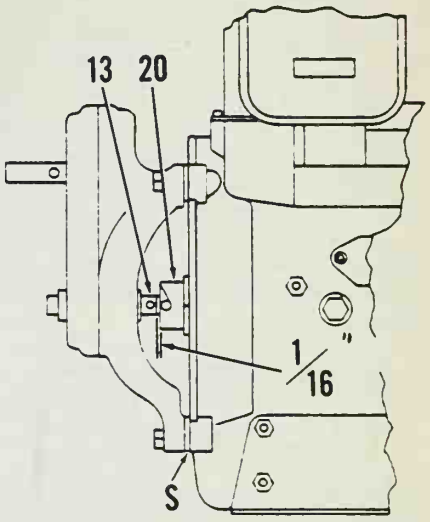


Fig. W1-20–Output shaft pin (13) must be at least 1/16-inch from crank jaw (20) when disengaged. Install shims (S) between starter housing and engine to obtain clearance.

WISCONSIN

Model	No. Cyls.	Bore	Stroke	Displ.
WD2-860	2	84 mm	78 mm	864 cc
WD2-1000	2	86 mm	86 mm	1000 cc

Engines covered in this section are air-cooled, two-cylinder, four-stroke diesel engines. Crankshaft rotation is counterclockwise at pto end. Number 1 cylinder is nearer pto end of engine.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0° C. (32° F.), SAE 20 for temperatures between 0° C. (32° F.) and 20° C. (68° F.), and SAE 40 for temperatures above 20° C. (68° F.). API oil classification should be CD. Oil sump capacity including oil filter is 2.0 liters. Manufacturer recommends renewing oil after first 25 hours of operation and after every 100 hours of operation thereafter.

An external oil filter (F – Fig. W2-1) is located on side of engine and should be renewed after first 25 hours of operation, then after every other oil change. A renewable oil filter is located on the oil pickup tube. Remove screws securing oil pickup (P – Fig. W2-2) and withdraw pickup from crankcase. Oil pickup filter should be renewed after every other oil change.

Oil pressure with engine warm and running at full speed should be 274 kPa. An oil pressure gage may be connected after unscrewing test port plug (T – Fig. W2-1). Refer to OIL PUMP section to adjust oil pressure.

ENGINE SPEED ADJUSTMENT

Idle speed is adjusted by turning idle speed screw (I – Fig. W2-3) and high speed is adjusted by turning high speed screw (H). Idle speed should be 1500-1800 rpm while maximum governed speed under load is 3000 rpm.

FUEL SYSTEM

FUEL FILTERS. A fuel filter is located in the fuel tank and an external fuel filter is mounted on side of engine. Renew fuel filters after every 200 hours of operation or sooner if required.

BLEED FUEL SYSTEM. On gravity-feed fuel systems, a fuel return line and check valve are connected to the fuel injection pump as well as the fuel supply line. Fuel supply line should bleed air automatically up to fuel injection pump on gravity flow systems. To bleed high pressure injection lines, loosen fittings for high pressure lines at injectors then rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection lines. Retighten injection lines.

On engines equipped with a fuel transfer pump, loosen fuel supply line fitting on injection pump then rotate engine crankshaft to operate fuel transfer pump until air-free fuel flows from fuel line. Retighten fuel supply line and loosen fittings for high pressure injection lines at injectors. Rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection lines. Retighten injection lines.

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (29 – Fig. W2-4) between pump body and mounting surface on crankcase. Refer to INJECTION PUMP section for pump removal and installation.

To check injection pump timing, unscrew high pressure injection line of number 1 cylinder from injection pump delivery valve holder (1). Unscrew delivery valve holder (1) and remove spring (5), spring guide (4) and delivery valve (6), then screw delivery valve holder (1) back into pump. Move throttle control to full speed position. Rotate engine in normal direction (counterclockwise at pto) so number 1 piston is on compression stroke – it may be necessary to connect a gravity-flow fuel tank to fuel injection pump if not so equipped. Note fuel will flow out of delivery valve holder. Stop engine rotation at moment fuel ceases to flow. Timing mark (R – Fig. W2-5) should be within 3 mm of injection timing mark (N) on crankcase. To advance injection timing, remove shim gaskets (29 – Fig.

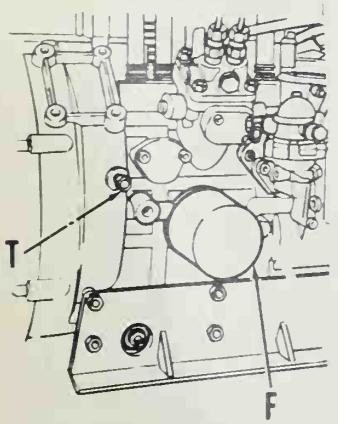


Fig. W2-1 – View showing location of external oil filter (F). Unscrew plug (T) and connect oil pressure gage to measure oil pressure.

