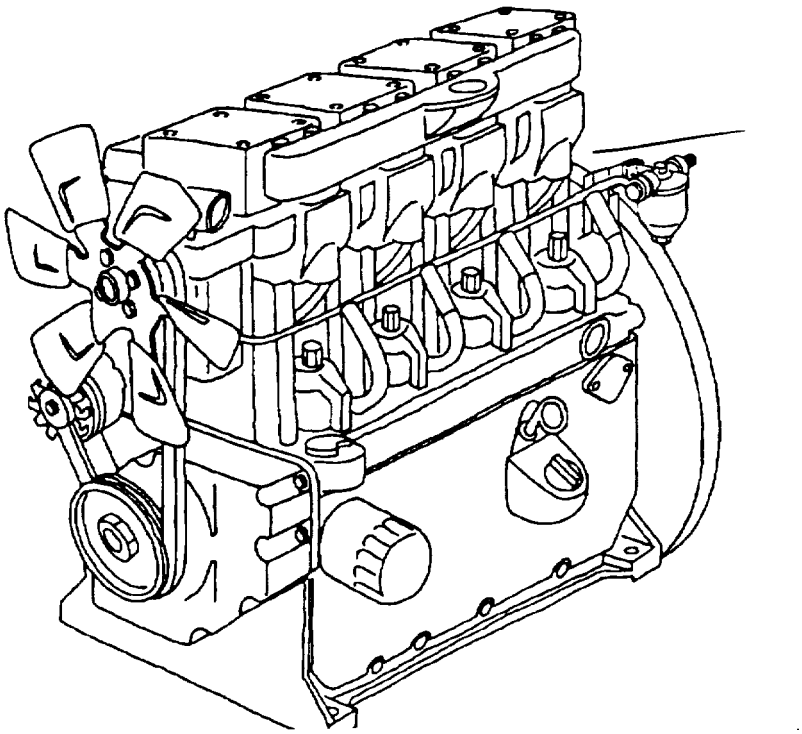
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AIR FORCE TO 38G1-93-2
MARINE CORPS TM 2815-24/3

TECHNICAL MANUAL

UNIT, DIRECT SUPPORT AND GENERAL SUPPORT MAINTENANCE INSTRUCTIONS

DIESEL ENGINE
MODEL DN4M
4 CYLINDER 1.2 LITER
NSN: 2815-01-350-2206



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TECHNICAL MANUAL
UNIT, DIRECT SUPPORT AND GENERAL SUPPORT
MAINTENANCE INSTRUCTIONS

DIESEL ENGINE
MODEL DN4M
4 CYLINDER 1.2 LITER
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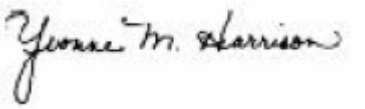
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Unit, Direct Support and General Support
Maintenance Instructions

DIESEL ENGINE
MODEL DN4M
4 CYLINDER 1.2 LITER
NSN: 2815-01-350-2206

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SAFETY SUMMARY

For first aid, refer to FM 21-11.

WARNING

The noise level when operating could cause hearing damage. Ear protection must be worn.

WARNING

Where applicable, prior to performing engine maintenance, ensure batteries are disconnected.

WARNING

Do not drain coolant until the coolant temperature is below operating temperature. Always loosen cooling system filler cap, radiator cap, or drain cock slowly to relieve any excess pressure.

WARNING

Diesel fuel is flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection required. Avoid repeated/prolonged contact. Good general ventilation is normally adequate.

WARNING

Cleaning solvent is flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection required. Avoid repeated/prolonged contact. Good general ventilation is normally adequate.

WARNING

Compressed air used for cleaning can create airborne particles that may enter the eyes. Pressure will not exceed 30 psig (207 kPa). Eye protection required.

TECHNICAL MANUAL

NO. 9-2815-253-24

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THE ARMY AND THE AIR FORCE AND
HEADQUARTERS, U.S. MARINE CORPS
WASHINGTON, D.C., 15 September 1993

Unit, Direct Support and General Support
Maintenance Instructions

DIESEL ENGINE
MODEL DN4M
4 CYLINDER 1.2 LITER
NSN: 2815-01350-2206

REPORTING ERRORS AND RECOMMENDING IMPROVEMENTS

You can help improve this manual. If you find any mistakes or if you know of a way to improve these procedures, please let us know.

(A) Mail your letter or DA Form 2028 (Recommended Changes to Publications and Blank Forms), or DA Form 2028-2 located in the back of this manual directly to: Commander, US Army Aviation and Troop Command, ATTN: AMSAT-I-MP, 4300 Goodfellow Blvd., St. Louis, MO 63120-1798. You may also submit your recommended changes by E-mail directly to <mpmt%avma28@st-louis-emh7.army.mil>. Instructions for sending an electronic 2028 may be found at the back of this publication immediately preceding the hard copy 2028.

(F) Air Force - AFTO Form 22 Directly to: Commander, Sacramento Air Logistics Center, ATTN: TILBA, McClellan AFB, CA 95652-5990 (AFMC).

(M) Marine Corps - NAVMC Form 10772 Directly to: Commander, Marine Corps Logistics Bases (Code 850), Albany, GA 31704-5000.

A reply will be furnished directly to you.

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CHAPTER 1
INTRODUCTION
SECTION I. GENERAL INFORMATION

1-1. SCOPE.

1-1.1. Type of Manual. This manual contains unit, direct support and general support maintenance instructions for the Model DN4M Diesel Engine, hereafter referred to as engine. Also included are descriptions of major systems/components and their functions in relation to other systems/components.

1-1.2. Purpose of Equipment. The engine provides a driving force for generators or other equipment requiring this size (24 HP) and compatibility.

1-2. MAINTENANCE FORMS. RECORDS. AND REPORTS.

1-2.1. Reports of Maintenance and Unsatisfactory Equipment. Department of the Army forms and procedures used for equipment maintenance will be those prescribed by DA Pam 738-750, the Army Maintenance Management System (TAMMS). Air Force personnel will use AFR 66-1, Maintenance Management Policy, for maintenance reporting and TO-00-35D54 for unsatisfactory equipment reporting.

1-2.2. Reporting of Item and Packaging Discrepancies. Fill out and forward SE 364, Report of Discrepancy (ROD), as prescribed in AR 735-11-2/DLAR 414-55/SECNAVINST 4355.18/AER 400-54/MCO 4430.3J.

1-2.3. Transportation Discrepancy Report (TDR) (SE 361). Fill out and forward Transportation Discrepancy Report (TDR) (SE 361) as prescribed in AR 55-38/NAVSUPINST 4610.33C/AER-75-18/MCO P4610.19D/DLAR 4500.15.

1-3. REPORTING EQUIPMENT IMPROVEMENT RECOMMENDATIONS (EIR).

1-3.1. Army. If your Military Standard Engine needs improvement, let us know. Send us an EIR. You, the user, are the only one who can tell us what you don't like about your equipment. Let us know why you don't like the design or performance. Put it on an SE 368 (Product Quality Deficiency Report) . Mail it to us at: Commander, U.S. Army Aviation and Troop Command, ATTN: AMSAT-I-MDO, 4300 Goodfellow Boulevard, St, Louis, Missouri 63120-1798. We will send you a reply.

1-3.2. Air Force. Air Force personnel are encouraged to submit EIR's in accordance with AFR 900-4.

1-4. DESTRUCTION OF ARMY MATERIEL TO PREVENT ENEMY USE.

Refer to TM 750-244-3 for procedures to destroy equipment to prevent enemy use.

1-5. PREPARATION FOR STORAGE OR SHIPMENT.

Refer to TB 740-97-2 for procedures to place the equipment into storage.

1-6. WARRANTY.

The engine is warranted for a specific period of time. Refer to the end item warranty technical bulletin. The warranty starts on the date found in block 23, DA Form 2408-9, in the equipment log book. Report all defects in material or workmanship to your supervisor, who will take appropriate action.

SECTION II. EQUIPMENT DESCRIPTION AND DATA

1-7. GENERAL.

The diesel engine (FIGURE 1-1) is four cylinder, four cycle, fuel injected, naturally-aspirated and liquid-cooled. The firing order is 1-3-4-2. The number one cylinder is toward the fan end of the engine. The serial number is found on right side of the cylinder body at number one cylinder location. Rotation of engine is counterclockwise as viewed from flywheel.

NOTE

All locations referenced herein are given facing the flywheel end (rear) of the engine.

1-8. DETAILED DESCRIPTION.

1-8.1. Cooling System. The cooling system consists of a radiator, water pump, cooling fan, thermostat and connecting hoses. The fan is mounted on shaft of water pump and both are belt driven from the crankshaft pulley. The thermostat controls engine temperature and is installed in the top of engine. The function of the cooling system is to maintain a specific operating temperature of 1700 to 2200F (770 to 1040C) for the engine.

1-8.2. Lubrication System. The lubrication system consists of the oil sump, a gear type oil pump, pressure relief valve, spin-on type oil filter and internal passages within the engine.

1-8.3. Fuel System. The function of the fuel system is to inject a metered quantity of clean atomized fuel into the engine cylinders at a precise time near the end of the compression stroke of each piston. The fuel system consists of the fuel tank, electrically driven transfer pump, fuel filter/water separator, fuel filter, and a fuel injection pump and fuel injector for each cylinder. The fuel tank, transfer pump and fuel filter/water separator are not mounted on engine.

1-8.4. Electrical System. The electrical system is 24 VDC operation and consists of a battery charging alternator, starter, externally mounted battery and other items as required. The battery charging alternator is mounted on front of engine and is belt driven. When the engine is operating, the battery charging alternator supplies 24 VDC to recharge the battery and maintain it at a full state of charge. The starter is mounted on the flywheel housing and when energized engages the ring gear of the flywheel to rotate the engine.

1-9. EQUIPMENT DATA.

TABLE 1-1. Equipment Data

Model	DN4M
Type	Four cylinder, four cycle, liquid cooled diesel
Bore/Stroke	3.38/3.12 in. (86/80 mm)
Displacement	113.5 cu. in. (1.8 liters)
Horsepower Rating	24.1 BHP 1800 rpm
Compression Ratio	18.5:1
Length	24.56 in. (623.82 mm)
Width	17.77 in. (451.4 mm)
Height	20.57 in. (522.5 mm)
Weight	305 lbs. (138.4 kg)
Rotation - looking at flywheel	Counterclockwise
Mean Piston Speed (1800 RPM)	954 ft/min (288 m/min)
Number of Flywheel Ring Gear Teeth	96
Idle Speed	1745 RPM
Firing Order	1-3-4-2
Lubrication System Capacity	5.9 qts (5.6 liters)
Coolant System Capacity (engine only)	0.79 gal (2.99 liters)
Oil Pressure (1800 RPM)	36 psi (248 kPa)
Oil Pressure Relief Valve Setting	45-59 psi (310-407 kPa)
Capacity Between Dipstick Marks	38.4 oz (1.2 liters)
Oil Filter Capacity	8.5 oz (0.25 liters)
Alternator	24 VDC - 18 amp
Starter	24 VDC - 3.2 kw

1. Intake Manifold
2. Cylinder Cover
3. Coolant Outlet and Thermostat
4. Fan Drive Pulley
5. Crankshaft Pulley
6. Gear End Cover
7. Starter Motor
8. Flywheel Housing
9. Starter Solenoid
10. Cylinder Head
11. Coolant Inlet
12. Exhaust Manifold
13. Fuel Injection Pumps
14. Fuel Inlet Connection
15. Fuel Filter
16. Dipstick
17. Oil Filler
18. Crankcase
19. Oil Filter
20. Water Pump

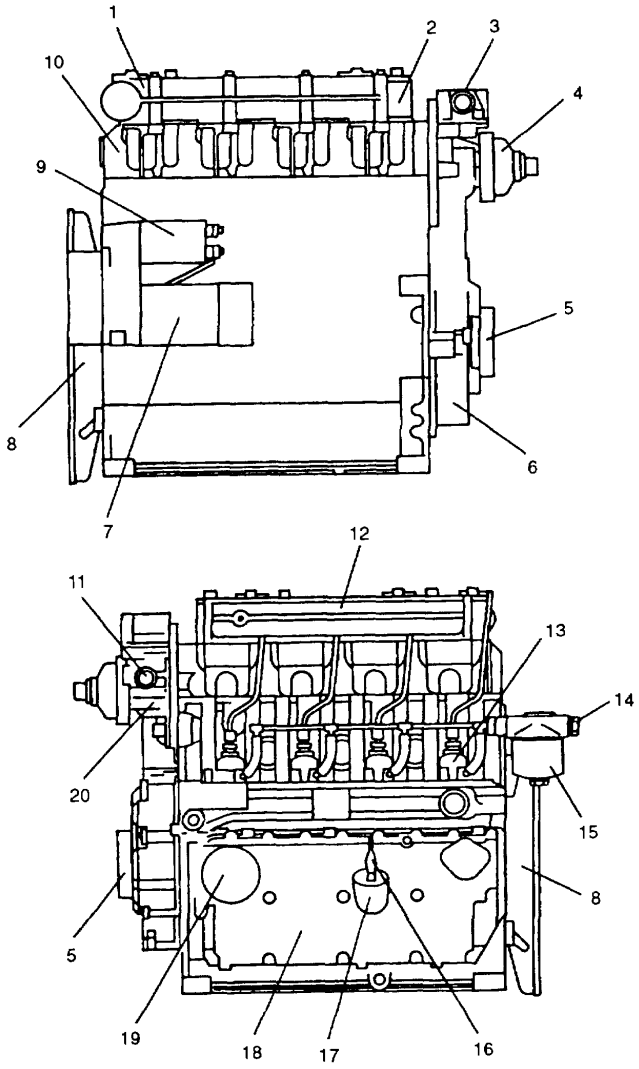


FIGURE 1-1. Engine Components

SECTION III. PREPARATION FOR USE

1-10. INSPECTING AND SERVICING ENGINE.

This section provides information and guidance for inspecting, servicing, and installing the engine.

1-10.1. Inspection.

a. Check that all packing materials have been removed.
b. Check engine identification plate for positive identification.
c. Inspect engine exterior for shipping damage.
d. Check fan belt drive for proper tension.
e. Inspect engine for loose or missing mounting hardware, or damaged or missing parts.

1-10.2. Service. Except for servicing the lubrication system all other servicing must be accomplished after engine is mounted in the end item, refer to end item lubrication order (LO).

CHAPTER 2
OPERATION
SECTION I. PRINCIPLES OF OPERATION

2-1. INTRODUCTION.

This section contains functional descriptions of the engine systems and how they are connected to the end item.

2-2. COOLING SYSTEM.

The cooling system consists of a radiator, hoses, thermostat, belt driven fan, water pump, and cooling jackets within the engine. The water pump forces coolant through passages (coolant jackets) in the engine block and cylinder head where coolant absorbs heat from the engine. When the coolant temperature is below operating temperature, the thermostat is closed and coolant is bypassed to the water pump inlet. As coolant temperature increases to 1600F (71 0C), the thermostat starts to open, restricting bypass flow and opening flow to the radiator. As coolant temperature continues to increase to 1850F (850C), the thermostat is fully opened, shutting off all bypass flow and providing full flow through the radiator. Air forced through the fins of the radiator by the fan cools the coolant pumped through the radiator. Items are added to the engine to monitor coolant temperature and to warn if temperature exceeds a predetermined value.

2-3. LUBRICATION SYSTEM.

The lubrication system consists of an oil sump, dipstick, pump, relief valve, and filter. The oil sump is a reservoir for lubricating oil. The dipstick indicates oil level in sump. The pump draws oil from the sump through a screen which removes large impurities. The oil then passes through a relief valve preset to limit oil pressure to 47 to 59 psi (324 to 407 kPa). The oil then passes through a spin-on type filter where small impurities are removed. From the filter, oil enters the cylinder head oil gallery and flows to the crankshaft and bearings. The connecting rod bearings are pressure fed through internal drillings in the crankshaft from the supply to the main bearings. Splash oil lubricates the gears, and the underside of the pistons. The governor camshaft is lubricated by a drilled bolt/oil jet. An internal crankcase drilling provides an oil feed to the hydraulic tappets. After passing through the block, the oil returns to the oil sump. Items are added to monitor oil pressure and to warn/stop engine if pressure drops to a dangerously low value.

2-4. FUEL SYSTEM.

2-4.1. The fuel system consists of an external fuel tank, electrically driven transfer pump, fuel filter/water separator, fuel filter, fuel injection pump and fuel injector for each cylinder, and piping. Fuel from an external source is supplied to the fuel injection pumps. The injection pumps provide a pressurized metered quantity of clean atomized fuel through the injector nozzles into the cylinders at a precise time near the end of the compression stroke of each piston. The fuel that is not used by the injectors is returned to the fuel tank via an excess fuel return line.

2-4.2. Extremely cold outside temperatures make starting the engine difficult. To improve engine starting, a cold weather starting aid has been provided that features four heater plugs in the intake manifold. The heater plugs are energized during engine preheat starting cycle.

2-5. ELECTRICAL SYSTEM.

The electrical system consists of external mounted batteries, starter, battery charging alternator, and related relays and switches for control of the system. Battery power supplied to the starter during the start cycle energizes the starter which engages the ring gear of the flywheel causing the engine to turn over. When engine start is complete, the starter is deenergized and disengages from the flywheel.

SECTION II. OPERATING INSTRUCTIONS

NOTE
Refer to end item operator's manual.

CHAPTER 3
MAINTENANCE
SECTION I. PREVENTIVE MAINTENANCE CHECKS AND SERVICES (PMCS)

3-1. PMCS PROCEDURES.

3-1.1. General. To ensure that engine is ready for operation at all times, it must be inspected so defects can be discovered and corrected before they result in serious damage or failure. Perform operator's PMCS prior to or in conjunction with performance of engine PMCS. For engine PMCS. Refer to TABLE 3-1.

TABLE 3-1. Preventive Maintenance Checks and Services (PMCS)

Item No.	Interval						Item to be Inspected	Procedures Check for and have repaired or adjusted as necessary	Equipment is Not Ready / Available If
	M	Q	S	A	B	H			
1			•			250	Oil Filter	Refer to paragraph 3-20.1.	
2				•		500	Fuel Filter	Replace fuel filter element. Refer to paragraph 3-16.1.	
3						1500	Fuel Injectors	Remove, inspect, and test. Refer to paragraph 3-17.	
4						1500	Engine Vacuum	Check engine vacuum. Refer to paragraph 3-5	
5					•	1500	Engine Oil Pressure	Check engine oil pressure. Refer to paragraph 3-22.	

SECTION II. TROUBLESHOOTING

3-2. TROUBLESHOOTING PROCEDURES.

3-2.1. Purpose of Troubleshooting Table. This section contains troubleshooting information for locating and correcting operating troubles which may develop in the engine. Each malfunction for an individual component unit or system is followed by a list of tests or inspections which will help you to determine probable causes and corrective action to take. You should perform tests/inspections and corrective actions in order listed.

This table cannot list all malfunctions that may occur, nor all tests or inspections and corrective actions. If a malfunction is not listed or cannot be corrected by listed corrective actions, notify your supervisor.

NOTE

Before you use this table, be sure you have performed your PMCS. Prior to performing troubleshooting procedures within this manual, perform your operator's troubleshooting and the end item maintenance manual troubleshooting procedures.