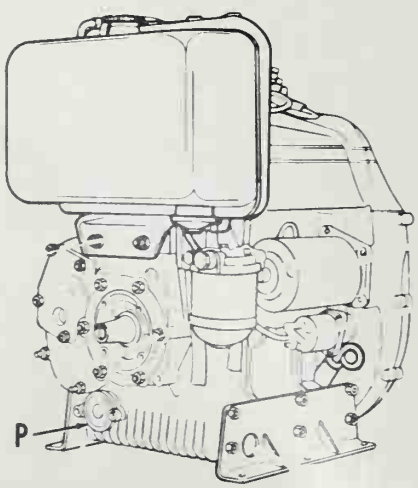


Fig. W2-2 – Remove oil pickup (P) for access to internal oil filter.

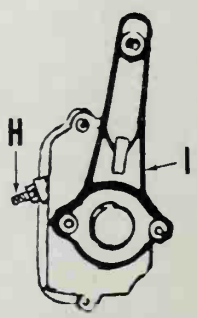


Fig. W2-3 – View showing location of high speed adjusting screw (H). Idle speed screw is located behind speed control lever at (I).

W2-4); install shim gaskets to retard injection timing. Reinstall removed pump parts after checking timing.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques. All values are in newton meters.

Connecting rod	34.3
Crankcase	See text
Cylinder head	44.1
Fan	34.3
Flywheel	176.4
Gear cover	24.5
Injection pump	24.5
Injector retainer plate	9.8
Main bearing center support halves	39.2
Main bearing center support	See text

VALVE TAPPET GAP

Valve tappet gap may be adjusted after removing rocker arm cover. Valve tappet gap with engine cold should be 0.15 mm for exhaust valve (1–Fig. W2-6) and 0.10 mm for intake valve (5).

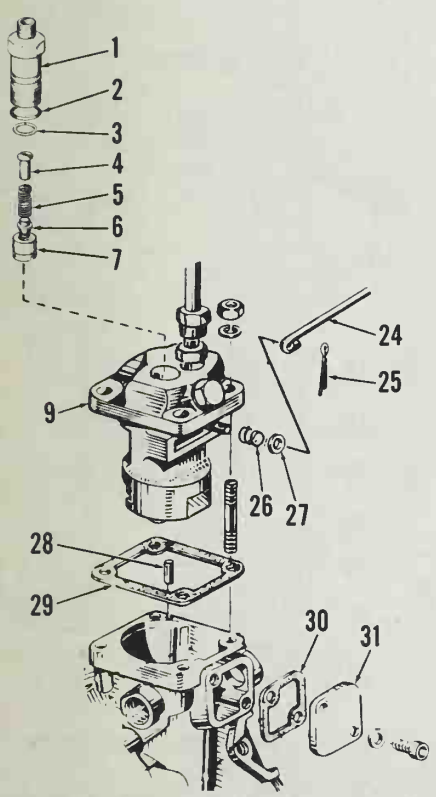


Fig. W2-4—Partial exploded view of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Spring
6. Delivery valve
7. Delivery valve seat
9. Fuel injection pump
24. Control rod
25. Cotter pin
26. Spring
27. Washer
28. Pin
29. Shim gasket
30. Gasket
31. Cover

CYLINDER HEAD AND VALVE SYSTEM

R&R AND OVERHAUL. To remove cylinder heads, disconnect high pressure and return fuel injection lines. Immediately cap fuel lines. Remove muffler, air cleaner, exhaust and intake manifolds. Turn compression release lever so connecting tang and slot on compression release shafts are vertical as shown in Fig. W2-7. Remove rocker arm covers, unscrew cylinder head retaining nuts and remove cylinder heads. Remove and discard rubber seals (R–Fig. W2-8) on cylinder head studs and upper push rod tube seals.

Valve face angle for both valves is 45½ degrees and valve seat angle is 45 degrees. Valve seats are renewable and must be installed with head heated to 200° C. (392° F.). There should be an interference fit of 0.079-0.120 mm between outside diameter of seat and bore in cylinder head.

Valve stem diameter is 6.945-6.960 mm for both valves and valve guide inside diameter is 7.000-7.015 mm. Valve stem clearance should be 0.040-0.070 mm with a maximum allowable valve stem clearance of 0.2 mm. Valve guides are renewable. To remove valve guide, press guide out top of cylinder head. To install valve guide, position locating ring (10–Fig. W2-9) on guide, then press guide into head from top side of head with ring end up. Press guide into head until locating ring is seated in head groove.

Reassemble by reversing disassembly procedure. Install new "O" rings on compression release shafts and install shafts so slot or tang on shaft end is towards inner side of cylinder head as shown in Fig. W2-7. Install new upper rubber seal on push rod tubes. Install new rubber seals on cylinder head studs shown in Fig. W2-8. Before tightening cylinder head nuts, install exhaust and intake manifolds to correctly position heads, then tighten cylinder head nuts to 44.1 N·m.

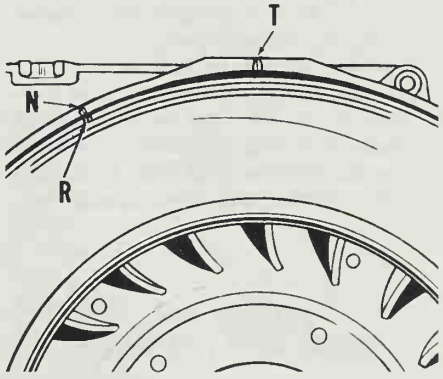


Fig. W2-5—Number 1 cylinder fuel injection should occur when flywheel reference mark (R) is aligned with crankcase mark (N). Number 1 piston is at top dead center when flywheel reference mark (R) is aligned with crankcase mark (T).

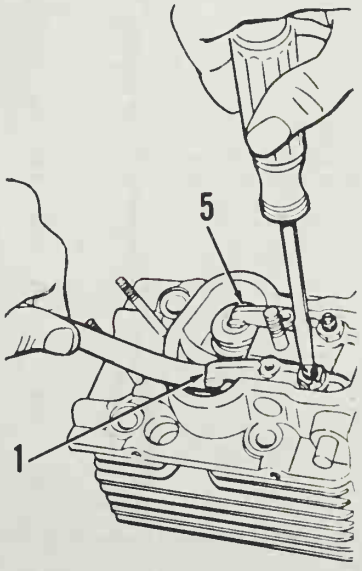


Fig. W2-6—Valve tappet gap should be 0.15 mm at exhaust rocker arm (1) and 0.10 mm at intake rocker arm (5).

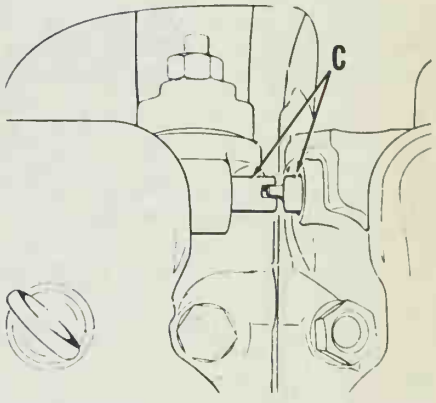


Fig. W2-7—Before removing cylinder head, rotate compression release shafts (C) so slot and tang in shaft ends are vertical.

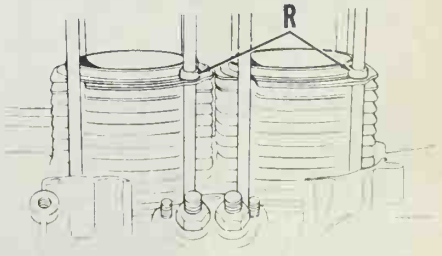


Fig. W2-8—View showing location of rubber seals (R) on cylinder head studs.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and high pressure injection line and immediately cap or plug all openings. Unscrew retainer plate and remove injector and copper washer.

Reverse removal procedure to reinstall injector. Install a new copper washer (9–Fig. W2-10). Tighten injector retaining plate nuts to 9.8 N·m.

TESTING. WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector operation may be checked. Only clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Opening pressure should be 19.6-20.6 MPa. Opening pressure is adjusted by varying number and thickness of shims (2–Fig. W2-10). Valve should not show leakage at orifice for 10 seconds at 18.0 MPa.

OVERHAUL. Clamp injector body (1–Fig. W2-10) in a vise with nozzle pointing upward. Unscrew nozzle holder nut (8) then remove injector components as shown in Fig. W2-10. Thoroughly clean all parts in a suitable solvent. Clean inside orifice of nozzle tip with a wooden cleaning stick. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle holder nut (8) to 49 N·m.

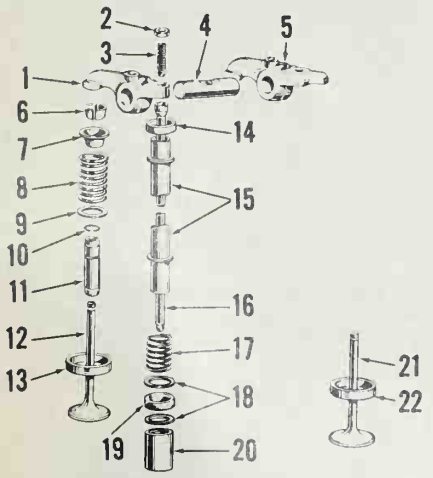


Fig. W2-9—Exploded view of valve train.

1. Exhaust rocker arm
2. Locknut
3. Adjuster
4. Rocker arm shaft
5. Intake rocker arm
6. Keys
7. Spring retainer
8. Valve spring
9. Washer
10. Circlip
11. Valve guide
12. Exhaust valve
13. Exhaust valve seat
14. Seal
15. Push rod tube
16. Push rod
17. Spring
18. Washer
19. Seal
20. Tappet
21. Intake valve
22. Intake valve seat

INJECTION PUMP

R&R AND OVERHAUL. To remove fuel injection pump, disconnect fuel lines and remove cover (31–Fig. W2-4) adjacent to pump. Place a clean rag underneath control rod (24) so cotter pin (25) cannot fall into crankcase. Then, remove cotter pin (25) and detach control rod end from pump control rack pin. Unscrew pump retaining nuts and remove fuel injection pump. Do not lose shim gaskets (29).

Refer to Fig. W2-11 for an exploded view of fuel injection pump. The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

Reverse removal procedure for reinstallation. Tighten pump retaining nuts to 24.5 N·m. If pump is renewed or overhauled, or original shim gaskets are not used, refer to INJECTION PUMP TIMING section and adjust pump timing.