SYMPTOM INDEX

Malfunction	Troubleshooting Procedures Page
Engine Will Not Crank	3-2
Starter Operates But Will Not Turn Over	3-2
Engine Hard to Start or Will Not Start	3-2
Engine Hard to Start or Will Not Start In Cold Weather	3-3
Engine Misfires or Runs Irregularly or Stalls Frequently	3-3
Engine Does Not Develop Full Power	3-4
Engine Overheating	3-4
Excessive Oil Consumption	3-5
Low Oil Pressure	3-5
Excessive Fuel Consumption	3-5
Black or Gray Smoke	3-6
Blue Exhaust Smoke	3-6
Abnormal Engine Noise	3-7
Detonation or Pre-Ignition	3-7

TABLE 3-2. Troubleshooting

MALFUNCTION TEST OR INSPECTION CORRECTIVE ACTION

1. ENGINE WILL NOT CRANK.

Step 1. Check for defective end item starting system.

Troubleshoot per end item maintenance manual. If not defective, do Step 2.

Step 2. Check for defective starter motor and solenoid.

a. Test starter and solenoid. Refer to paragraph 3-24.3.1.

b. Repair/replace defective starter and/or solenoid. Refer to paragraph 3-24.

2. STARTER OPERATES BUT WILL NOT TURN OVER.

Check for worn or broken starter pinion gear and/or flywheel ring gear.

a. Remove starter and inspect pinion gear and flywheel ring gear for damage.

b. Replace defective clutch assembly and/or flywheel ring gear. Refer to paragraph 3-24 and/or refer to end item maintenance manual.

3. ENGINE HARD TO START OR WILL NOT START.

Step 1. Check for stop/start lever in wrong position.

a. Check position of lever. If in proper position, do Step 2.

b. Adjust stop/start lever. Refer to paragraph 3-23.5.

Step 2. Check for clogged fuel filter.

Refer to paragraph 3-16 for inspection. If not clogged, do Step 3.

Table 3-2. Troubleshooting Continued

MALFUNCTION TEST OR INSPECTION CORRECTIVE ACTION

Step 3. Check for air in fuel system lines.
Prime fuel system at fuel filter. Refer to paragraph 3-12. If fuel system is free of air, do Step 4.
Step 4. Check for fuel injector nozzles dirty or faulty.
a. Remove and test fuel injectors. Refer to paragraph 3-17. If not defective, do Step 5.
b. Replace fuel injector(s). Refer to paragraph 3-17.
Step 5. Check for improper fuel pump timing.
a. Check fuel pump timing. Refer to paragraph 3-14. If fuel pump timing is correct, do Step 6.
b. Adjust fuel pump timing. Refer to paragraph 3-14.
Step 6. Check for defective fuel injection pumps.
a. Test fuel injection pumps. Refer to paragraph 3-13.3.
b. Replace defective fuel injection pumps. Refer to paragraph 3-13.

4. ENGINE HARD TO START OR WILL NOT START IN COLD WEATHER.

Step 1. Check for faulty heater plugs.
a. Test heater plugs. Refer to paragraph 3-.2. If heater plugs not defective, do Step 2.
b. Replace defective heater plug(s). Refer to paragraph 3-6.
Step 2. Refer to Malfunction 3 and perform Step 1 through Step 6.

5. ENGINE MISFIRES OR RUNS IRREGULARLY OR STALLS FREQUENTLY.

Step 1. Check for air in fuel system lines.
Prime fuel system at fuel filter. Refer to paragraph 3-12. If no air, do Step 2.
Step 2. Check for clogged fuel filter.
Refer to paragraph 3-16 for inspection. If not clogged, do Step 3.
Step 3. Check for defective governor system.
Adjust governor system. Refer to paragraph 3-23.5. If properly adjusted, do Step 4.
Step 4. Check for low coolant temperature.
a. If coolant temperature not low, do Step 5.
b. Replace defective thermostat. Refer to paragraph 3-9.
Step 5. Check for fuel injector nozzles dirty, defective or leaking.
a. Remove and test fuel injectors. Refer to paragraph 3-17. If not defective, do Step 6.
b. Replace fuel injector nozzle(s). Refer to paragraph 3-17.

Table 3-2. Troubleshooting Continued

MALFUNCTION TEST OR INSPECTION CORRECTIVE ACTION

Step 6. Check for defective fuel injection pumps.
a. Test fuel injection pumps. Refer to paragraph 3-13.3. If not defective, do Step 7.
b. Replace fuel injection pump(s). Refer to paragraph 3-13.

Step 7. Check for improper fuel pump timing.
Adjust fuel pump timing. Refer to paragraph 3-14. If adjusted properly, do Step 8.

Step 8. Weak or broken valve springs.
a. Remove and check valve springs. Refer to paragraph 3-27.
b. Replace defective valve springs. Refer to paragraph 3-27.

6. ENGINE DOES NOT DEVELOP FULL POWER.

Step 1. Check for blocked air intake system.
Remove blockage as found. If no blockage is found, do Step 2.

Step 2. Check for loss in vacuum.
a. Perform vacuum check. Refer to paragraph 3-5.2.
b. If no loss in vacuum, do Step 3.

Step 3. Engine overheated.
Refer to Engine Overheating, Malfunction 7. If not a problem. Refer to Malfunction 5.

7. ENGINE OVERHEATING.

Step 1. Inspect coolant level.
a. Check engine for coolant leaks. If engine has no leaks, do Step 2.
b. Repair coolant leaks. Refer to end item maintenance manual.

Step 2. Check for defective thermostat.
a. If thermostat is suspected of being defective, replace thermostat. Refer to paragraph 3-9.
b. If engine continues to overheat, do Step 3.

Step 3. Check for defective water pump.
a. Remove and check water pump for damage. Refer to paragraph 3-10. If not defective, do Step 4.
b. Replace defective water pump. Refer to paragraph 3-10.

Step 4. Check for improper fuel pump timing.
Adjust fuel pump timing Refer to paragraph 3-14.

Table 3-2. Troubleshooting Continued

MALFUNCTION TEST OR INSPECTION CORRECTIVE ACTION

8. EXCESSIVE OIL CONSUMPTION.

Step 1. Check for oil leakage.
- a. Inspect engine for oil leaks. If no leaks, do Step 2.
- b. Repair or replace defective components.

Step 2. Check for blocked air intake system.

Remove blockage as found. If no blockage, do Step 3.

Step 3. Check for defective intake or exhaust valve seals or valve guides.
- a. Repair or replace defective components. Refer to paragraph 3-27.
- b. Disassemble and inspect valve seals and guides. Refer to paragraph 3-27. If not defective, and trouble persists notify next higher level of maintenance.

9. LOW OIL PRESSURE.

Step 1. Check for improper grade of oil.
- a. Refer to end item lubrication order. If proper grade of oil, do Step 2.
- b. If improper grade of oil. Refer to paragraph 3-20.1 and change oil and filter.

Step 2. Check for engine running hot.
- a. Refer to Engine Overheating, Malfunction 7, in this table.
- b. If not running hot, repair or replace engine.

10. EXCESSIVE FUEL CONSUMPTION.

Step 1. Check for leak in fuel system.
- a. Check fuel system for leaks. If no leaks, do Step 2.
- b. Repair fuel system.

Step 2. Check for blocked air intake system.

Remove blockage as found. Refer to End Item Maintenance Manual. If no blockage is found, do Step 3.

Step 3. Check for defective fuel injectors.
- a. Remove and test fuel injectors. Refer to paragraph 3-17. If not defective, do Step 4.
- b. Replace fuel injector(s). Refer to paragraph 3-17.

Step 4. Check for loss in vacuum.
- a. Perform vacuum check. Refer to paragraph 3-5.2.
- b. If no loss in vacuum, do Step 5.

Table 3-2. Troubleshooting Continued

MALFUNCTION TEST OR INSPECTION CORRECTIVE ACTION

Step 5. Check for improper fuel pump timing.
- a. If timing is correct, do Step 6.
- b. Adjust fuel pump timing. R refer to paragraph 3-14.

Step 6. Defective fuel injection pumps.
- a. Test fuel injection pumps. Refer to paragraph 3-13.3.
- b. Replace fuel injection pump(s). Refer to paragraph 3-13.

11. BLACK OR GRAY SMOKE.

Step 1. Check for defective fuel injectors.
- a. Remove and test fuel injectors. Refer to paragraph 3-17. If not defective, do Step 2.
- b. Replace fuel injector(s). Refer to paragraph 3-17.

Step 2. Check for improper fuel pump timing.
- a. Adjust fuel pump timing. Refer to paragraph 3-14.
- b. If fuel pump timing is OK. Repair or replace engine.

12. BLUE EXHAUST SMOKE.

Step 1. Check for blocked air intake system.

Remove blockage as found. If no blockage is found, do Step 2.

Step 2. Check for loss in vacuum.
- a. Perform vacuum check. Refer to paragraph 3-5.2.
- b. If vacuum is correct, proceed with Step 3.
- c. If vacuum is not good, repair or replace engine.

Step 3. Check for defective intake or exhaust valve seals or valve guides.
- a. Repair or replace defective components. Refer to paragraph 3-27.
- b. Disassemble and inspect valve seals and guides. Refer to paragraph 3-27. If not defective, repair or replace engine.

Table 3-2. Troubleshooting Continued

MALFUNCTION TEST OR INSPECTION CORRECTIVE ACTION

13. ABNORMAL ENGINE NOISE.

Step 1. Check for worn tappets.

a. Inspect tappets for wear. Refer to paragraph 3-27. If not worn, do Step 2.

b. Replace worn tappets. Refer to paragraph 3-27.

Step 2. Check for bent pushrods.

a. Replace bent pushrods. Refer to paragraph 3-26.

b. Inspect pushrods for straightness. Refer to paragraph 3-26. If straight, repair or replace engine.

14. DETONATION OR PRE-IGNITION.

Step 1. Check for defective fuel injectors.

a. Remove and test fuel injectors. Refer to paragraph 3-17. If not defective, do Step 2.

b. Replace fuel injectors. Refer to paragraph 3-17.

Step 2. Check for improper fuel pump timing.

Adjust fuel pump timing. Refer to paragraph 3-14. If timing is correct, do Step 3.

Step 3. Check for carbon buildup in compression chambers.

a. Remove cylinder head and inspect for carbon buildup. Refer to paragraph 3-27.

b. Remove carbon and/or replace components as necessary.

SECTION III. GENERAL MAINTENANCE

3-3. GENERAL.

This section provides general maintenance not found in other sections of Chapter 3.

3-3.1. General Instructions.

WARNING

Where applicable, prior to performing engine maintenance, ensure batteries are disconnected. Failure to observe this warning could result in personal Injury.

NOTE

Refer to end item maintenance manual for removal of any components necessary to gain access to engine.

a. It is strongly recommended that bolts or nuts securing cylinder heads, covers, and doors be tightened in proper sequence.

b. When assembling an engine, it is always advisable to replace nuts, bolts, and lockwashers that have been removed from high stress locations, in particular nuts and/or bolts from connecting rods and cylinder heads should be replaced.

c. When assembling an engine it is always advisable to apply a small quantity of new lubricating oil to all moving parts. After any maintenance work on engine has been completed lubricating oil and fuel levels must be checked and all safety guards installed before operating.

d. When a new fan drive belt has been installed, check belt tension after first 20 hours of operation.

e. Wear protective overalls, and keep items of loose clothing clear of all hot and moving parts.

f. Whenever possible, clean components and surrounding area before removing or disassembling. Take care to exclude all dirt and debris from fuel injection equipment while it is being serviced.

g. Some parts are cemented with gasket compound with others being dry. Before assembly, remove all traces of old gasket and compound. Take extreme care to exclude dirt from all gasket surfaces and gasket compound from all tapped holes unless otherwise specified.

h. It is recommended that all oil seals are replaced once they have been removed from their original position. Seals must be installed square in housing and all lip seals must be installed with lip facing lubricant to be retained.

A service tool should be used to install all oil seals and care must be taken to prevent damaging new seal when it passes over shafts.

i. Replace all nuts, bolts, capscrews and studs with damaged threads. Do not use a tap or die to repair damaged threads which may impair the strength and closeness of the threads and is not recommended.

j. Do not allow grease or oil to enter a blind threaded hole as hydraulic action present when bolt or stud is screwed in could split or stress housing.

k. To check or retorque a bolt or nut, item is slackened a quarter of a turn and then tightened to specified value.

l. A steel ISO metric bolt, capscrew or nut can be identified by the letter M either on head or one hexagon flat.

The strength grade will also be marked on top or one flat.

m. On nuts with identification marks on one face the frictional area of that surface will be reduced, therefore nut should be installed with unmarked face towards component.

n. Service tools are designed to aid disassembly and assembly procedures and their use will prevent possible unnecessary damage to components. It is recommended that service tools are always used, some operations cannot be safely carried out without aid of relevant tool.

o. When removing/disconnecting fuel or lubrication lines and coolant hoses cap/cover all openings to prevent entry of foreign material.

3-4. DISASSEMBLY AND ASSEMBLY SEQUENCE FOR OVERHAUL.

The following paragraphs provide the sequence of disassembly and assembly for complete overhaul of the engine. Step-by-step procedures can be found in remaining Sections of Chapter 3.

3-4.1. Disassembly. Every effort must be made to maintain engine in a clean condition and repair oil leaks. With a new or overhauled engine parts settle during first few hours running and their tightness must be subsequently checked. When engine is being disassembled all items must be identified, retained in their respective cylinder orientation, and all related components must be treated similarly. The instructions given deal with individual components and it may be necessary to remove other components prior to performing certain procedures.

a. Drain engine coolant, fuel, and lubrication systems. Refer to end item maintenance manual.
b. Remove fan drive belt. Refer to end item maintenance manual.
c. Remove battery charging alternator. Refer to end item maintenance manual.
d. Remove fan. Refer to end item maintenance manual.
e. Remove intake and exhaust manifolds. Refer to paragraphs 3-6 and 3-7.
f. Remove fuel pump to injector pipes. Refer to paragraph 3-18.
g. Remove injectors. Refer to paragraph 3-17.
h. Remove cylinder head covers. Refer to paragraph 3-25.
i. Remove valve rockers and pushrods. Refer to paragraph 3-26.
j. Remove water pump. Refer to paragraph 3-10.
k. Remove cylinder head. Refer to paragraph 3-27.
l. Lift out pushrod tubes, rubber seals, and washers. Refer to paragraph 3-27.
m. Remove remaining fuel pipes and fuel filter. Refer to paragraphs 3-15 and 3-16.
n. Remove dipstick and crankcase door. Refer to paragraph 3-20.
o. Remove oil pressure relief valve and the oil strainer. Refer to paragraph 3-21.
p. Remove connecting rod caps. Refer to paragraph 3-30.
q. Carefully remove carbon buildup from the top of cylinder bore.
r. Turn crankshaft until piston is at Top Dead Center (TDC).
s. Lift out pistons and connecting rods. Refer to paragraph 3-30.
t. Insert common screwdriver in flywheel to lock flywheel.
u. Remove crankshaft pulley; left hand thread. Remove screwdriver.
v. Move engine control to stop position.
w. Remove each fuel injection pump. Use care to retain shim pack with each pump. Refer to paragraph 3-13.
x. Remove gear end cover. Refer to paragraph 3-28.
y. Release speeder spring from governor lever assembly.
z. Remove governor lever assembly and governor rack. Refer to paragraph 3-23.
aa. Remove governor sleeve. Refer to paragraph 3-23.
ab. Remove governor weights. Refer to paragraph 3-23.
ac. Use a suitable magnet and remove hydraulic tappets and fuel pump tappets. Refer to paragraphs 3-27 and 3-13.
ad. Rotate engine until governor weight slots in camshaft are vertical. Refer to paragraph 3-23.
ae. Remove two camshaft thrust plate screws and control lever tension spring. Refer to paragraphs 3-29 and 3-23.

af. Carefully remove camshaft. Refer to paragraph 3-29.
ag. Remove oil pump. Refer to paragraph 3-21.
ah. Remove crankshaft pinion. Refer to paragraph 3-33.
ai. Remove flywheel. Refer to paragraph 3-31.
aj. Remove flywheel housing. Refer to paragraph 3-31.
ak. Remove flywheel end main bearing housing. Refer to paragraph 3-32.
al. Use a manifold bolt to remove center main bearing locating dowel. Refer to paragraph 3-32.
am. Gently withdraw crankshaft. Refer to paragraph 3-33.
an. Remove all main and camshaft bearing shells. Refer to paragraph 3-34.
ao. Cap or cover all openings to prevent entry of foreign material.

3-4.2. Assembly.

NOTE

When assembling engine use normal engine lubricating oil (MIL-L-2104) to spray all moving parts during assembly and all bearings and bushings must be well lubricated during assembly. Replace all gaskets.

a. Remove all caps/covers.
b. Install main and camshaft bearing shells Refer to paragraph 3-34.
c. Install gear end thrust bearings. Refer to paragraph 3--34.
d. Install crankshaft. Ensure that center bearing dowel hole is correctly aligned. Refer to paragraph 3-33.
e. Install flywheel end thrust bearings. Refer to paragraph 3-32.
f. Install flywheel end main bearing housing. Refer to paragraph 3-32.
g. Check crankshaft end play. Refer to paragraph 3-33. Normal end play should be 0.007 to 0.015 in. (0.18 to 0.38 mm).
h. Install center main bearing locating dowel. Refer to paragraph 3-32.
i. Install flywheel housing. Refer to paragraph 3-31.
j. Install flywheel. Refer to paragraph 3-31.
k. Heat crankshaft pinion and install it with timing marks outward. Refer to paragraph 3-33.
l. Install oil pump. Refer to paragraph 3-21.
m. Install governor lever and speeder spring. Refer to paragraph 3-23.
n. Install camshaft, aligning timing marks arid ensure thrust plate is located correctly. Refer to paragraph 3-29.
o. Install fuel pump tappets. Refer to paragraph 3-13.
p. Install hydraulic tappets. Refer to paragraph 3-27.
q. Install governor weights and governor sleeve. Refer to paragraph 3-23.
r. Install governor lever assembly and springs. Refer to paragraph 3-23.
s. Set governor. Refer to paragraph 3-23.
t. Install fuel injection pumps. Refer to paragraph 3-13.
u. Install gear end cover. Refer to paragraph 3-28.
v. Adjust engine control. Refer to paragraph 3-23.5.
w. Install crankshaft pulley Refer to paragraph 3-28.

NOTE

The pistons with rings and connecting rods assembled, must be submerged in engine lubricating oil (MIL-L-2104) just before installing into cylinder. Drain after submersion so that no oil is left in combustion chamber or inside the piston.

x. Install pistons and connecting rods. Refer to paragraph 3-30.
y. Install oil pressure relief valve and oil strainer. Refer to paragraph 3-21.
z. Install crankcase door and dipstick. Refer to paragraph 3-20.
aa. Install pushrod rubber seals, washers, and pushrod tubes. Refer to paragraph 3-27.
ab. Install cylinder head. Refer to paragraph 3-27.
ac. Install pushrods and valve rockers. Refer to paragraph 3-26.
ad. Install cylinder head covers. Refer to paragraph 3-25
ae. Install fuel injectors and fuel injector pipes. Refer to paragraphs 3-17 and 3-18.
af. Install water pump. Refer to paragraph 3-10.
ag. Install intake and exhaust manifolds. Refer to paragraphs 3--6 and 3.-7.
ah. Install fan. Refer to end item maintenance manual.
ai. Install battery charging alternator. Refer to end item maintenance manual.
aj. Install fan drive belt and tension it. Refer to end item maintenance manual.
ak. Install fuel filter and all other fuel pipes. Refer to paragraphs 3-15 and 3-16.
al. Service engine coolant, fuel, and lubrication systems. Refer to end item maintenance manual and lubrication order.

3-5. CRANKCASE VACUUM.

3-5.1. General. The value depends to some extent on the type and size of air cleaner installed on tie engine. Regardless of type air cleaner used, vacuum with a clean air cleaner must not be less than a minimum of 0.79 in. (20 mm) water gage (WG). The vacuum is measured with a manometer at the lubricating oil dipstick hole with the engine running. In engines in good condition vacuum increases slightly with engine speed but not proportionally. A fluctuating vacuum may indicate faulty oil seals, valves, or piston blow-by troubles. Crankcase pressure can cause serious oil leaks and often occurs in engines which need overhauling.

3-5.2. Measure Vacuum.

NOTE

Average vacuum should be 1.37 in. (34.8 mm) WG. Minimum allowed is 0.79 in. (20 mm) WG.

a. Remove lubricating oil dipstick.
b. If water manometer is available, connect one end of a 0.374 in. (9.5 mm) OD plastic tube to a water manometer. Insert other end of tube into dipstick hole. Refer to FIGURE 3-1.

WARNING

The noise level when operating could cause hearing damage. Ear protection must be worn.

c. Start engine and record reading on manometer.
d. Stop engine, disconnect manometer and install oil dipstick.
e. If water manometer is not available, place a piece of thick paper over the oil fill opening. If crankcase vacuum retains paper, vacuum is good.

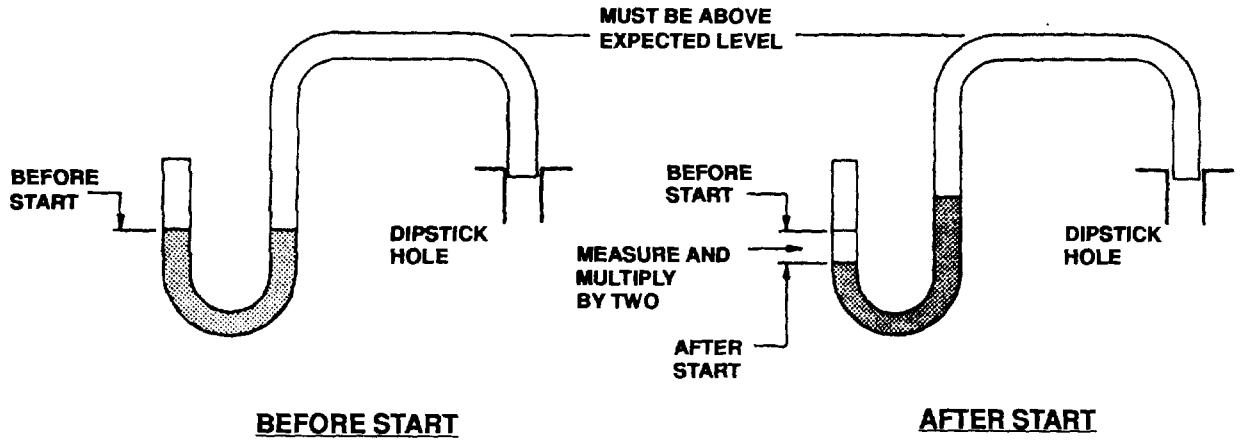


FIGURE 3-1. Locally Manufactured Water Manometer

SECTION IV. INTAKE AND EXHAUST SYSTEM MAINTENANCE

3-6. INTAKE MANIFOLD.

3-6.1. Removal.

a. Remove air intake piping. Refer to end item maintenance manual.
b. Tag and disconnect electrical leads from heater plugs (1, FIGURE 3-2).
c. If damaged or defective, remove heater plugs (1) from manifold.
d. Remove eight bolts (2) and eight washers (3) securing intake manifold (4); remove manifold (4) and four gaskets (5). Discard gaskets (5).
e. Cover all openings.

3-6.2. Inspect and Measure.

a. Inspect manifold for cracks, corrosion, or other damage. Replace if damaged.
b. Inspect attaching hardware for damage. Replace if damaged.
c. Inspect heater plugs for damage.
d. Set multimeter for ohms and test heater plugs. Normal reading is 4 to 5 ohms. Zero resistance indicates a shorted heater and a high reading indicates an open heater.

3-6.3. Installation.

a. Remove all covers.
b. Install new or tested heater plugs (1, FIGURE 3-2) in manifold (4).
c. Clean intake manifold (4) and cylinder head mating surfaces of any traces of old gasket.
d. Position four new gaskets (5) and intake manifold (4) on cylinder head.
e. Install eight washers (3) and eight bolts (2). Tighten bolts to 78 in-lbs (8.8 Nm).
f. Connect electrical leads to heater plugs. Refer to end item maintenance manual. Remove tags.
g. Install air intake piping. Refer to end item maintenance manual.

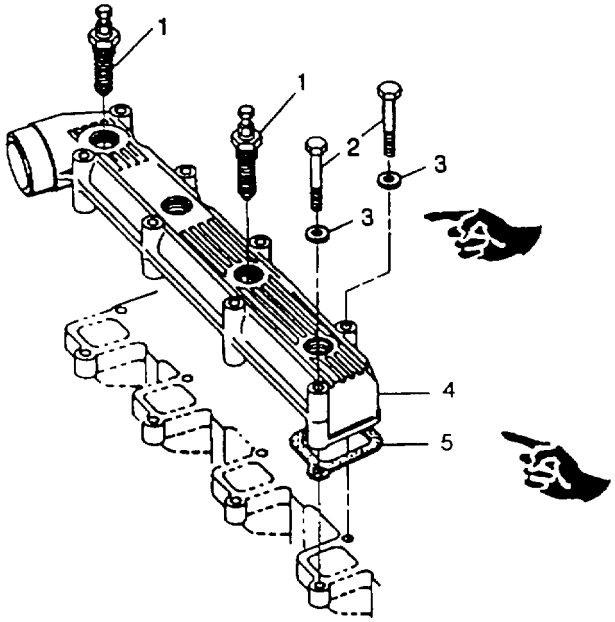


FIGURE 3-2. Intake Manifold

3-7. EXHAUST MANIFOLD.

3-7.1. Removal.

a. Remove exhaust piping. Refer to end item maintenance manual.
b. Remove eight nuts (1, FIGURE 3-3), exhaust manifold (2), and four gaskets (3) from studs (4). Discard gaskets (3).
c. If damaged, remove eight studs (4).
d. Cover all openings.

3-7.2. Inspection.

a. Inspect manifold for cracks, corrosion, or other damage. Replace if damaged.
b. Inspect attaching hardware (studs and nuts) for thread damage. Replace if damaged.

3-7.3. Installation.

a. Remove covers.
b. Clean exhaust manifold and cylinder head mating surfaces of any traces of old gaskets.
c. If removed, install eight studs (4, FIGURE 3-3).
d. Install four new gaskets (3), manifold (2), and eight nuts (1). Tighten nuts to 78 in-lbs (8.8 Nm).
e. Install exhaust piping. Refer to end item maintenance manual.

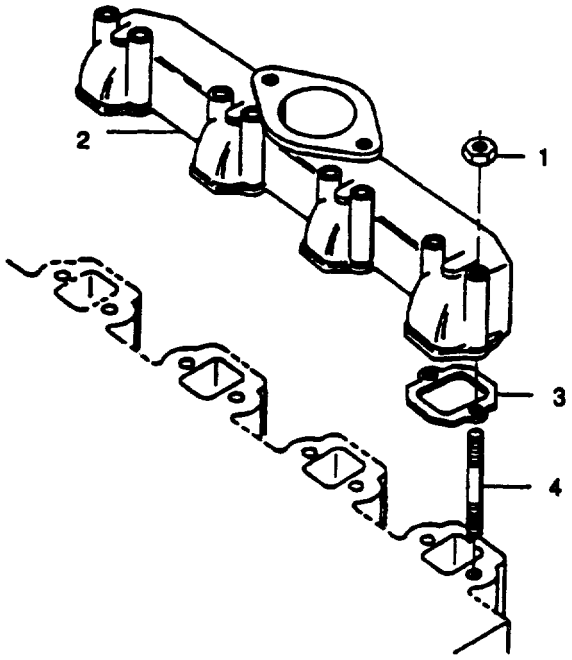


FIGURE 3-3. Exhaust Manifold

SECTION V. COOLING SYSTEM MAINTENANCE

3-8. GENERAL.

This section provides maintenance for cooling system components. Components of cooling system not mentioned in this Section can be found in the end item maintenance manual.

WARNING

If the engine has been operating and coolant Is hot, allow engine to cool before you slowly loosen filler cap and relieve pressure from cooling system. Failure to follow this procedure could result In personal Injury.

3-9. THERMOSTAT.

3-9.1. Removal.

a. Remove negative battery cable.
b. Drain coolant system. Refer to end item maintenance manual.
c. Loosen hose clamp and disconnect outlet hose from thermostat housing (3, FIGURE 3-4).
d. Remove two capscrews (1), washers (2), thermostat housing (3), and gasket (4). Discard gasket (4).
e. Remove thermostat (5) from water pump.

NOTE

If thermostat is suspected of being defective, replace thermostat.

3-9.2. Inspection.

a. Inspect thermostat for excessive wear or damage.
b. Inspect housing for cracks, corrosion, or other damage.

3-9.3. Replacement.

a. Replace thermostat if worn or damaged.
b. Replace housing if badly corroded or damaged.

3-9.4. Installation.

a. Remove all covers.
b. Clean any debris and traces of old gasket from thermostat housing (3, FIGURE 3-4) and water pump (11) mating surfaces. Dry all surfaces.
c. Install thermostat (5) in water pump.
d. Install new gasket (4), thermostat housing (3), two washers (2), and capscrews (1).
e. Connect outlet hose to thermostat housing (3) and secure with hose clamp.
f. Service coolant system. Refer to end item maintenance manual.

3-10. WATER PUMP.

3-10.1. Removal.

a. Drain coolant system. Refer to end item maintenance manual.
b. Relieve fan belt tension.

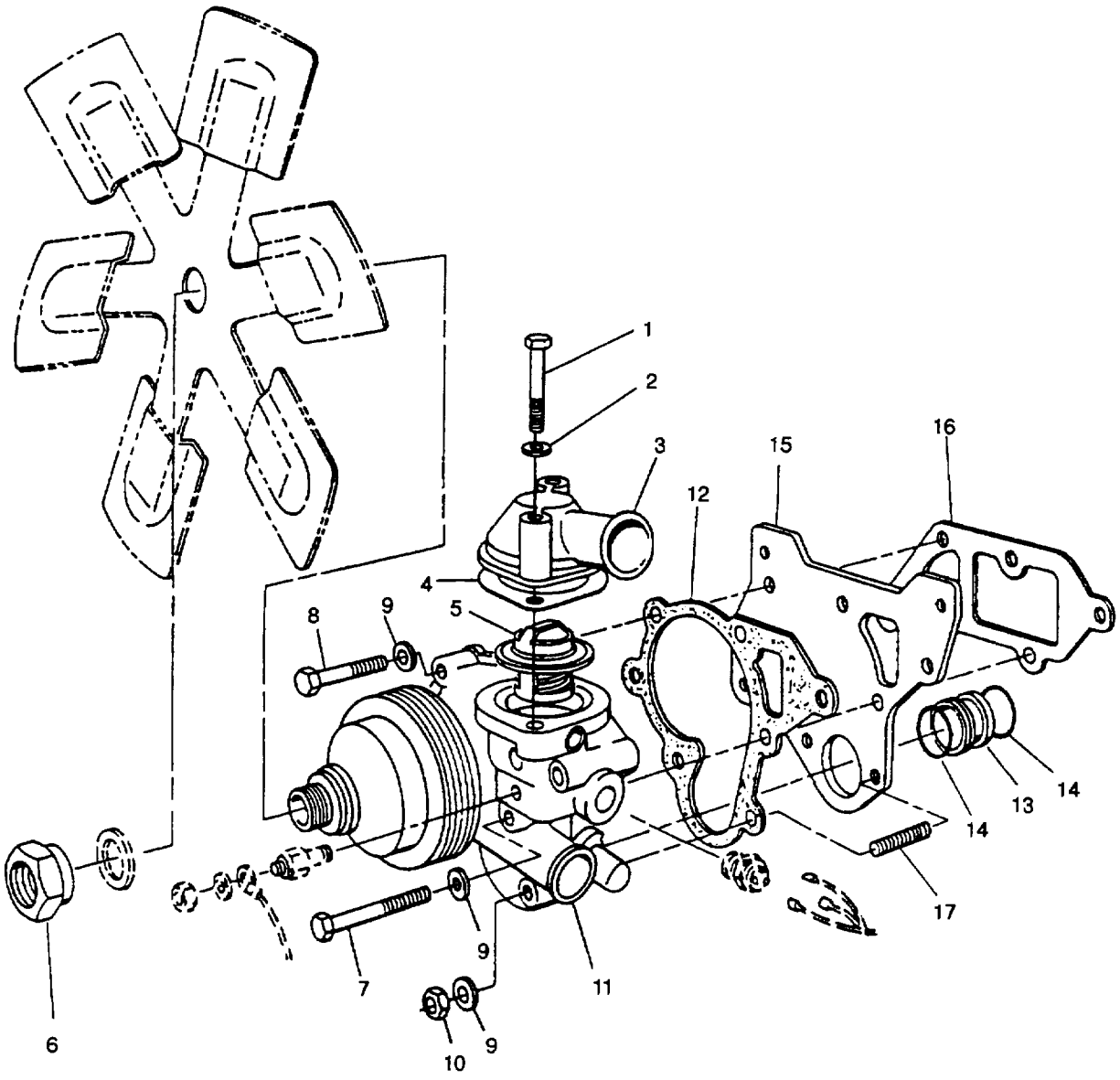


FIGURE 3-4. Cooling System

NOTE

Nut (6, FIGURE 3-4) has left hand threads.

c. Remove nut (6), washer, fan, and fan belt.
d. If installed, tag and disconnect electrical leads to temperature sensors.
e. Loosen clamps and disconnect inlet and outlet hoses.

NOTE

Identify location of two shorter capscrews (8) for use during installation.

f. Remove five capscrews (7 and 8), two nuts (10), and seven washers (9).
g. Slide water pump (11) with thermostat (5) and housing (3) attached, from mounting studs (17). Remove and discard gasket (12).
h. Remove sleeve (13) and two performed packings (14) Discard performed packings.
i. Remove mounting plate (15) and gasket (16). Discard gasket.
j. If damaged, remove two mounting studs (17).
k. Cover all openings.

3-10.2. Inspection.

a. Inspect pump impeller for damage, corrosion, or missing blades.
b. Inspect pump rotation for abnormal noise, binding, and other abnormal conditions.
c. Inspect pump housing for cracks, corrosion, or any other damage.
d. Inspect sleeve for corrosion or any other damage.
e. Inspect mounting studs for damage.

3-10.3. Installation.

a. Remove all covers.
b. Clean all mating surfaces of any traces of old gaskets. Dry all surfaces.

CAUTION

If two water pump studs (17, FIGURE 3-4) have been removed, they must be Installed and finger tightened. Do not overtighten as this will cause thread damage preventing a flat sealing surface.

c. If removed, install two mounting studs (17) finger tight.
d. Install two new preformed packings (14) and sleeve (13).
e. Install new gasket (16), mounting plate (15), new gasket (12), and water pump (11).
f. Secure pump to crankcase with seven washers (9) , two nuts (10) and five capscrews (8 and 7). Install two shorter capscrews (8) as noted during removal. Tighten hardware to 186 in-lbs (21.0 Nm).
g. Connect inlet and outlet hoses to water pump and tighten hose clamps.
h. If removed, install temperature sensors in water pump and connect electrical leads. Remove tags.

NOTE

Nut (6) has left hand threads.

i. Install fan belt, fan, washer, and nut (6). Tighten nut (6) to 20 to 24 ft-lbs (27 to 32 Nm).
j. Tighten fan belt.
k. Service coolant system. Refer to end item maintenance manual.

SECTION VI. FUEL SYSTEM MAINTENANCE

3-11. GENERAL.

This section provides maintenance for fuel system components. Components of the fuel system not mentioned in this, section can be found in end item maintenance manual. Observe the following precautions:

a. Always cap fuel connections after removal to prevent contamination.
b. When priming or checking fuel pump timing, care must be taken to wipe spilled fuel from outside of engine.
c. Special care must be taken to see that no leakage exists from fuel pipe connections on pump.
d. When tightening or loosening fuel pump delivery connections, use two wrenches to prevent pump from twisting on its seating and causing misalignment of pump calibration.
e. When installing fuel pipe from pump to injector, fuel pipe must be correctly aligned and line up freely at both ends. Do not pry on pipe to install, or leakage may result.

3-12. BLEEDING/PRIMING FUEL SYSTEM.

The following procedure is performed with engine running or cranking and repeated at each fuel pump.

a. Loosen two screws (1, FIGURE 3-5) on fuel filter to allow air to escape. Tighten screws.
b. Loosen injector fuel pipe (2) at fuel injection pump.
c. Loosen delivery valve holder (3) on fuel injection pump up to a quarter of a turn until no air bubbles are expelled.
d. Tighten delivery valve holder (3) using 17 mm crowsfoot wrench to 35 ft-lbs (47.5 NM).
e. Tighten injector pipe nut (2) to 21 ft-lbs (28.5 Nm).

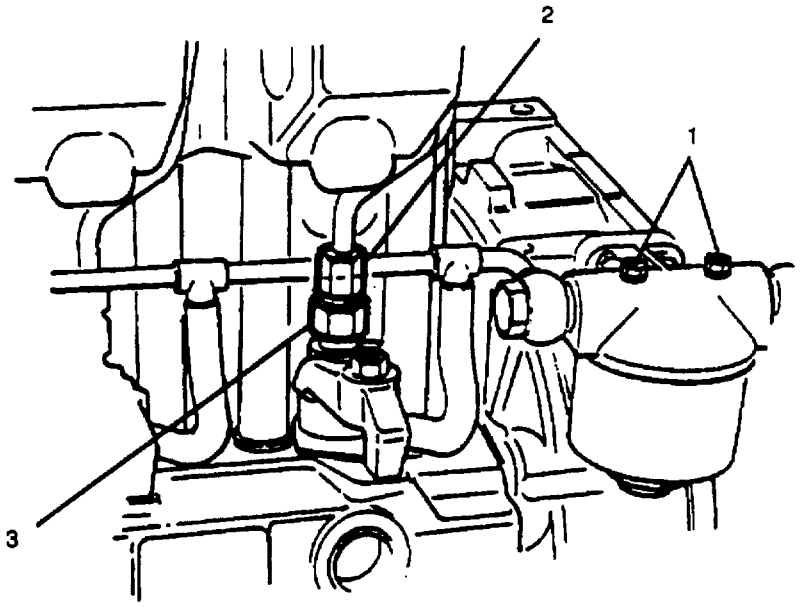


FIGURE 3-5. Priming Fuel System

3-13. FUEL INJECTION PUMP.

3-13.1. Removal.

WARNING

Fuel Is flammable. Keep fuel away from heat and open flame. Failure to follow this warning could result In personal Injury or death.