PISTON, PIN, RINGS AND CYLINDER

R&R AND OVERHAUL. Remove cylinder head as previously outlined. If piston and cylinder do not require service but only removal, proceed as follows: Rotate crankshaft so piston to be removed is at top dead center. Lift cylinder up until piston pin is exposed, remove piston pin retainer, withdraw piston pin and remove cylinder and piston as a unit. If piston, rings or cylinder requires service, lift cylinder off crankcase, remove piston pin retainer, withdraw piston pin and remove piston.

Standard size pistons and cylinders

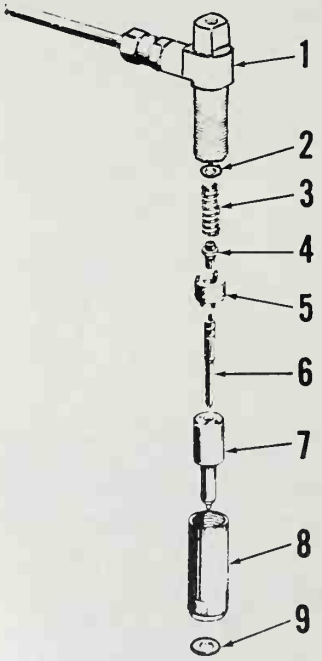


Fig. W2-10—Exploded view of injector.

1. Body
2. Shim
3. Spring
4. Push piece
5. Spacer
6. Valve
7. Nozzle
8. Nozzle holder
9. Gasket

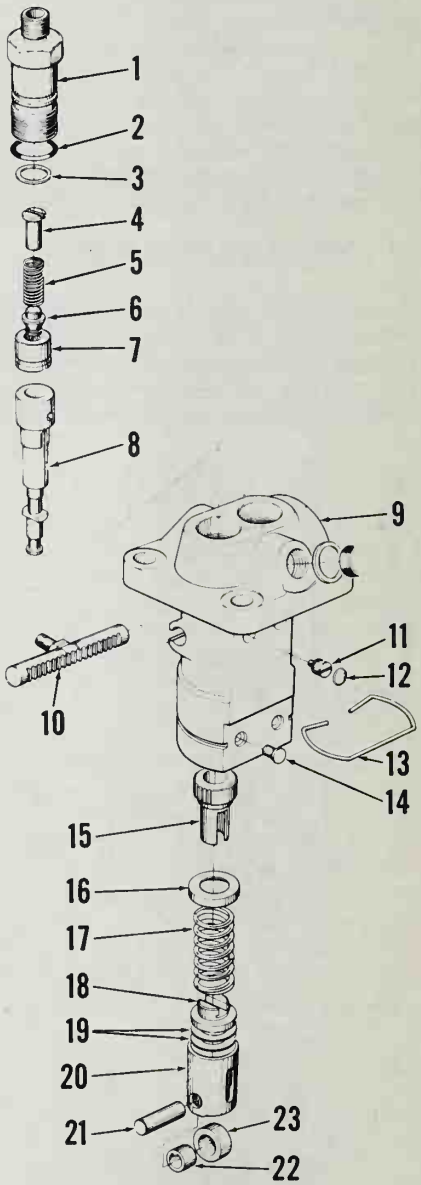


Fig. W2-11—Exploded view of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Spring
6. Delivery valve
7. Delivery valve seat
8. Plunger
9. Body
10. Control rack
11. Pin
12. Plug
13. Clip
14. Pin
15. Control sleeve
16. Spring seat
17. Spring
18. Spring seat
19. Shims
20. Tappet
21. Pin
22. Inner roller
23. Outer roller

are color-coded red, yellow, blue or green. A paint dot is located on inside of piston and on outside of cylinder. Piston diameter is measured 12 mm from bottom of piston skirt on Model WD2-860 or 15 mm from bottom of piston skirt on Model WD2-1000. Refer to following table for standard piston and cylinder sizes (all dimensions are in millimeters):

Pistons and rings are available in 0.5 and 1.0 mm oversizes.

Piston clearance should be 0.066-0.086 mm for Model WD2-860 and 0.071-0.091 mm for Model WD2-1000.

The top compression ring is a keystone type and second compression ring is rectangular. Piston ring end gap for all rings should be 0.3-0.45 mm. Second compression ring side clearance should be 0.050-0.082 mm for Model WD2-860 and 0.070-0.102 mm for Model WD2-1000. Oil ring side clearance should be 0.040-0.072 mm for both models.

Reverse disassembly procedure for reassembly. Arrow (A – Fig. W2-13) on piston crown must point towards flywheel end of engine. With piston at top dead center, clearance between piston crown and top edge of cylinder should be 0.8-0.9 mm. Install cylinder shim gaskets (3 – Fig. W2-12) required to obtain desired clearance.

Standard Piston/Cylinder Diameter

	Red or Yellow	Blue or Green
WD2-860		
Piston	83.925-83.935	83.935-83.945
Cylinder	84.000-84.011	84.011-84.022
WD2-1000		
Piston	85.920-85.930	85.930-85.940
Cylinder	86.000-86.011	86.011-86.022

GOVERNOR

REMOVE AND REINSTALL. Refer to Fig. W2-15 for an exploded view of governor and control linkage. Remove cover (83) and gear cover (98 – Fig. W2-18) for access to governor and linkage. Do not lose camshaft shims (95) which may remain on gear cover. Mark shims (71 – Fig. W2-15) so they may be returned to original position.