CAUTION

If more than one fuel pump Is being removed extreme cam must be taken to ensure that shim pack Is replaced to Its original cylinder, otherwise when Installed, fuel pumps may not operate properly.

NOTE

To retain governor setting leave one fuel pump in position.

NOTE

Catch fuel in a suitable container.

a. Loosen damp (4, FIGURE 3-7) and disconnect fuel supply line (11) from fuel injector pump (5).

b. Position engine speed control counterclockwise to stop position and hold in this position with a plastic tie-wrap. Refer to FIGURE 3-6.

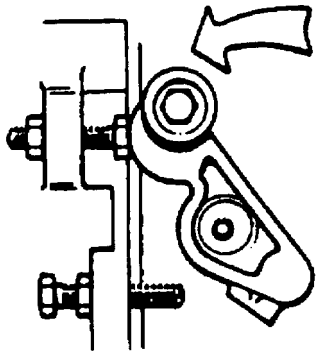


FIGURE 3-6. Engine Speed Stop

c. Remove fuel injector pipe between pump (5, FIGURE 3-7) and fuel injector. Refer to paragraph 3-18.

d. Remove fuel supply lines. Refer to paragraph 3-15.

e. Remove nut (1) and damp (2) securing fuel injection pump (5).

f. Lift fuel injection pump (5) out of crankcase and remove shim pack (6). Tag them as to which cylinder they came from.

g. If necessary, remove thrust cup (8) and tappet (7) from crankcase using magnetic pick-up. Tag them as to which cylinder they came from.

h. If damaged, remove stud (3).

i. Cap/cover all openings.

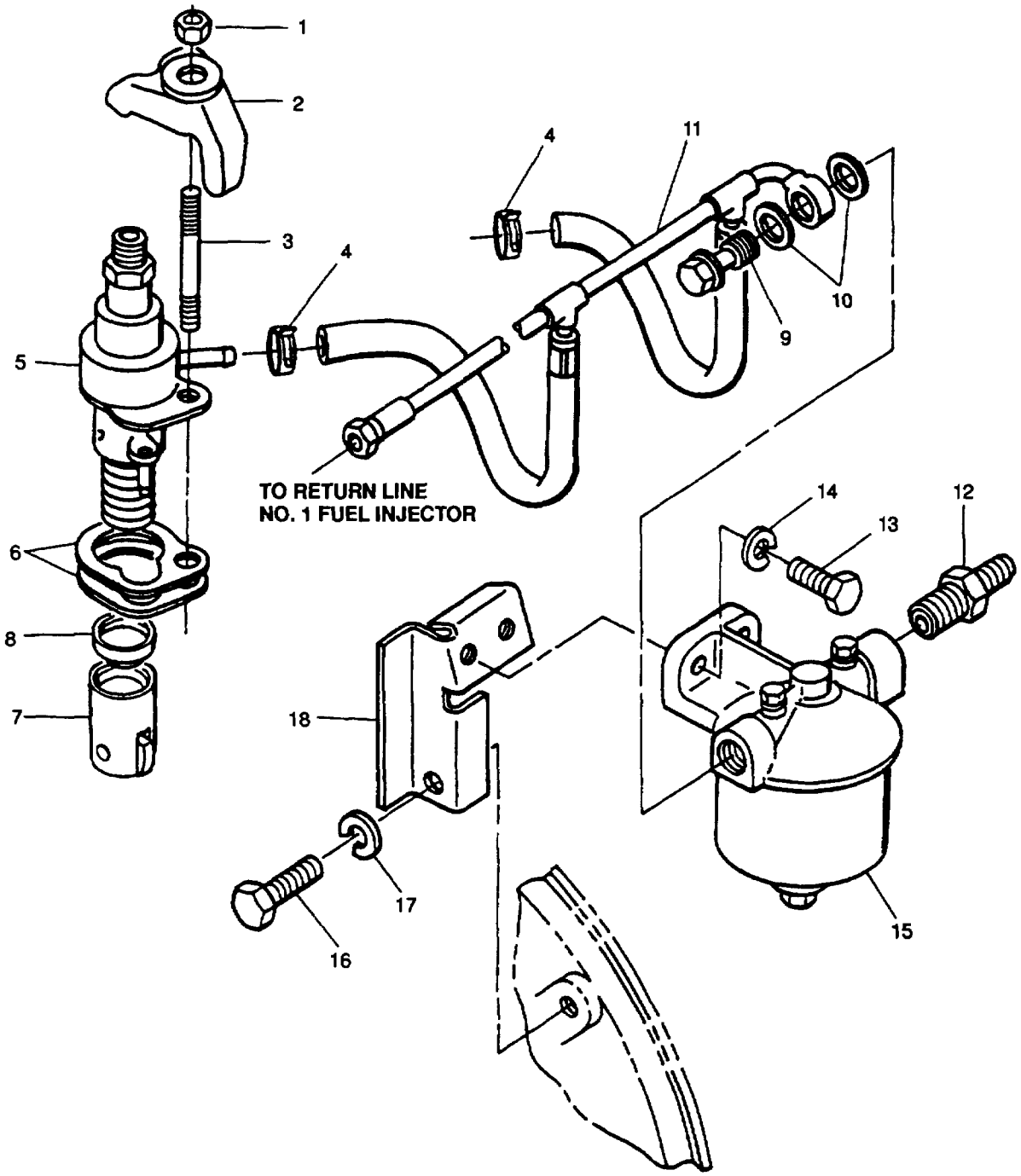


FIGURE 3-7. Fuel Injection Pump, Fuel Filter, and Supply Lines

3-13.2. Inspection.

a. Inspect pump housing for cracks, corrosion, or any other damage.
b. Inspect shim pack for corrosion or damage.
c. Inspect tappet for cracks, corrosion, or any other damage.

3-13.3. Test.

NOTE

This test must be performed with engine installed in end item.

a. Disconnect fuel injector pipe from top of pump to be tested.
b. Connect a fuel pressure gage capable of displaying 3000 psi (20,685 kPa).
c. Using end item controls, crank engine and observe pressure gage.
d. Pressure gage should read approximately 3000 psi (20,685 kPa). If reading is not as specified, replace fuel pump.
e. Remove pressure gage and connect fuel injector pipe. Tighten coupling nut to 21.0 ft-lbs (28.5 Nm).

3-13.4. Installation.

a. Remove all caps/covers.
b. Before installing fuel injection pump, ensure governor is correctly adjusted. Refer to paragraph 3-23.5.

CAUTION

Under no circumstances must any attempt be made to remove fuel pump tappet stud from crankcase, to prevent damage to engine block.

c. If tappet (7, FIGURE 3-7) and thrust cup (8) were removed, install them as follows:
   (1) Tappet is installed in crankcase using long nosed pliers held open against top inside edge of tappet recess.
   (2) Submerge tappet in dean engine lubricating oil (MIL-L-2104).
   (3) Insert tappet in crankcase with longer slot facing outward to ensure it is correctly located over tappet stud. Refer to FIGURE 3-8. Install thrust cup (8, FIGURE 3-7).

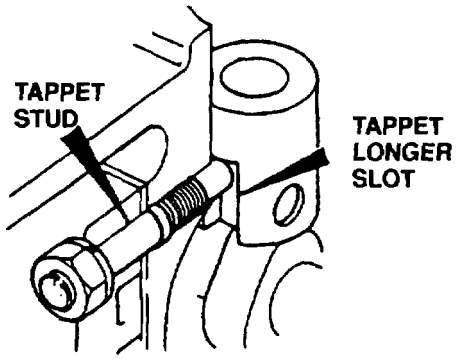


FIGURE 3-8. Fuel Pump Tappet and Stud

d. Press down on top of thrust cup (8) and fuel pump tappet (7) and slowly turn crankshaft until fuel pump tappets felt to be at its lowest position.
e. Remove gear end cover. Refer to paragraph 3-28.1 and remove rack spring (15, FIGURE 3-19) from governor lever.
f. Using fuel pump rack setting gage (317-50114), damp pump rack in shutdown position. Screw on gage threads into end cover tapped hole. Refer to FIGURE 3-9.

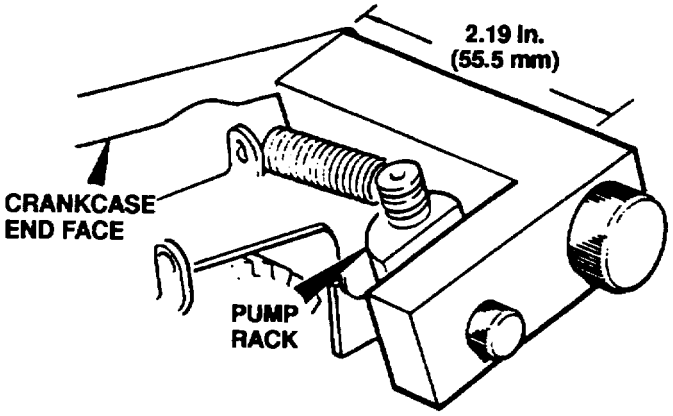


FIGURE 3-9. Setting Pump Rack

g. If removed, install stud (3, FIGURE 3-7).
h. Install correct original shim pack (6) on fuel pump (5).
   (1) Do not remove or add to original shims installed between pump flange and steel plate.
   (2) Use extreme care to ensure that individual shim packs are installed between each fuel pump plate and crankcase and that they are retained with their original respective cylinder.
   (3) Shims are available in three sizes and are color coded. Refer to TABLE 3-3.

TABLE 3-3. Color Coded Shim Packs for Fuel Pump

Color	Size
Green	0.003 in. (0.075 mm)
Slate Blue	0.005 in. (0.125 mm)
Black	0.010 in. (0.250 mm)

i. If original shim thickness is not known or if fuel pump is being replaced, fuel pump must be timed. Refer to paragraph 3-14.

j. Gently insert fuel pump and shims into crankcase. Ensure that fuel pump rack engages with slot in governor rack

CAUTION

If fuel pump is not turned counterclockwise or moves before tightening, it is possible that engine will not stop when required.

k. Carefully turn fuel pump counterclockwise until pump rack is felt against stop.

l. Holding pump in this position, install damp (2) and secure with nut (1) (beveled face towards clamp) finger tight.

m. Tighten nut to 25 ft-lbs (33.9 Nm).

n. Install fuel injector pipe between pump (5) and fuel injector. Refer to paragraph 3-18.

o. Connect fuel supply line (11) to fuel injection pump using damp (4).

p. Remove rack setting gage.

q. Connect governor lever to rack spring (15, FIGURE 3-19).

r. Install gear end cover. Refer to paragraph 3-28.3.

3-14. FUEL INJECTION PUMP TIMING.

WARNING

Cleaning solvent Is flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection required. Avoid repeated/prolonged contact. Good general ventilation Is normally adequate.

Each fuel injection pump is timed individually during assembly at factory and when an existing or new fuel injection pump is installed, it is only necessary to reinstall existing shim pack or a new pack of same thickness as original. This procedure is necessary only if original shims have been lost or mixed with those of another pump. Use care to avoid dirt entering into engine during fuel injection pump timing procedure. If practical, start with a thorough cleaning. Use dry cleaning solvent (P-D-680) to remove all external dirt. For each fuel injection pump to be timed, repeat following procedure.

a. Remove cylinder head cover and fuel injector. Refer to paragraphs 3-25.1 and 3-17.1.

b. Turn engine over manually to establish TDC between compression and power strokes for cylinder being timed. Normal engine direction of rotation is clockwise as viewed from the fan end. Correct top center occurs approximately 140 degrees of crankshaft rotation after intake valve closes.

c. Remove intake valve rocker lever nut and rocker lever. Refer to paragraph 3-26.1.

WARNING

Do not stand over valve springs when depressing valves. Failure to observe this warning could result in personal Injury.

d. Using valve spring tool, depress intake valve until it contacts the piston crown (approximately 0.051 to 0.059 inches [1.3 to 1.5 mm]). Then remove collets, carrier, and spring from intake valve.

NOTE

If valve can be depressed more than approximately 0.25 in. (6.35 mm), piston is not in correct position. Engine should be rotated to correct position to avoid possibility of dropping valve into cylinder once carrier and spring are removed.

e. Valve can now be depressed until head of valve rests on top of piston. Refer to FIGURE 3-10.

t. Mount a dial indicator. Refer to FIGURE 3-10 to cylinder head to check intake valve drop. Carefully turn engine a small amount either side of TDC and dial indicator can be zeroed at TDC.

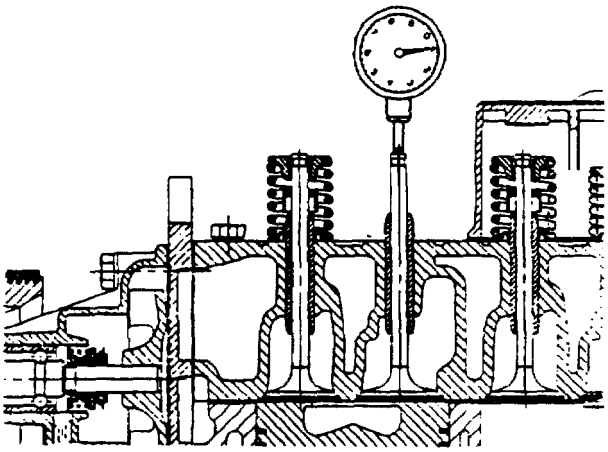


FIGURE 3-10. Checking Piston Drop

g. Measure piston drop. Engine should then be rotated opposite normal crankshaft rotation (counterclockwise as viewed from fan end) to approximately 0.01 in. (0.2544 mm) drop beyond specified piston drop of 0.99 in. (2.519 mm). Then rotate in direction of normal crankshaft rotation until specified piston drop is reached. It is important that specified piston drop be approached in direction of normal crankshaft rotation.

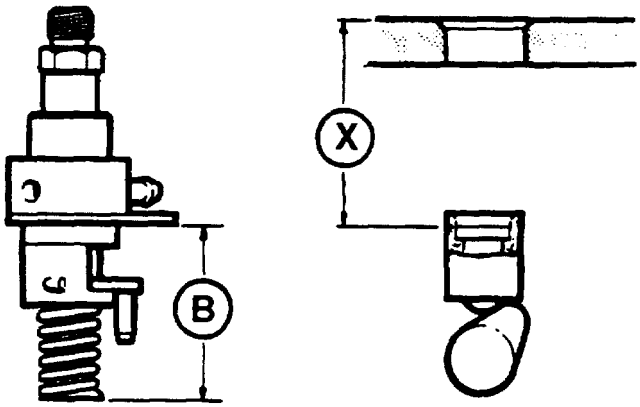
NOTE

It may be necessary to push down on valve stem to overcome friction of stem seal and maintain contact of valve head to piston crown.

NOTE

Ensure top face of crankcase is clean.

h. Using a depth gage, measure distance (X) from top face of crankcase to top of fuel pump tappet cap. Refer to FIGURE 3-11. Subtract dimension (X) from dimension (B) 2.02 in. (51.196 mm) to obtain required thickness of shim pack to be installed between fuel injection pump plate and crankcase.



**B=2.02 in. (51.196mm)
AT PORT CLOSURE**

FIGURE 3-11. Fuel Injection Pump Dimensions

i. Install intake valve spring, carrier, and collets. Refer to paragraph 3-27.5.

i. Install rocker lever and rocker lever nut. Refer to paragraph 3-26.3.

NOTE

Hydraulic tappet bleed down must be verified before proceeding. Refer to paragraph 3-26.3.

k. Install fuel injection pump. Refer to paragraph 3-13.4.

l. Install fuel injector and fuel injector pipe. Refer to paragraphs 3-17.4 and 3-18.3.

m. Install cylinder head cover. Refer to paragraph 3-25.3.

3-15. FUEL SUPPLY LINES.

3-15.1. Removal.

a. Loosen clamps (4, FIGURE 3-7) and disconnect supply hoses of fuel line (11) from fuel injection pumps (5).

b. Disconnect fuel return hose from fuel supply line (11).

c. Remove swivel union plug (9) securing fuel line (11)to fuel filter (15); remove fuel line (11) and two seals (10). Discard seals (10).

d. Cap all openings.

3-15.2. Inspection.

a. Inspect metal portions of fuel line for dents or deformations.

b. Inspect hoses of fuel line for cracks, deterioration, or any other damage.

3-15.3. Installation.

a. Remove all caps.

b. Connect fuel line (11, FIGURE 3-7) to fuel filter (15) using two new seals (10) and swivel union plug (9).

c. Connect supply line (11) hoses to fuel injection pumps (5) and secure with damps (4).

d. Connect fuel return line to supply line (11).

3-16. FUEL FILTER.

3-16.1. Service.

WARNING

Fuel Is flammable. Keep fuel away from heat and open flame. Failure to observe this warning could result In severe personal Injury or death.

NOTE

Catch fuel in suitable container.

a. Remove through bolt (1, FIGURE 3-12) and canister (2).

b. Remove and discard fuel filter (3) and gaskets.

c. Install new filter (3) and gaskets.

d. Fill canister (2) with dean fuel.

e. Install canister (2) with bolt (1).

f. Prime fuel system. Refer to paragraph 3-12.

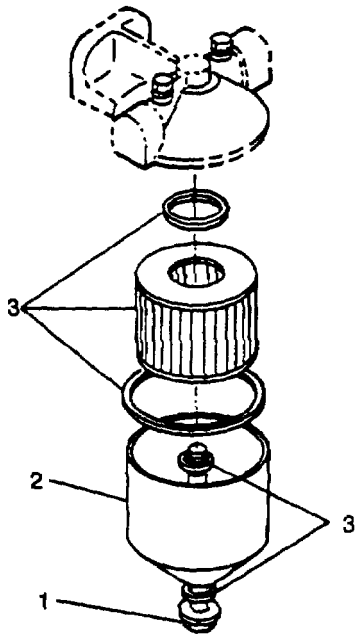


FIGURE 3-12. Fuel Filter

3-16.2. Removal.

WARNING

Fuel Is flammable. Keep fuel away from heat and open flame. Failure to observe this warning could result In severe personal Injury or death.

NOTE
Catch fuel in suitable container.

a. Disconnect end item fuel supply line from fuel filter (15, FIGURE 3-7).

b. If damaged, (or if replacing filter assembly), remove fitting (12) from filter (15).

c. Remove swivel union plug (9) securing fuel line (11) to fuel filter (15); remove fuel line (11) and two seals (10). Discard seals (10).

d. Remove two capscrews (13) and lockwashers (14) securing filter (15) to mounting bracket (18) remove filter. Discard lockwashers (14).

e. If damaged, remove capscrew (16) and lockwasher (17) securing bracket (18) to flywheel housing. Discard lockwasher (17).

f. Cap all openings.

3-16.3. Installation.

a. Remove all caps.

b. If removed, position bracket (18, FIGURE 3-7) on flywheel housing and secure with capscrew (16) and new lockwasher (17). Tighten capscrew to 58 ft-lbs (78.6 Nm).

c. Position fuel filter (15) on bracket (18) and secure with two capscrews (13) and new lockwashers (14).

d. Connect fuel supply line (11) to fuel filter (15) using two new seals (10) and swivel union plug (9).

e. If removed or replaced, install fitting (12) in filter (15).

f. If required, connect end item fuel supply line to fuel filter (15).

3-17. FUEL INJECTOR.

3-17.1. Removal.

WARNING

Fuel is flammable. Keep fuel away from heat and open flame. Failure to observe this warning could result in severe personal injury or death.

CAUTION

Do not apply excessive force to injection fuel pipes. Failure to observe this caution could result in damage to fuel pipes.

NOTE

Catch fuel in suitable container.

a. Disconnect and remove fuel injector pipe (3 or 4, FIGURE 3-13). Refer to paragraph 3-18.1.
b. Disconnect fuel return hose (5) from injector (8).
c. Remove bolt (6) securing clamp (7); remove clamp.
d. Remove fuel injector (8) from cylinder head.
e. Remove injector copper sealing washer (9) from cylinder head taking care not to damage seating area.
f. Cover all openings.

3-17.2. Inspection.

a. Check nozzle body and nozzle needle for damage or deformation. If damaged or deformed, replace fuel injector nozzle.
b. Inspect threaded components for thread damage and replace as necessary.

3-17.3. Test.

a. Attach fuel injector to a fuel injector tester. Point fuel injector into a clear container.

WARNING

Keep body clear of test spray. Fluid can be injected into blood-stream causing blood poisoning and possible death.

b. Open valve on fuel injector tester and operate lever at one stroke per second.
c. Spray should start at 3480 psi (23,995 kPa) for used injector and 3552 to 3697 psi (24,491 to 25,491 kPa) for new injector and a well atomized spray pattern should be visible.
d. Injector leakoff rate is 10 to 40 seconds between 2205 and 1470 psi (15,203 and 10,136 kPa).

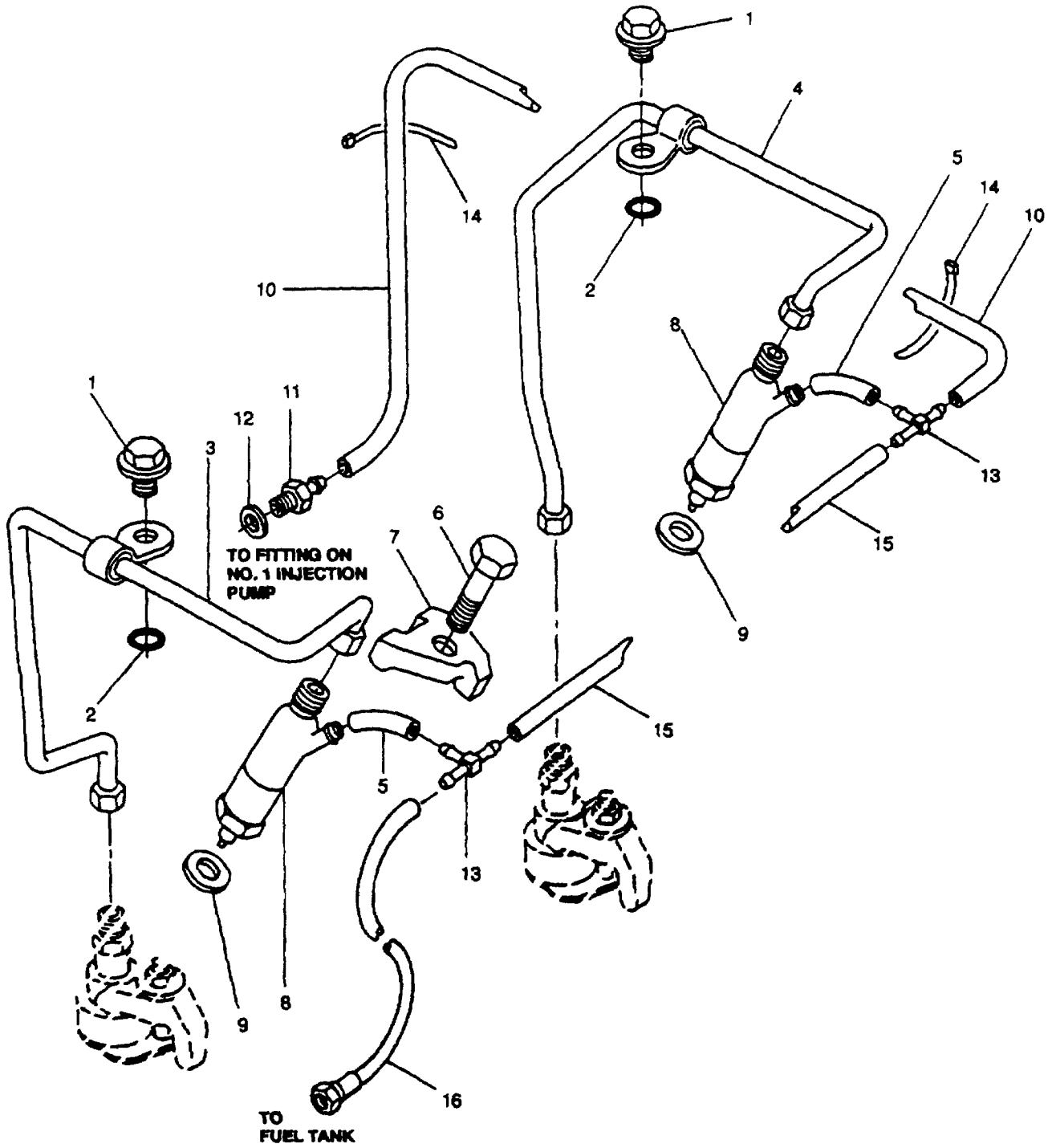


FIGURE 3-13. Fuel Injector, Fuel Injector Pipes, and Fuel Return Line

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3-17.4. Installation.

a. Remove all covers.

b. Ensure seating in cylinder head is clean and smooth.

NOTE

If injector sealing washer (9, FIGURE 3-13) has been used more than once it will become compressed and may adversely affect combustion. It is recommended that new injector sealing washers are installed on assembly. Ensure that two washers are not installed to an injector.

c. Lightly smear a very small amount of general purpose grease (630AA) to one side of new injector sealing washer (9). Place one washer only over each injector nozzle greased side first.

d. Install injector (8).

e. Install damp (7) and finger tighten bolt (6).

f. Install a new performed packing (2) into recess on cylinder head cover.

g. Install injector pipe (3 or 4) and finger tighten nuts.

h. Install cylinder head cover nut retaining injector pipe clip and tighten to 78 in-lbs (8.8 Nm).

i. Tighten injector clamp bolt (6) to 186 in-lbs (21.0 Nm).

j. Tighten injector pipe (3 or 4) nuts to 21.0 in-lbs (28.5 Nm).

k. Install injector fuel return hose (5).

3-18. FUEL INJECTOR PIPES AND FUEL RETURN LINE.

3-18.1. Removal.

a. Disconnect hose (10, FIGURE 3-13) from union (11).

b. Remove union (11) and washer (12) from end of fuel supply hose.

c. Disconnect hose (10) from tee fitting (13). Remove tiedown straps (14) and remove hose (10). Discard tiedown straps.

d. Remove hoses (5) from fuel injectors (8) and tee fittings (13).

e. Remove tee fittings (13) from hose (15); remove hose (15).

f. Disconnect hose (16) from tee fitting (13); remove hose (16).

g. Loosen nuts on fuel injector pipes (3 and 4) at fuel injection pump and fuel injector (8).

h. Remove cylinder head cover nuts (1) securing fuel injector pipes (3 and 4) dips; remove pipes (3 and 4) if damaged, replace preformed packing (2).

i. Cap all openings.

3-18.2. Inspection.

a. Inspect fuel injector pipes for wear, kinks, or fitting damage. Replace as necessary.

b. Inspect hoses for cracks, deterioration, or any other damage.

3-18.3. Installation.

a. Remove all caps.

b. Connect fuel injector pipes (3 and 4, FIGURE 3-13) to fuel injectors (8) and fuel injection pumps. Tighten nuts finger tight.

c. Secure fuel injector pipe clips using cylinder head cover nuts (1). Tighten nuts to 78 in-lbs (8.8 Nm).

d. Starting at fuel injector (8), tighten fuel injector pipes (3 and 4) nuts to 21.0 ft-lbs (28.5 Nm).

e. Install tee fitting (13) into hose (16).
f. Install tee fittings (13) in hose (15).
g. Connect hoses (5) to tee fittings (13) and to fuel injectors (8).
h. Connect hose (10) to tee fitting (13) and secure hose (10) with new tiedown straps (14).
i. Install union (11) and washer (12) to end of fuel supply hose.
j. Connect hose (10) to union (11).

3-19. FUEL SOLENOID.

3-19.1. Removal.

a. Tag and disconnect electrical leads from solenoid (8, FIGURE 3-14).
b. Remove capscrew (1), knob (2), washer (3), and retaining nut (4) securing linkage (5) to lever (13).
c. Remove two capscrews (6) and washers (7) securing solenoid (8) to bracket (11); remove solenoid (8) with linkage (5).
d. Count number of threads exposed prior to unscrewing linkage (5). This will aid installation and adjustment.
e. If damaged or if replacing solenoid, loosen locknut on linkage (5) and unscrew linkage from solenoid (8).
f. If damaged, remove two nuts (9) and washers (10) securing bracket (11) to engine; remove bracket (11).
g. If damaged, remove two studs (12) and washers (10) from engine block.

3-19.2. Inspection.

a. Inspect linkage for bends or any other damage.
b. Inspect threaded components for thread damage.
c. Refer to end item maintenance manual for inspection of solenoid.

3-19.3. Adjustment. For adjustment of fuel solenoid installation. Refer to end item maintenance manual.

3-19.4. Installation.

a. If removed, install two studs (12, FIGURE 3-14) and washers (10) in engine block.
b. If removed, position bracket (11) on studs (12) and secure with two nuts (9) and washers (10).
c. If removed, screw linkage (5) into solenoid (8) leaving number of threads exposed as noted during removal. Tighten linkage locknut.
d. Position solenoid (8) with linkage (5) on bracket (11) and secure with two capscrews (6) and washers (7).
e. Connect linkage (5) to lever (13) using capscrew (1), knob (2), washer (3), and retaining nut (4).
f. Connect electrical leads to solenoid (8) as tagged during removal. Remove tags.
g. Adjust fuel solenoid installation. Refer to end item maintenance manual.

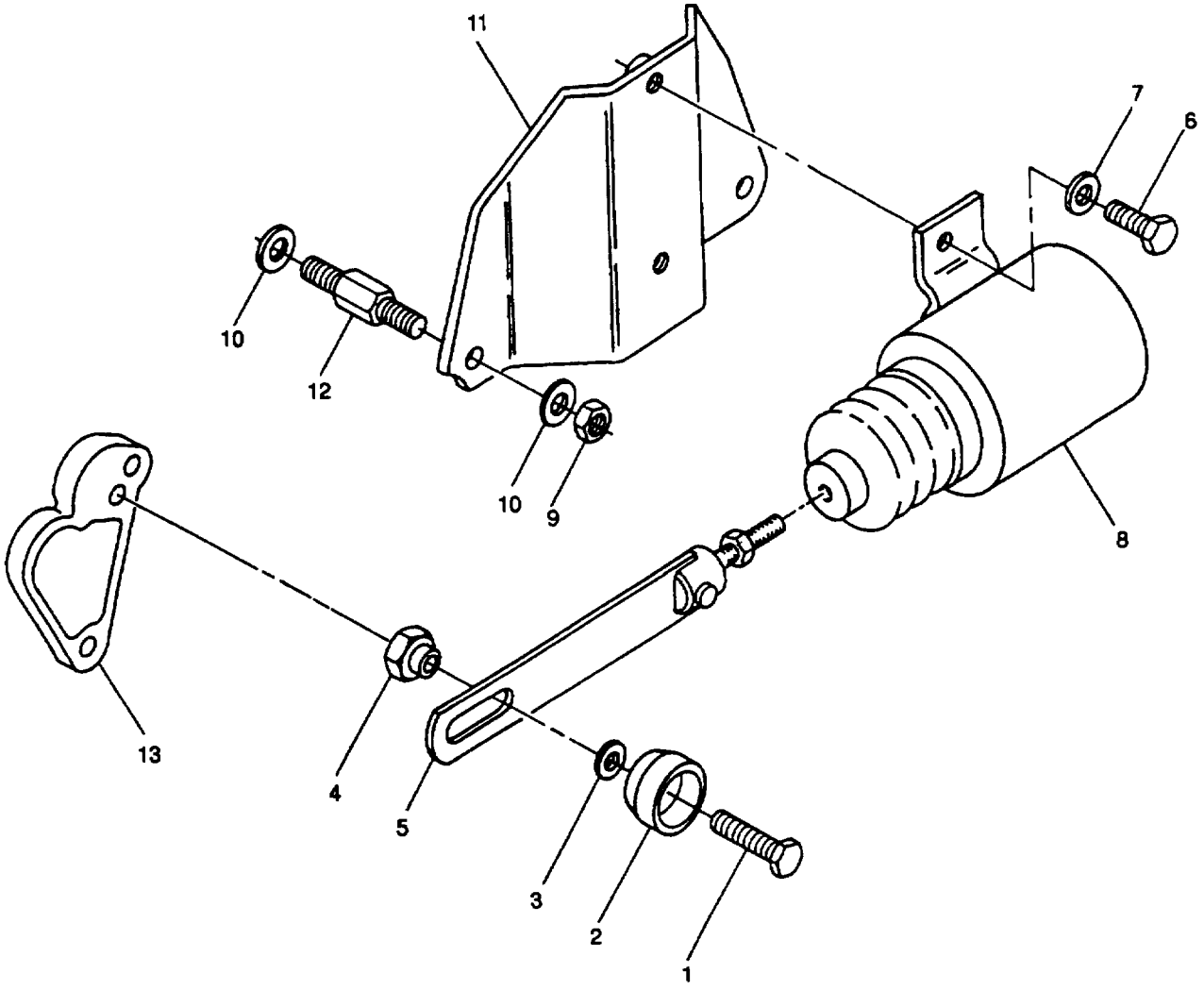


FIGURE 3-14. Fuel Solenoid Installation

SECTION VII. LUBRICATION SYSTEM MAINTENANCE

3-20. OIL FILTER AND CRANKCASE DOOR.

3-20.1. Oil Filter Cartridge Replacement.

a. Drain lubrication system. Refer to end item maintenance manual.
b. Loosen cartridge (1, FIGURE 3-15) by turning counterclockwise with a filter wrench.
c. Discard used cartridge.
d. Wipe filter mating surface with a dean rag.
e. Apply light coat of engine lubricating oil (MIL-L-2104) to new cartridge (1) gasket.
f. Place cartridge on adapter (2) and turn clockwise until cartridge is hand tight.
g. Using filter wrench, turn cartridge an additional 1/2 to 3/4 turn.
h. Service lubrication system. Refer to end item lubrication order.
i. Operate engine and check for leakage.

3-20.2. Crankcase Door.

3-20.2.1 Removal.

a. Drain lubrication system. Refer to end item maintenance manual.
b. Remove oil filter cartridge. Refer to paragraph 3-20.1.
c. Remove fuel solenoid and bracket. Refer to paragraph 3-19.1.
d. Remove thirteen bolts (3, FIGURE 3-15) four nuts (5), two stand off studs (6), and nineteen washers (4) securing crankcase door (7) to crankcase; remove door (7) and gasket (8). Discard gasket.
e. If damaged, remove tappet studs (9) from engine.

3-20.2.2 Replace.

a. Remove crankcase door. Refer to paragraph 3-20.2.1.
b. Remove adapter (2, FIGURE 3-15).
c. Remove oil filler cap (10) and preformed packing (11) Discard preformed packing.
d. Remove dipstick (12) and remove preformed packing (13) from dipstick. Discard preformed packing.
e. Remove two nuts (14) and lockwashers (15) securing plate (16); remove plate (16) and gasket (17). Discard lockwasher (15) and gasket (17).
f. Remove two studs (18).
g. Install two studs (18).
h. Position new gasket (17) and plate (16) on studs (18) and secure with two nuts (14) and new lockwashers (15).
i. Install new preformed packing (13) on dipstick (12) and install dipstick.
j. Install new preformed packing (11) on oil filler cap (10) and install cap.
k. Install adapter (2).
l. Install crankcase door. Refer to paragraph 3-20.2.4.

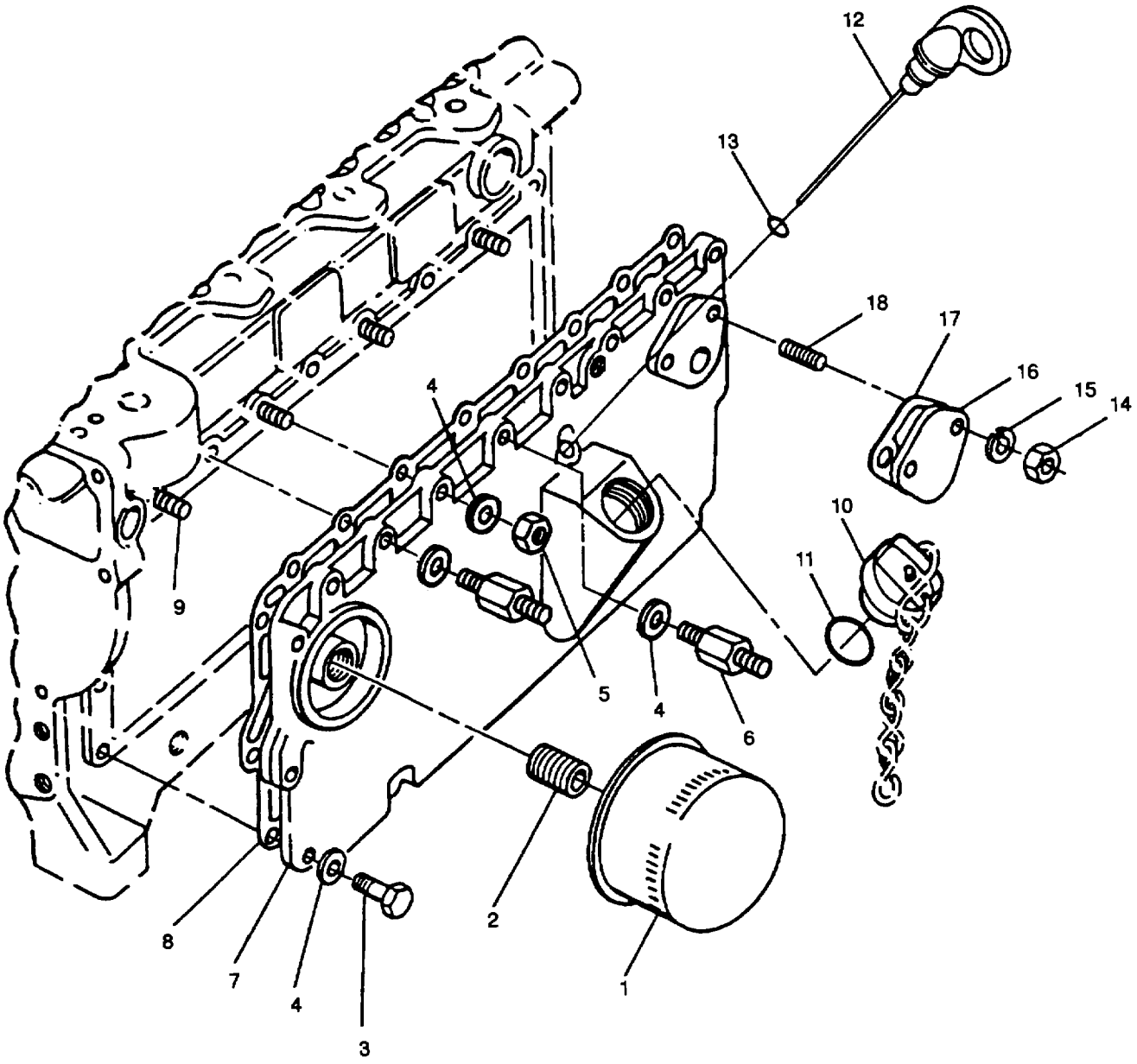


FIGURE 3-15. Oil Filter and Crankcase Door

3-20.2.3 Inspection.

a. Inspect dipstick (12, FIGURE 3-15) for legibility. Replace if damaged.
b. Inspect performed packings (13 and 11) for deterioration and replace as necessary.
c. Inspect crankcase door (7) for cracks, dents, or other damage. Replace if damaged.
d. Inspect adapter (2) for thread damage and replace as necessary.