Governor gear (69) is pressed on oil pump drive gear shaft (65) so oil pump and governor unit must be removed to press governor gear off shaft. Governor gear and flyweights (69) are available only as a unit assembly. Install thrust washer (68) on shaft before pressing governor gear assembly onto shaft.

Distance (D – Fig. W2-17) between speed control rod ends should be 129 mm. Remove cover (31 – Fig. W2-14) and place a rag underneath control rod so cotter pin cannot fall into crankcase. Detach cotter pin securing rod end and withdraw control rod (24). Adjust length of control rod by turning rod end (73 – Fig. W2-17).

Reassemble by reversing removal procedure. Install shims (71 – Fig. W2-15) in their original location. Install spring (74) so long end is connected to intermediate lever (75) as shown in Fig. W2-16. Tighten gear cover nuts to 24.5 N·m.

Maximum fuel delivery screw (T – Fig. W2-18) is located in gear cover (98) and should be adjusted to provide acceptable power without excessive smoke. With engine warm and under no load, accelerate engine quickly. If smoke is excessive turn screw (T) clockwise. If additional fuel is needed turn screw counterclockwise. Carefully turn screw in ⅛-turn or less increments.

OIL PUMP

R&R AND OVERHAUL. Refer to GOVERNOR section and remove governor and oil pump unit. Press governor off oil pump gear shaft (65 – Fig. W2-15). Inspect oil pump gears and housing and renew if damaged or worn excessively. Oil pump housing and gears are available individually. Reverse disassembly procedure to assemble oil pump. Be sure thrust washer (68) is on oil pump shaft before pressing governor assembly onto shaft.

The oil pressure relief valve (40 – Fig.

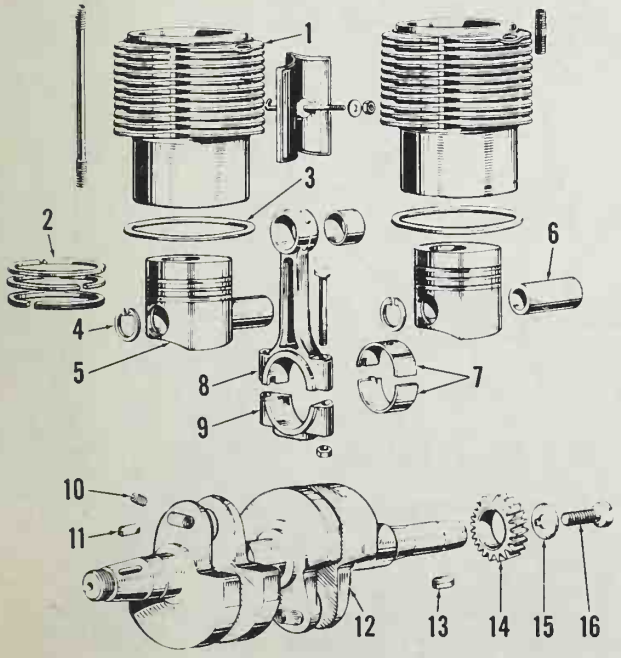


Fig. W2-12 – Exploded view of crankshaft assembly.

1. Cylinder
2. Piston rings
3. Gasket
4. Snap ring
5. Piston
6. Piston pin
7. Rod bearing
8. Connecting rod
9. Rod cap
10. Plug
11. Key
12. Crankshaft
13. Key
14. Gear
15. Slotted washer
16. Capscrew

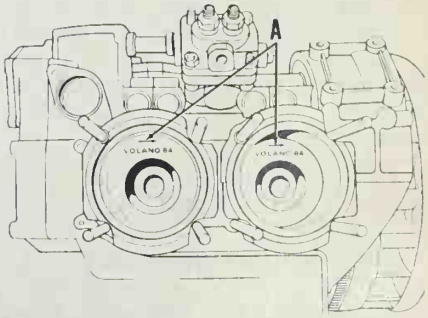


Fig. W2-13 – Arrow (A) on piston crown must point towards flywheel.

W2-14) is located adjacent to oil filter. Oil pressure is adjusted by removing or installing shims (42). Refer to LUBRICATION section for oil pressure testing.

CAMSHAFT

R&R AND OVERHAUL. To remove camshaft, refer to previous sections and remove cylinder heads and fuel injection pump. Remove push rods and push rod tubes. Extract and mark tappets so they can be returned to original bores. Refer to GOVERNOR section and remove governor linkage. Remove fuel transfer pump on models so equipped. Set aside shims (95–Fig. W2-18) for future use. Detach gear (94) from camshaft (91), then rotate camshaft so flat (F–Fig. W2-19) on camshaft flange coincides with crankcase projection (P). Carefully withdraw camshaft.

The camshaft is supported by bushings in the gear cover and crankcase. To inspect bushing (58–Fig. W2-14) in crankcase, remove flywheel and cover (54). If camshaft bushing (58) must be renewed, disassemble crankcase. Maximum allowable camshaft journal clearance is 0.2 mm. Camshaft bushings are available in undersizes of 0.25 and 0.50 mm.

To install camshaft, rotate crankshaft so number 1 piston is at top dead center. Insert camshaft gear (94–Fig. W2-18) through control linkage opening in crankcase so dowel pin (101–Fig. W2-20) side of gear is towards end of crankcase. Insert camshaft through camshaft gear into crankcase while noting flat (F–Fig. W2-19) on camshaft flange which must coincide with crankcase projection (P). Engage camshaft gear with crankshaft gear so camshaft gear timing mark (M–Fig. W2-20) is aligned with crankcase timing arrow (A). Hold camshaft gear then rotate camshaft so camshaft flange notch engages camshaft gear pin (101). Install camshaft screws and recheck timing marks. Place original shims (95–Fig. W2-18) on camshaft and install governor linkage and gear cover. Tighten gear cover nuts to 24.5 N·m. Check camshaft end play which should be 0.15-0.25 mm. Install or remove shims (95) as needed to obtain desired end play. Complete reassembly by reversing removal procedure.

CRANKSHAFT AND CRANKCASE

R&R AND OVERHAUL. Refer to Fig. W2-14 for an exploded view of crankcase which is constructed in three sections: flywheel end, center and pto end.

To remove crankshaft, remove cylinders, pistons and camshaft as previously outlined. Remove electric starter, flywheel and alternator. Remove covers (33) at crankcase joints–there is only one cover if engine

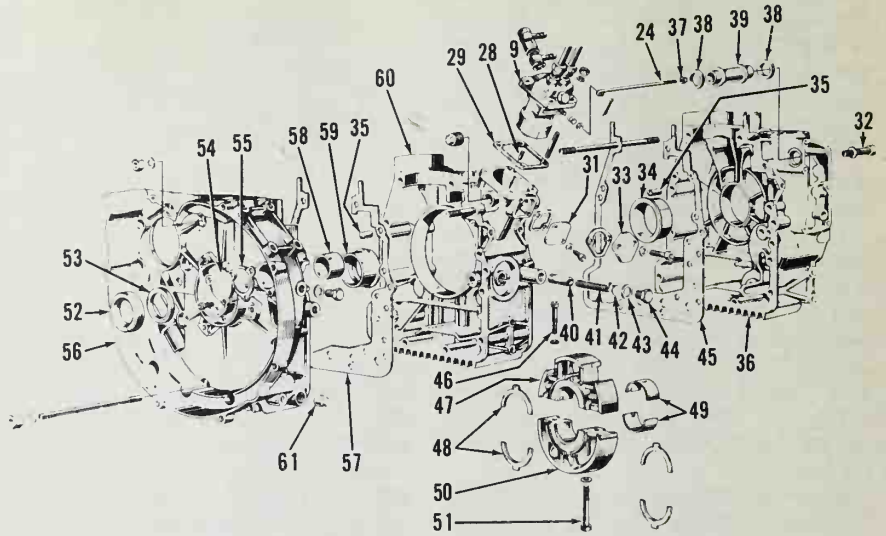


Fig. W2-14–Exploded view of crankcase assembly.

9. Fuel injection pump
24. Control rod
28. Pin
29. Shim gasket
31. Cover
32. Socket head screw
33. Cover
34. Main bearing
35. Pin
36. Pto crankcase section
37. Nut
38. Seal
39. Tube
40. Oil pressure relief valve
41. Spring
42. Shim
43. Washer
44. Plug
45. Gasket
46. Screw
47. Upper main bearing support half
48. Thrust washers
49. Main bearing
50. Lower main bearing support half
51. Screw
52. Inner seal ring
53. Oil seal
54. Cover
55. Gasket
56. Flywheel crankcase section
57. Gasket
58. Camshaft bushing
59. Main bearing
60. Center crankcase section
61. Oil drain plug

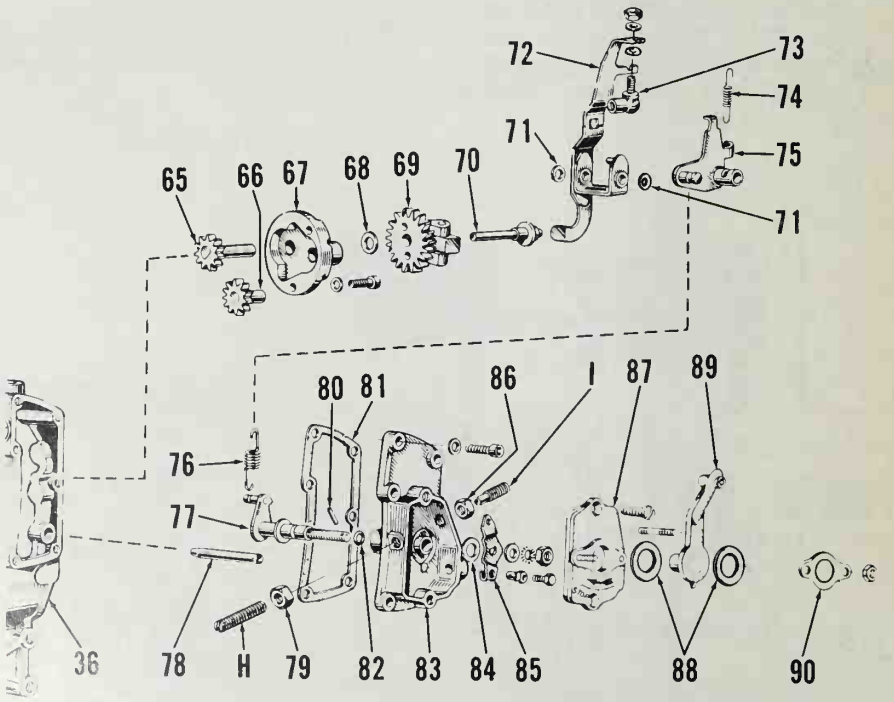


Fig. W2-15–Exploded view of oil pump, governor and linkage.