3-20.2.4 Installation.

a. Ensure crankcase door and crankcase mating surfaces are dean and dry.
b. If removed, install tappet studs (9, FIGURE 3-15) in engine block Refer to FIGURE 3-8 for proper alignment with tappet slot and tappet movement.
c. Position new gasket (8) and crankcase door (7) on crankcase and secure with eleven bolts (3), four nuts (5) and two standoff studs (6) with nineteen washers (4). Tighten bolts (3) to 78 in-lbs (8.8 Nm) in sequence shown in FIGURE 3-16.
d. Install fuel solenoid and bracket. Refer to paragraph 3-19.4.
e. Install oil filter cartridge. Refer to paragraph 3-20.1.
f. Service lubrication system. Refer to end item lubrication order.
g. Operate engine and check for leakage.

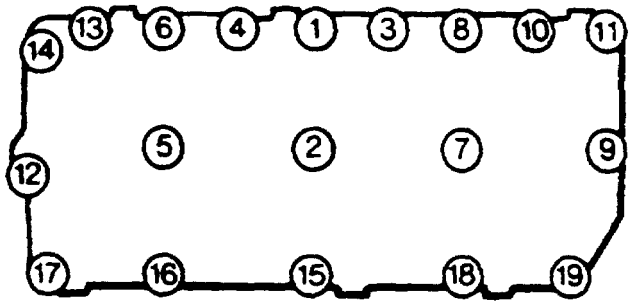


FIGURE 3-16. Crankcase Door Fastener Tightening Sequence

3-21. OIL PUMP AND STRAINER.

3-21.1. Removal.

a. Drain lubrication system. Refer to end item maintenance manual.
b. Remove camshaft. Refer to paragraph 3-29.1.
c. Remove crankcase door. Refer to paragraph 3-20.2.1.
d. From inside crankcase, unscrew oil pressure relief valve (1, FIGURE 3-17) from oil pump (5).
e. Unscrew strainer (2) coupling nut from oil pump (5).
f. Remove two capscrews (3) and washers (4) securing oil pump (5); remove oil pump.

3-21.2. Inspect and Test.

a. Inspect pump for freedom of movement by turning gear.
b. Check oil pressure relief valve setting using hydraulic test stand. Valve should relieve at 47 to 59 psi (324 to 407 kPa).
c. Inspect strainer for blockage and clean as necessary.
d. Inspect all parts for wear or damage and replace defective components.

3-21.3. Installation.

a. Position oil pump (5, FIGURE 3-17) in crankcase with cutout section of pump behind gear facing top of crankcase.
b. Secure oil pump (5) with two capscrews (3) and washers (4). Tighten capscrews to 78 in-lbs (8.8 Nm).
c. Install oil strainer (2) in right pump port with strainer gauze parallel with sump base. Tighten retaining nut.
d. Install relief valve (1) in left pump port and tighten retaining nut.
e. Install crankcase door. Refer to paragraph 3-20.2.4.
f. Install camshaft. Refer to paragraph 3-29.3.
g. Service lubrication system. Refer to end item lubrication order.
h. Operate engine and check for proper operation and for leakage.

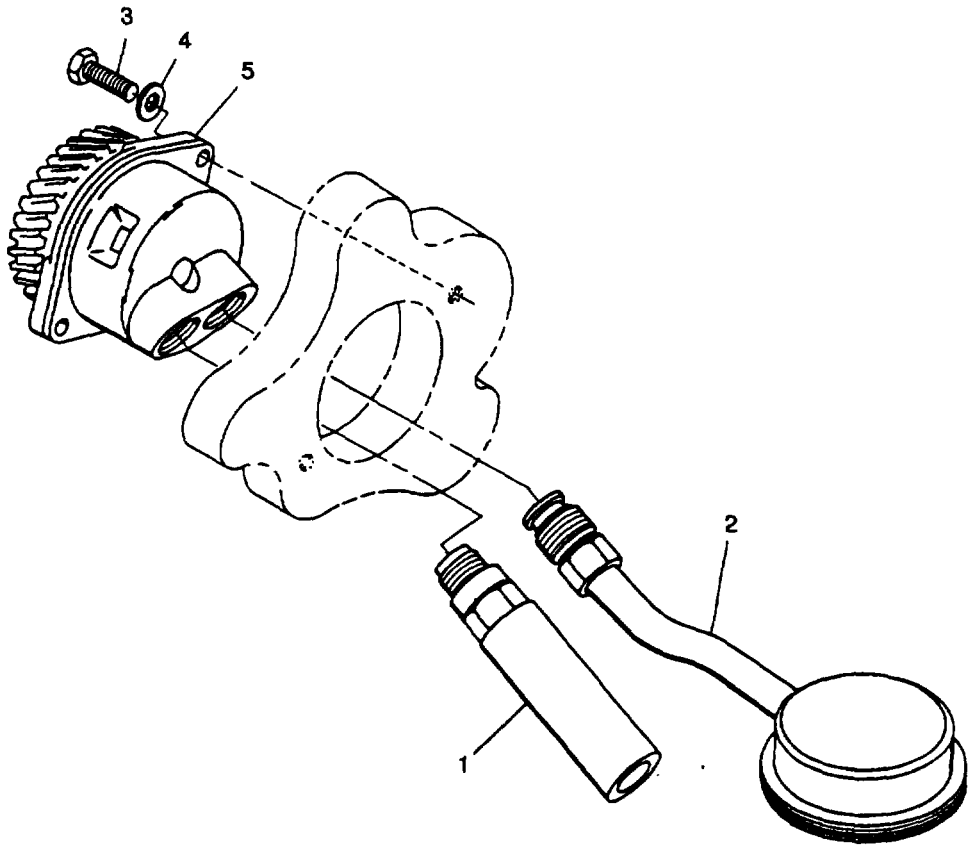


FIGURE 3-17. Strainer and Oil Pump

3-22. ENGINE OIL PRESSURE TEST.

a. Tag and disconnect electrical leads to oil pressure sender, remove oil pressure sender, and install test pressure gage, 0-150 psi (0-1034 kPa). Refer to FIGURE 3-18.
b. Start engine and check oil pressure.
c. Remove oil pressure gage and install oil pressure sender.
d. Install electrical connectors. Remove tags.
e. Engine oil pressure should be 36 psi (248 kPa) at 1800 rpm.

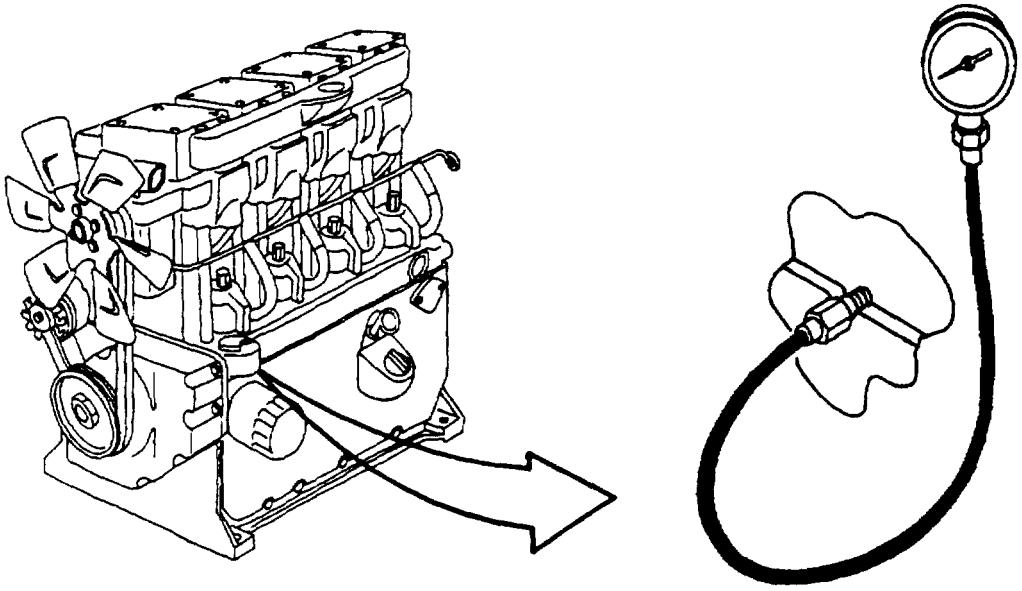


FIGURE 3-18. Oil Pressure Test Setup

SECTION VIII. GOVERNOR SYSTEM MAINTENANCE

3-23. GOVERNOR SYSTEM.

3-23.1. Removal.

a. Remove fuel injection pumps. Refer to paragraph 3-13.1.
b. Remove gear end cover. Refer to paragraph 3-28.1.
c. Unhook speeder spring (1, FIGURE 3-19) from retainer (2) and lever (29); remove spring.
d. Unhook spring (3) from pivot pin (4).
e. Remove lower pivot pin (4) from lower pivot support (5) and governor lever (6). Remove pivot retainer (7). Remove spring (3) from lower pivot support (5).
f. Remove upper pivot pin (8) from upper pivot support (9) and governor lever (6). Remove pivot retainer (10). Use care to retain all end play shims (11) that are installed.
g. Carefully remove governor lever assembly and fuel pump rack (6) from crankcase.

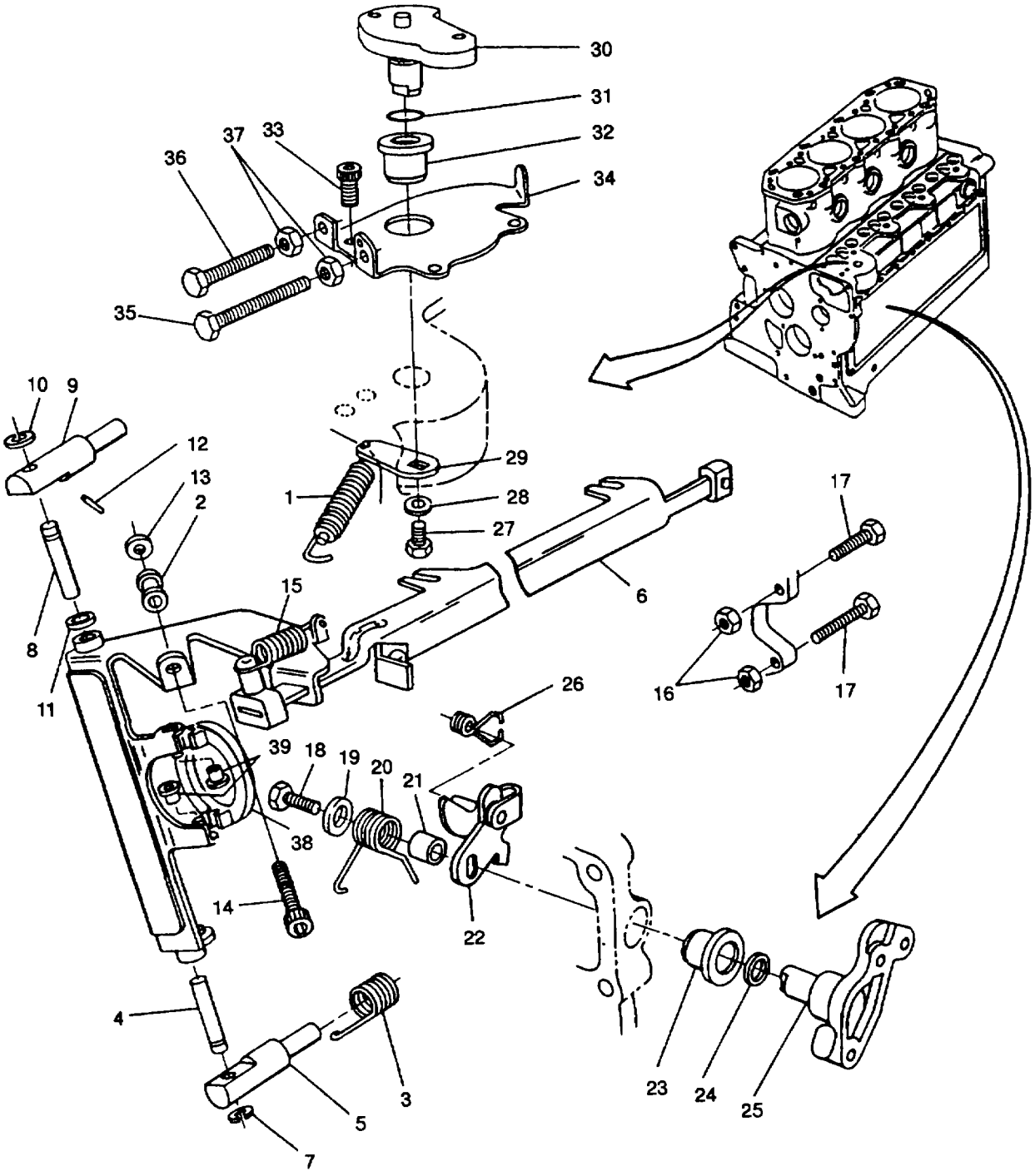


FIGURE 3-19. Governor System

3-23.2. Repair.

a. Remove two thrust washers (1 and 3, FIGURE 3-20) and sleeve (2) from camshaft.
b. Remove pin (12, FIGURE 3-19), shim (13) and retainer (2) from droop adjust screw (14); remove screw (14).
c. Disconnect spring (15) from governor lever (6) bushing.
d. Remove two nuts (16) and capscrews (17) from end cover.
e. Remove capscrew (18) and washer (19) from inside crankcase, remove spring (20), bushing (21), and lever assembly (22). From outside crankcase remove bushing (23), preformed packing (24), and lever (25). Discard preformed packing (24). Remove trip lever spring (26).
f. From inside crankcase, remove capscrew (27) and washer (28); remove lever (29).
g. From outside crankcase, remove speed quadrant (30) and preformed packing (31). Discard preformed packing (31).
h. If damaged, remove bushing (32).
i. Remove capscrew (33) securing base plate (34) to crankcase; remove base plate (34).
j. Remove two capscrews (35 and 36) and nuts (37) from base plate (34).
k. Remove thrust collar (38) and two bushings (39) from governor lever (6).
l. Turn camshaft until a weight (4, FIGURE 3-20) is horizontal.
m. Remove capscrew (5) and lockwasher (6) securing each retainer plate (7) to camshaft gear. Remove retainer plate (7) with weights. Discard lockwasher.
n. Remove pin (8), shims (9), and weights (4) from retainer plate.
o. Repeat steps l through n for other retainer plates and weights.
p. Lightly lubricate pins (8) with engine lubricating oil (MIL-L-2104) and install them and shims (9) in new weights (4).
q. Install weights (4) and pins (8) with large section of weights facing out.
r. Install retainer plates (7) and secure each with a capscrew (5) and new lockwasher (6). Tighten capscrews to 78 in-lbs (8.8 Nm).
s. Ensure all weights (4) move freely.
t. Install two bushings (39, FIGURE 3-19) and thrust collar (38) on governor lever (6).
u. Install two capscrews (35 and 36) and nuts (37) on base plate (34).
v. Position base plate (34) on crankcase and secure with capscrew (33).
w. If removed, install new bushing (32).
x. From outside crankcase, install new preformed packing (31) and speed quadrant (30) into crankcase hole.
y. From inside crankcase install lever (29) on speed quadrant (30) and secure with capscrew (27) and washer (28).
z. From outside crankcase, position bushing (23), new preformed packing (24) and lever (25) into crankcase hole.
aa. Install trip lever spring (26) on lever assembly (22).
ab. From inside crankcase, position lever assembly (22), bushing (21), and spring (20) on lever (25) and secure with capscrew (18) and washer (19).
ac. Connect spring (15) to bushing and hole on governor lever (6).
ad. Install droop adjust screw (14) in governor lever (6) and install retainer (2), shim (13), and pin (12). Turn screw (14) fully counterclockwise.
ae. Install two thrust washers (1 and 3, FIGURE 3-20) and sleeve (2) on camshaft.

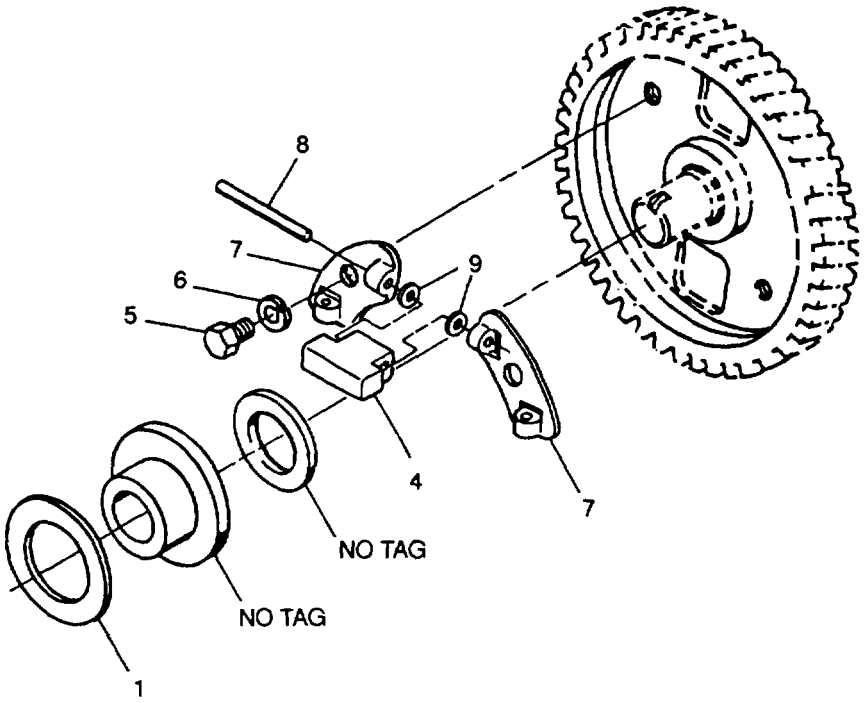


FIGURE 3-20. Governor Weights

3-23.3. Inspection.

a. Inspect all external components for corrosion.
b. Inspect all threaded components for thread damage and rounded corners on hex heads.
c. Inspect all springs for broken coils, distortion, or missing ends.
d. Inspect area components for enlarged or worn holes.
e. Inspect area bushings for scores or other damage.

3-23.4. Installation.

a. Carefully install governor lever (6, FIGURE 3-19) assembly onto camshaft and use care to ensure that flywheel end of fuel pump rack is located in its housing.
b. If removed, install pivot retainers (7 and 10) on upper and lower pivot pins (4 and 8).
c. Secure governor lever (6) to lower pivot support (5) using pivot pin (4). Connect spring (3) to pivot pin (4).
d. Install top pivot pin (8) through upper pivot support (9) and into governor lever (6). Be sure to use original end play shims (11).

NOTE

Long loop of speeder spring (1) connects to retainer (2).

e. Connect speeder spring (1) to retainer (2) and lever (29).
f. Check governor end play. Refer to paragraph 3-23.5.
g. Install gear end cover. Refer to paragraph 3-28.3.
h. Install fuel injection pumps. Refer to paragraph 3-13.4.
i. Perform governor system adjustments. Refer to paragraph 3-23.5, steps b thru d.

3-23.5. Adjustment.

a. Adjust governor lever (6, FIGURE 3-19) assembly end play as follows:

(1) Move lever assembly (6) until it abuts against top pivot support (9). Check that it falls freely under its own weight.

(2) Check governor lever (6) assembly end play. Add or remove 0.0098 in. (0.25 mm) shims (11), at top pivot support (9) to obtain an end play of 0.0039 to 0.0118 in. (0.1 to 0.33 mm).

NOTE

Adjustments in steps b thru d must be done with gear end cover installed.

b. Adjust control lever (25) setting as follows:

(1) Turn control lever (25) counterclockwise into stop position.

(2) Adjust upper capscrew (17) until it just touches curved part of lever (25) and lock it in this position with nut (16).

(3) Move lever (25) clockwise to run position and make appropriate 'G' setting.

c. Make governor 'G', setting as follows:

NOTE

The 'G' setting is made to ensure that fuel pumps deliver correct amount of fuel for desired engine speed.

NOTE

This adjustment requires use of governor setting gage (317-50115).

(1) Move lever (25) clockwise to run position.

(2) Insert 26.5 part of setting gage between head of upper capscrew (17) and top of curved part of lever (25).

(3) Adjust lower capscrew (17) until lever (25) just touches setting gage.

(4) Tighten lower capscrew locknut (16).

(5) Remove gage.

NOTE

Speed adjustment must be made with engine installed. Refer to end item maintenance manual.

NOTE

Speed adjustments are made after governor has been correctly set. Capscrews (35 and 36) are used to adjust speed control.

NOTE

Engine speed is controlled by speeder spring (1) inside crankcase.

d. Adjust speed in accordance with end item maintenance manual.

SECTION IX. ELECTRICAL SYSTEM MAINTENANCE

3-24. STARTER ASSEMBLY.

3-24.1. Removal.

NOTE

Perform testing on starter motor before removal from engine assembly. Refer to paragraph 3-24.3.1.

a. Remove nuts (1, FIGURE 3-21), lockwashers (2), capscrew (3), and lockwasher (4). Tag and disconnect all electrical leads. Discard lockwashers.
b. Support weight of starter and remove two capscrews (5) and washers (6) securing starter. Remove starter.
c. Cover opening in flywheel housing.

3-24.2. Disassembly.

a. Tag and disconnect wire from solenoid (1, FIGURE 3-22).
b. Remove two screws (2) securing solenoid (1); remove solenoid.
c. Remove two through bolts (3).
d. Remove screws (4) securing brush holder assembly (5) to rear bracket (6) and remove rear bracket.
e. Remove brush holder assembly (5) and frame assembly (7).
f. Using a screwdriver, pull brushes upward and remove brush holder assembly (5) from frame assembly (7).
g. Remove armature (8).
h. Remove screws (9) and remove cover (10).
i. Remove retaining ring (11), washer (12), and gasket (13) from shaft.

CAUTION

Center bracket (15) has spring tension. Use care when removing screw (14) to avoid damaging parts.

j. Remove screw (14) and center bracket (15) from front bracket (16).

NOTE

Count washers (17). They are used to adjust shaft end play.

k. Remove washer(s) (17).

NOTE

Note direction that lever assembly is installed before removing it. This will aid in reassembly.

l. Remove gear (18), spring set (19), packing (20), and lever assembly (21) from overrunning clutch (22).
m. Push down on stopper (24) and pinion gear (25). Remove retaining ring (23). Remove stopper (24), pinion gear (25), and spring (26) from overrunning clutch (22).
n. Remove overrunning clutch (22) from front bracket (16).

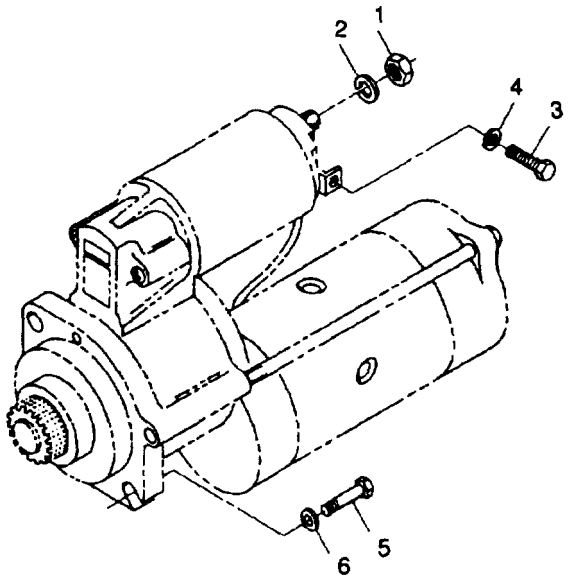


FIGURE 3-21. Starter Connection and Mounting Hardware

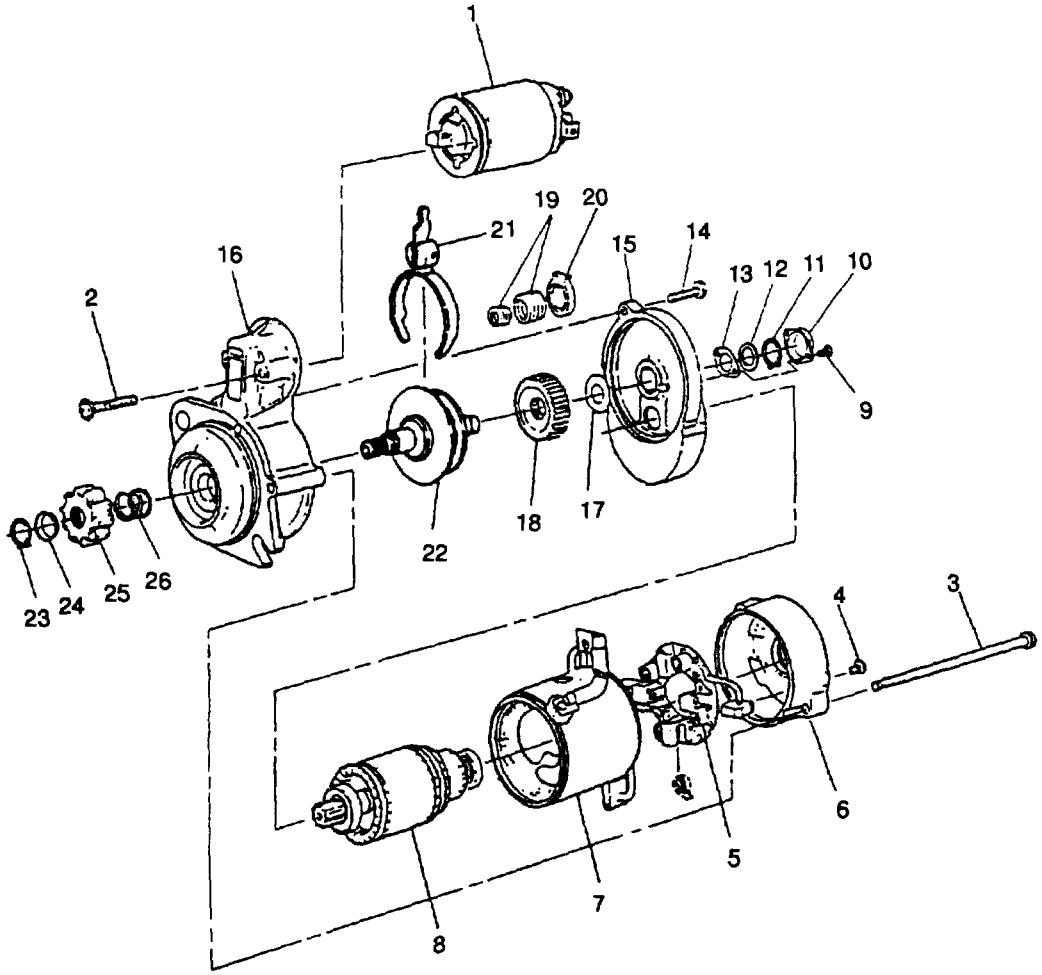


FIGURE 3-22. Starter Assembly

3-24.3. Testing.

3-24.3.1 Testing Starter (Installed).

a. Make sure batteries are fully charged and that all battery and starter cables are serviceable and properly installed.

b. Set multimeter for volts DC and connect as shown in FIGURE 3-23, Test A. If voltage is indicated solenoid is defective.

c. Momentarily connect a jumper as shown in FIGURE 3-23, Test B. Multimeter should indicate battery voltage and starter should crank the engine. If multimeter does not read battery voltage, the solenoid is defective. If multimeter indicates battery voltage, but starter does not operate, starter is defective.

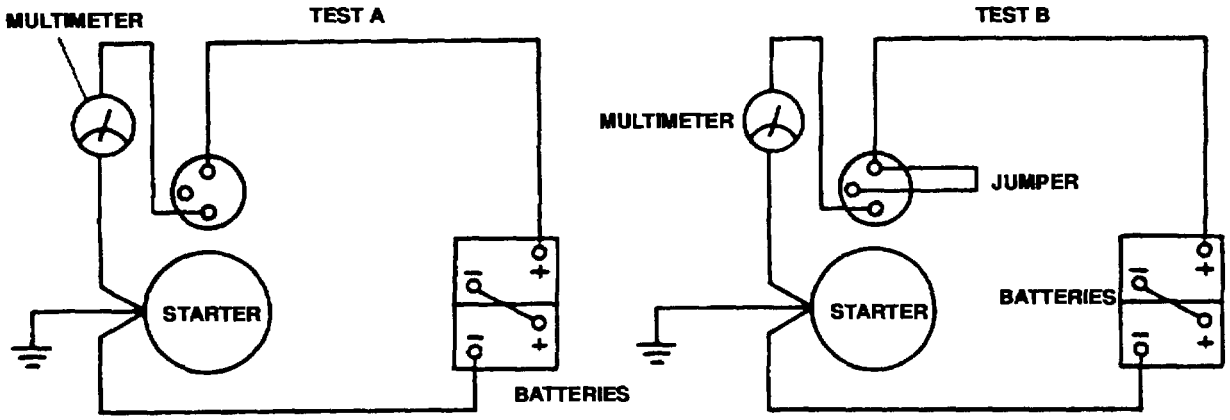


FIGURE 3-23. Starter Solenoid Test Circuit

3-24.3.2 Testing Starter Components.

a. Test armature for grounds.
   (1) Set multimeter for ohms and touch armature shaft and each commutator bar with multimeter leads.
   (2) If multimeter indicates a low reading (approximately zero ohms), armature is grounded and requires replacing.

b. Test armature for open circuits.
   (1) Check for continuity between commutator segments with multimeter.
   (2) If an open circuit is indicated, armature must be replaced.

c. Test field coil.
   (1) Check for continuity between brushes with a multimeter.
   (2) If there is no continuity indicated, field coil is open and field coil frame must be replaced.
   (3) Check for continuity between field coil frame and brushes.
   (4) If continuity is indicated, field coil is grounded and field coil frame must be replaced.

d. Test solenoid.
   (1) Check for continuity between solenoid terminals M and B with a multimeter. Refer to FIGURE 3-24.
   (2) No continuity should be indicated when solenoid plunger is in normal (out) position.
   (3) Push solenoid plunger in and observe multimeter. Multimeter should indicate continuity. If no continuity is indicated, solenoid must be replaced.

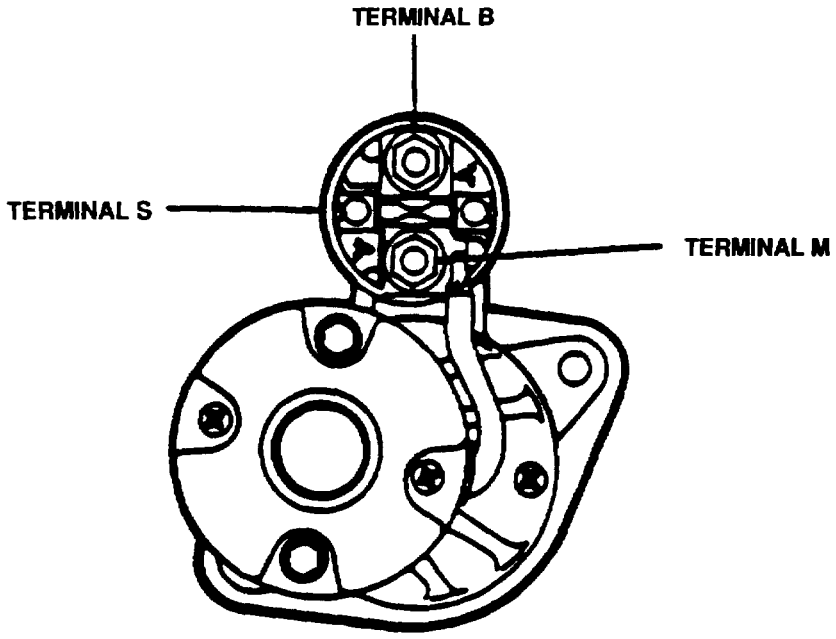


FIGURE 3-24. Solenoid Terminals

3-24.4. Cleaning and Inspection.

WARNING

Cleaning solvent is flammable and toxic to eyes, skin, and respiratory tract. Skin/eye protection required. Avoid repeated/prolonged contact. Good general ventilation Is normally adequate.

CAUTION

Do not clean overrunning clutch in solvent or other cleaning solution. Washing clutch will remove grease which may result In damage to the clutch.

a. Wipe all metallic parts with a cleaning cloth (TX-1250) that has been slightly dampened with dry cleaning solvent (P-D-680).
b. Inspect all parts for damaged threads, cracks, distortion, or other visible damage.

WARNING

Compressed air used for cleaning can create airborne particles that may enter the eyes. Pressure will not exceed 30 psig (207 kPa). Eye protection required.

c. Inspect armature commutator. If commutator is dirty or discolored, dean with abrasive paper (#400). Use compressed air to blow sand out from between commutator segments.
d. Clean around brushes and holders by wiping off all brush dust and dirt. If brushes are shorter than 0.433 in. (11.0 mm) they should be replaced.
e. Check for free movement of brushes. Brushes should move freely when placed in brush holders. Replace brush springs if weak or worn.

NOTE

If pinion gear is worn or damaged, inspect flywheel ring gear also.

f. Inspect armature shaft gear, bearings, reduction gear, and pinion gear for wear or damage. Replace any part that is damaged.

g. When pinion gear is placed upon overrunning clutch, pinion gear should turn freely in one direction and lock when turned in opposite direction. Refer to FIGURE 3-25.

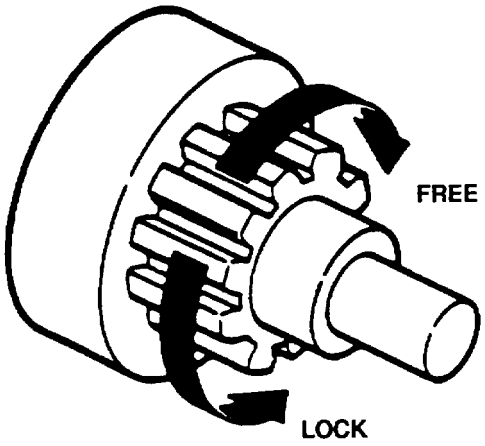


FIGURE 3-25. Overrunning Clutch

3-24.5. Assembly.

a. Apply a light coating of general purpose grease (630AA) to following starter components before assembling.
   (1) Armature (8, FIGURE 3-22) shaft gear.
   (2) Gear (18).
   (3) Armature shaft bearings.
   (4) Stopper (24).
   (5) Sleeve bearing in front bracket (16).
   (6) Pinion gear (25).
   (7) Lever (21) sliding portion.
   (8) Solenoid (1) plunger.

b. Position overrunning clutch (22) into front bracket (16).

c. Install spring (26) and pinion gear (25) on overrunning clutch shaft.

d. Slide stopper (24) onto shaft and install new retaining ring (23) in groove. Stopper (24) must fully engage retaining ring when installed.

e. Install lever (21) (as noted during removal), spring set (19), and packing (20).

f. Adjust pinion shaft end play as follows:
   (1) Place gear (18) on pinion shaft.
   (2) Install center bracket (15) and secure with screw (14).
   (3) Install new gasket (13), washer (12), and new retaining ring (11).
   (4) Measure pinion shaft end play with a feeler gage between center bracket (15) and washer (12).
   (5) Adjust end play to between 0.0039 to 0.020 in. (0.1 to 0.5 mm) with adjustment washers (17).

g. Install cover (10) and secure with two screws (9).
h. Install armature (8) in center bracket (15).
i. Install brushes in brush holder assembly (5).
j. Position frame assembly (7) on center bracket (15). Tab on frame assembly (7) must fit in notch in center bracket.
k. Pull brushes upward and install brush holder assembly (15) on frame assembly (7). Ensure brushes in brush holders seat against commutator bars.
l. Position rear bracket (6) and secure brush holder assembly (5) to rear bracket (6) with two screws (4).
m. Install two through bolts (3).

NOTE
Be sure that rectangular hole in solenoid (1) plunger shaft engages lever (21) in housing.

NOTE
Apply sealing compound (MIL-R-46082) to screws (2) before assembly.

n. Install solenoid (1) and secure with screws (2).
o. Reconnect wire to solenoid. Remove tag.
p. Check pinion gap as follows:
   (1) Connect a 24 VDC power source positive lead to terminal 'S' on solenoid and negative lead to starter frame.
   (2) Apply power to solenoid and pinion gear will shift.
   (3) Disconnect terminal 'M' wire to stop pinion from rotating.
   (4) Gently push pinion shaft towards solenoid and measure amount of travel. Refer to FIGURE 3-26. Pinion gap should be 0.0118 to 0.787 in. (0.3 to 2.0 mm).
   (5) Adjust gap by increasing or decreasing number of fiber washers between solenoid and front bracket. Increasing number of washers decreases gap and decreasing number of washers increase gap.

3-24.6. Installation.

a. Remove cover in flywheel housing.
b. Position starter in flywheel housing and secure with two capscrews (5, FIGURE 3-21) and washers (6). Tighten capscrews to 30 ft-lbs (40.7 Nm).
c. Connect wires to starter as tagged during removal using capscrew (3), new lockwasher (4), nuts (1), and new lockwashers (2). Remove tags.

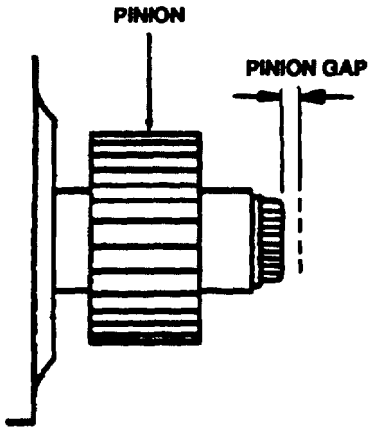


FIGURE 3-26. Checking Pinion Gap

SECTION X. ENGINE SUBASSEMBLY MAINTENANCE

3-25. CYLINDER COVER.