H. High speed screw
I. Idle speed screw
36. Pto crankcase section
65. Drive gear
66. Driven gear
67. Oil pump body
68. Thrust washer
69. Governor assy.
70. Push rod
71. Shims
72. Governor arm
73. Control rod end
74. Spring
75. Pivot
76. Spring
77. Lever & shaft
78. Shaft
79. Locknut
80. Pin
81. Gasket
82. "O" ring
83. Side cover
84. Washer
85. Lever
86. Locknut
87. Cover
88. Washers
89. Speed control lever
90. Plate

is equipped with a fuel transfer pump. Unscrew eleven retaining nuts from crankcase flywheel section and separate flywheel section from remainder of crankcase. Remove socket head screw (32–Fig. W2-14 or W2-21) adjacent to camshaft bore. Separate center crankcase section with crankshaft from pto crankcase section. Remove control rod tube (39) and seals (38). Detach connecting rods. Unscrew two socket head screws (51) in bottom of center crankcase which secure main bearing support in crankcase. Press crankshaft and main bearing support out of center crankcase. Unscrew main bearing support screws (46) and separate support halves (47 and 50) from crankcase.

Crankshaft main journal diameter should be 52.702-52.733 mm for center journal and 46.044-46.069 mm for end journals. Main bearing clearance should be 0.043-0.079 mm for center main bearing and 0.046-0.084 mm for end main bearings. Maximum allowable main bearing clearance is 0.2 mm. Main bearings are available in undersizes of 0.25 and 0.50 mm.

Crankpin diameter should be 48.267-48.294 mm and rod bearing clearance should be 0.030-0.071 mm with a maximum allowable clearance of 0.2 mm.

To reassemble crankshaft and crankcase, proceed as follows: Install main bearings (34 and 59) so flange is to inside of crankcase and oil hole is aligned in flywheel crankcase section bearing (59). Place thrust washer halves (48) on both sides of main bearing support halves (47 and 50) with grooved side out. Install main bearing support halves (47 and 50) on crankshaft and tighten screws (46) to 39.2 N·m. With bearing support held towards one end of crankshaft, measure clearance between thrust rings (48) and side of crankshaft to determine crankshaft end play. Clearance should be 0.1-0.3 mm. Thrust washer halves are available in standard and 0.1 mm oversize thicknesses.

Heat center crankcase to 150° C. (300° F.). With crankshaft pointing in correct direction, insert crankshaft into crankcase so mating line of bearing support is matched with crankcase alignment marks (M–Fig. W2-22) and immediately start support retaining screws but do not tighten.

Install connecting rods and tighten rod nuts to 34.3 N·m. With control rod tube (39–Fig. W2-14) and seals (38) in place, mate pto crankcase section (36) with center crankcase section (60). Install socket head screw (32–Fig. W2-14 and W2-21) and tighten to 34.3 N·m only if center crankcase has cooled to ambient temperature. Mate flywheel crank-

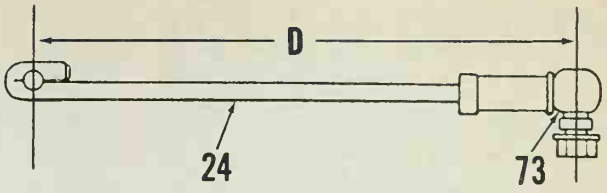


Fig. W2-17–Length (D) between control rod ends should be 129 mm.

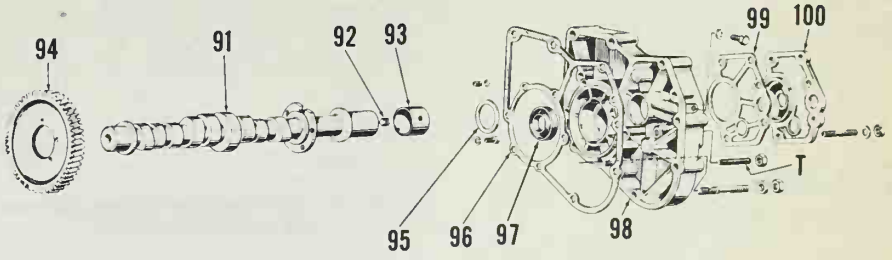


Fig. W2-18–Exploded view of camshaft.

91. Camshaft
92. Plug
93. Bushing
94. Gear
95. Shims
96. Gasket
97. Oil seal
98. Gear cover
99. Gasket
100. Cover

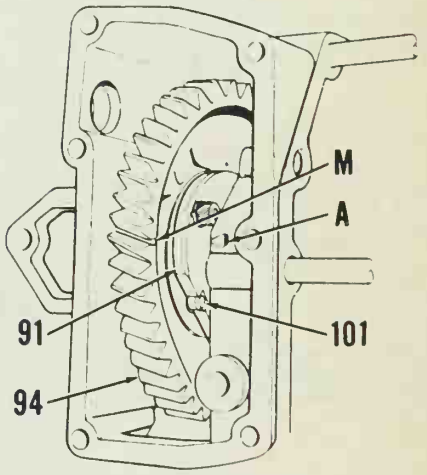


Fig. W2-20–Mate camshaft (91) with gear (94) as outlined in text.

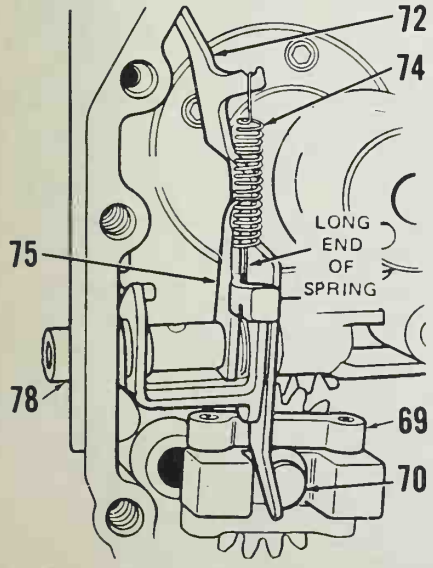


Fig. W2-16–View of governor linkage. Long end of spring (74) attaches to pivot (75).

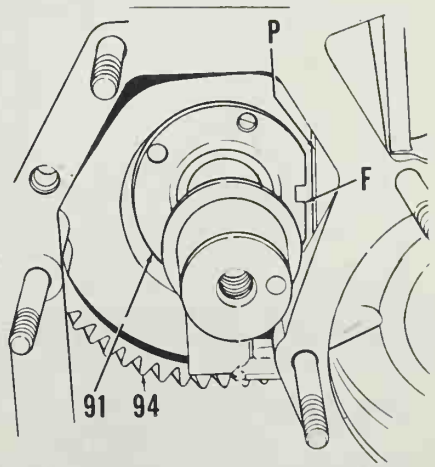


Fig. W2-19–Turn camshaft (91) so flat (F) on flange will pass crankcase projection (P).

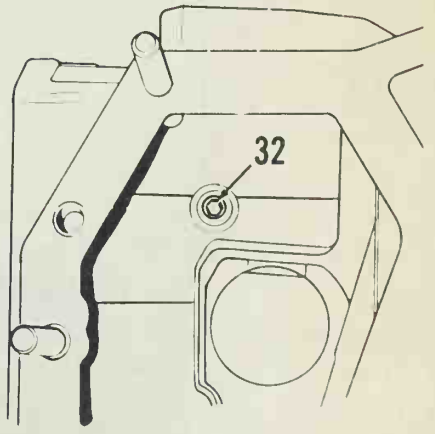


Fig. W2-21–View showing location of socket head screw (32) in pto crankcase section.

case section (56–Fig. W2-14) with center crankcase. Tighten M8 nuts to 24.5 N·m and M10 nuts to 34.3 N·m (see Fig. W2-23). If not previously tightened, tighten pto crankcase socket head screw (32–Fig. W2-14 and W2-21) to 34.3 N·m. Tighten main bearing support retaining screws (51–Fig. W2-14) to 39.2 N·m. Complete remainder of reassembly by reversing disassembly procedure.

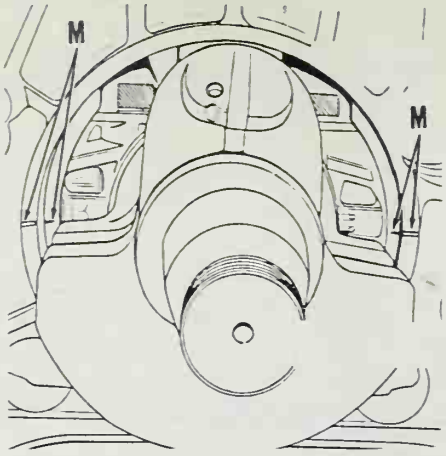


Fig. W2-22–Align crankshaft support and crankcase marks (M) as shown.

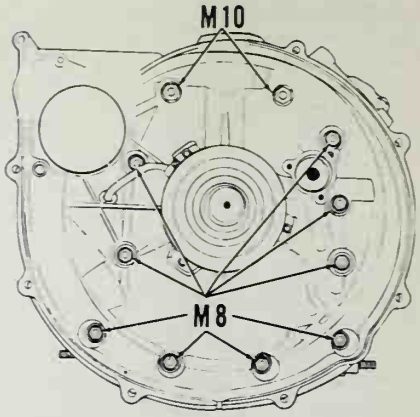


Fig. W2-23–View showing location of M8 and M10 nuts in flywheel crankcase section.

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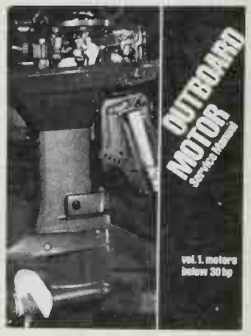

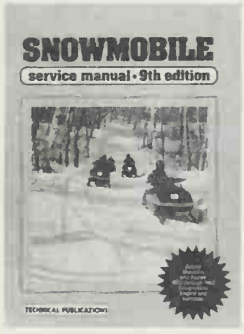

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