3-25.1. Removal. Remove two nuts (1, FIGURE 3-27) and performed packings (2) securing each valve cover (3) to cylinder head; remove cover (3) and gasket (4). Discard gasket (4) and performed packings (2).

3-25.2. Inspection.

a. Inspect cover for cracks, dents, or any other damage.
b. Inspect nuts for rounded hex comers or thread damage.

3-25.3. Installation.

a. Remove any traces of old gasket from cylinder head and valve covers (3, FIGURE 3-27) mating surfaces.
b. Ensure mating surfaces are clean and dry.
c. Position each valve cover (3) with new gasket (4) on cylinder head and secure with two nuts (1) and new preformed packings (2). Tighten nuts (1) to 78 in-lbs (8.8 Nm).

3-26. ROCKER LEVER.

3-26.1. Removal.

a. Remove cylinder covers. Refer to paragraph 3-25.1.
b. Remove nut (5, FIGURE 3-27) securing rocker lever (6) to cylinder head bolt (7); remove rocker lever.
c. Remove pushrod (9).
d. Repeat steps b and c for remaining rocker levers and pushrods.
e. Do not remove cylinder head bolt (7) and spacer (8) unless damaged or cylinder head is being removed.

3-26.2. Inspect and Measure.

a. Check pushrod (9, FIGURE 3-27) as follows:
   (1) Lay pushrod on a surface plate.
   (2) Roll pushrod along surface plate checking for curvature with a feeler gage. Normal reading should be 0.008 in. (0.2 mm) or less.
   (3) Inspect both ends of pushrod for excessive wear or damage. If excessive wear or damage is found, replace pushrod.
b. Inspect rocker lever valve stem contact surface for step wear and scoring. If contact surfaces have light step wear or scoring, they may be honed with an oil stone. If step wear or scoring is severe, rocker lever must be replaced.

3-26.3. Installation.

CAUTION

Ensure that no piston is at TDC when Installing pushrods. Failure to follow this procedure could cause damage to pushrods.

a. Lightly oil pushrod (9, FIGURE 3-27) with engine lubricating oil (MIL-L-2104) and install it in cylinder head. Ensure pushrod does not interfere with cylinder head clearance hole.
b. Lightly oil rocker lever (6) and install it on cylinder head bolt (7). Secure with nut (5) finger tight.
c. Gradually tighten nut (5) until heel of rocker lever (6) makes contact with ball end of pushrod (9). Ensure rocker lever is centered over valve stem.

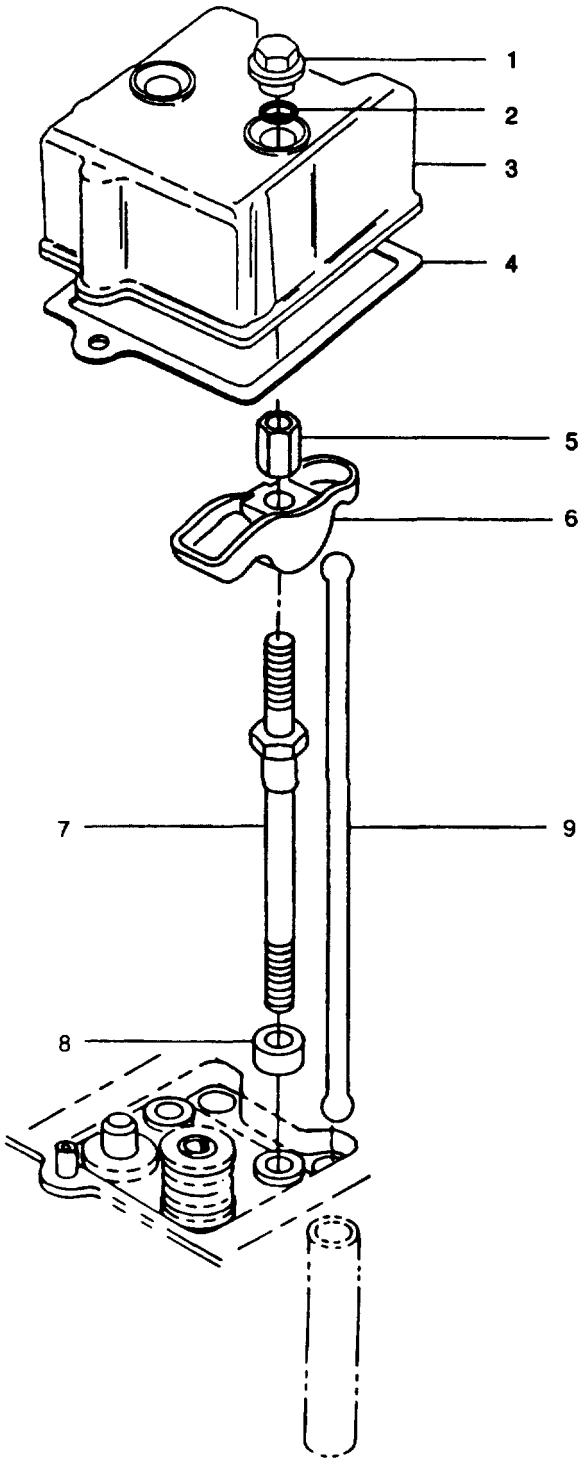


FIGURE 3-27. Cylinder Cover and Rocker Lever

d. Tighten nut (5) to 25 ft-lbs (33.9 Nm).
e. Repeat above steps a thru d, for remaining pushrods and rocker levers.
f. Wait for up to 90 seconds on a new tappet or up to 45 minutes on a used engine for the hydraulic tappet to bleed down.

CAUTION

Do not force crankshaft to rotate if rotation is not free easy movement. This will prevent engine damage If a piston comes In contact with valve.

NOTE

Check for bleed down by rotating pushrods. If a pushrod rotates after the respective valve has dosed, that hydraulic tappet has bled down.

g. Manually turn the crankshaft very slowly, checking that all pushrods will rotate after their respective valve has closed.

3-27. CYLINDER HEAD ASSEMBLY.

3-27.1. Removal.

a. Remove intake manifold. Refer to paragraph 3-6.1.
b. Remove exhaust manifold. Refer to paragraph 3-7.1.

NOTE

Cap all fuel line connections that have been opened to prevent contamination of fuel system.

c. Remove fuel injector pipes. Refer to paragraph 3-18.1.
d. Remove fuel injectors. Refer to paragraph 3-17.1.
e. Remove four nuts (1, FIGURE 3-28) securing lifting eyes (2); remove lifting eyes (2).
f. Remove cylinder covers. Refer to paragraph 3-25.1.
g. Remove rocker levers and pushrods. Refer to paragraph 3-26.1.

NOTE

There are three types of cylinder head bolts used. Note location of these for proper location during installation.

h. Remove four bolts (3), four bolts (4), and eight washers (5). Refer to FIGURE 3-27 and remove eight bolts (7) and spacers (8).

NOTE

Check old gasket for number of identification holes; (i.e., one, two or three) This will aid installation.

i. Lift off cylinder head (6, FIGURE 3-28) and gasket (7). Discard gasket.

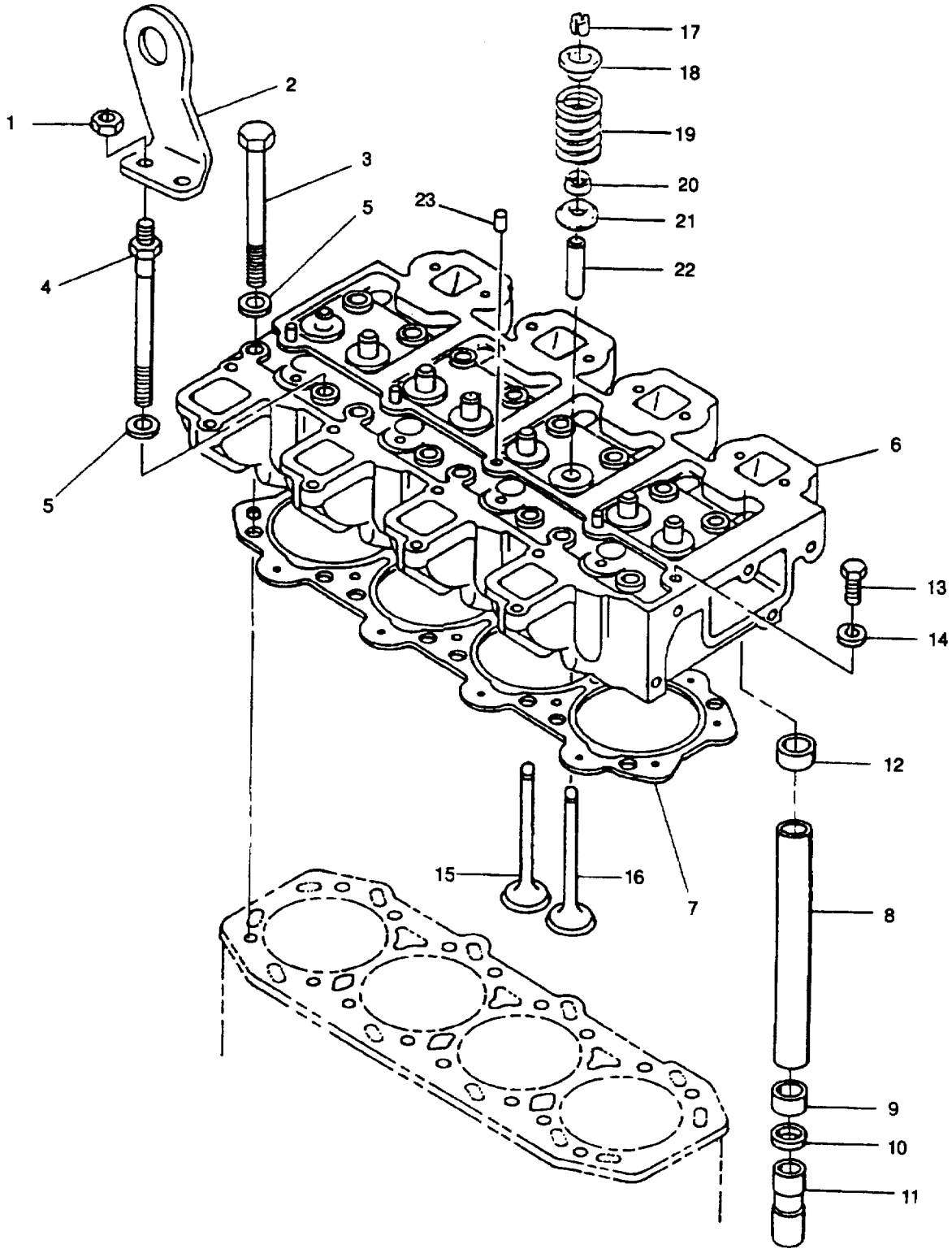


FIGURE 3-28. Cylinder Head Assembly

3-27.2. Disassembly.

a. Remove pushrod tubes (8, FIGURE 3-28), seals (9), washers (10) and tappets (11) from crankcase.
b. Remove seals (12) from cylinder head (6). Discard seals (12).
c. If necessary, remove capscrew (13) and washer (14).
d. Position head upright on bench and place a suitable block of wood under head of valve (15 or 16).

WARNING

Do not stand in front of valve springs while compressing them. Failure to follow this warning could result In personal Injury.

e. Using standard valve spring compressor tool remove each valve as follows:
   (1) Push down on tool until collets (17) can be removed.
   (2) Gently release tool. Remove carrier (18), spring (19), seal (20), and plate (21). Discard seal.
   (3) Turn cylinder head (6) over and remove valve (15 or 16).

NOTE

If valves are to be reused, tag them with cylinder number from which they were removed. Manufacturer recommends that all valves and springs be replaced during a major overhaul.

f. Insert hex key (allen wrench) into breather tube (23) to support bore of tube. Using pliers, remove breather tube(s) (23).

3-27.3. Inspect and Measure.

a. Using appropriate measuring devices, check components listed in TABLE 3-4 for wear. Replace components that exceed maximum clearance.

NOTE

Replace the spring if the length is 1.67 in. (42.5 mm) or less.

b. Check that intake valve seat is sunk 0.037 to 0.05 in. (0.95 to 1.26 mm) and exhaust valve seat is sunk 0.052 to 0.065 in. (1.33 to 1.64 mm) below combustion surface. If not, regrind valve seats. Refer to paragraph 3-27.4.
c. Check cylinder head clearance as follows:

NOTE

This procedure is used to determine what size head gasket is required. Start with medium size gasket.

   (1) Place head gasket onto crankcase. Align holes in gasket with those in crankcase. Rotate engine so pistons are below cylinder head deck
   (2) Using a very small amount of general purpose grease (630AA), place four pieces of solder (SN60WRAP2) size 0.062 in. (1.58 mm) thick on pistons as shown in FIGURE 3-30. Space solder on outer edge and as near as possible in line with piston pin. Care must be taken to ensure that solder will be clear of valve recesses.
   (3) Install cylinder head and torque bolts. Refer to paragraph 3-27.6.
   (4) Manually rotate engine through two complete revolutions.
   (5) Remove cylinder head and measure the thickness of solder. This should be 0.0276 to 0.0354 in. (0.7 to 0.9 mm) and is obtained by a single gasket under head.

TABLE 3-4. Cylinder Head Component Wear Limits

	Initial Dimension		Maximum Clearance	
Components	**inches**	**(mm)**	**inches**	**(mm)**
Hydraulic tappet diameter	0.842 0.843	(21.386) (21.405)		
Hydraulic tappet bore	0.8435 0.8445	(21.425) (21.450)	0.004	(0.11)
Valve spring free length (See Note Below)	1.72 1.79	(43.7) (45.5)		
Valve guide bore - installed	0.283 0.285	(7.195) (7.250)		
Valve stem diameter	0.2817 0.2823	(7.155) (7.170)	0.0065	(0.165)

3-27.4. Repair.

a. Using valve guide replacement tool (317-50033). Refer to FIGURE 3-29; remove each valve guide as follows:
   (1) Place cylinder head on its side in a soft-jawed vice.
   (2) Screw mandrel (1) into tool (2).
   (3) Place sleeve (3) onto tool.
   (4) Fit bevelled adapter (4) into sleeve (3) and locate bevel into valve seat.
   (5) Locate mandrel (1) through guide from valve seat side.
   (6) Screw small threaded sleeve (5) onto mandrel (1) at valve rocker side.
   (7) Holding sliding handle firmly to prevent rotation, turn double handled lever clockwise until guide is withdrawn through head.
   (8) If it is found difficult to start moving guides a sharp tap with a copper hammer should break seal.
b. Regrind valves and valve seats in cylinder head.

NOTE

Valves seat grinding angles are: 15°, 44.5°, and 60°. Valve angle is 45°.

c. Using valve guide removal and replacement tool (317-50033). Refer to FIGURE 3-29; install each valve guide.
   (1) Install mandrel (1) into valve guide hole from valve rocker end.
   (2) Place valve guide over mandrel (1) with counterbored end of guide facing towards valve seats.
   (3) Place depth stop (317-50108) (6) over mandrel (1) and screw on threaded sleeve (5).
   (4) Fit tool complete with bevelled adapter (4) onto mandrel (1) at valve seat side.
   (5) Hold sliding handle firmly to prevent rotating. Turn double handled lever clockwise until depth stop prevents
   further movement. At this point guide will protrude 0.463 to 0.482 in. (11.75 to 12.25 mm) above cylinder head.

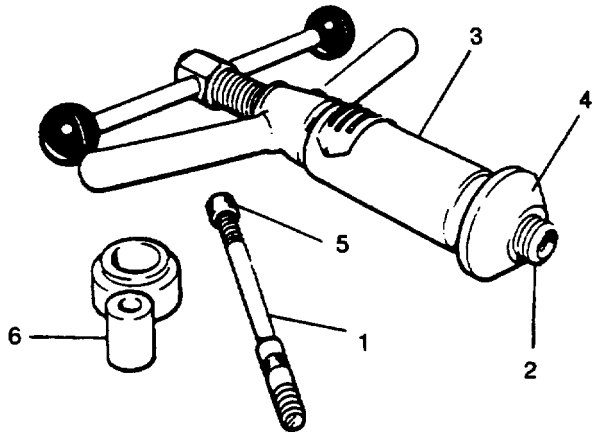


FIGURE 3-29. Valve Guide Tool and Depth Stop

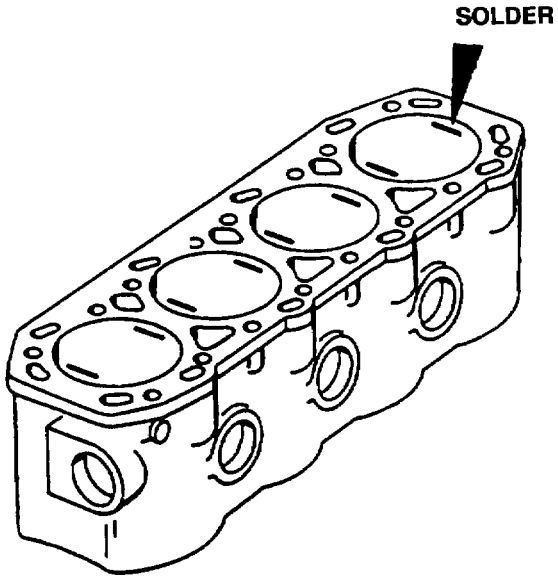


FIGURE 3-30. Checking Cylinder Head Clearance

3-27.5. Assembly.

a. Using standard valve spring compressor tool install each valve (15 or 16, FIGURE 3-28) as follows:

(1) Lightly lubricate valve stem with engine lubricating oil (MIL-L-2104) and insert valve (15 or 16).

(2) Lay head (6), upright on bench and place a block of wood under head of valve being replaced.

(3) Place valve spring plate (21) in position.

(4) Install a new valve stem seal (20) to valve guide (22) taking care to ensure it is correctly located over valve guide and is not distorted.

(5) Install valve spring (19) and spring carrier (18).

(6) Push down on tool until collets (17) can be installed in position with their tops slightly sunk in valve spring carrier (18).

(7) Gently release tool and check that collets (17) are correctly located.

b. If removed, install capscrew (13), washer (14), and breather tubes (23).

3-27.6. Installation. When installing cylinder head, valve to piston contact can be avoided by waiting for up to 45 minutes for lubricating oil to bleed down.

a. Ensure cylinder head (6, FIGURE 3-28) and crankcase mating surfaces are clean and dry.

CAUTION

Removal of any part of the valve gear will allow the hydraulic tappet to extend and hydraulically lock.

NOTE

When new tappets have been installed, the engine must be cranked for at least 15 seconds before attempting to start it.

b. Install hydraulic tappets (11) (solid end first) and new washers (10) in crankcase.

NOTE

Seal (12) has a lip on one side and seal (9) has no lip.

c. Install new pushrod seal (12) in cylinder head (6) and new pushrod seal (9) in crankcase.

d. Lightly coat bore of seals (9 and 12) with general purpose grease (630AA).

CAUTION

Use extreme care to ensure pushrod tubes (8) are centered and fully Installed in seals (9). Misalignment of pushrod tubes can cause serious damage to seals.

e. Install pushrod tubes (8) into crankcase.

f. Install cylinder head guide studs in opposite comers of engine block deck.

NOTE

If old head gasket size is not known, perform Check Cylinder Head Clearance. Refer to paragraph 3-27.3.

g. Three head gaskets (7) are available. Check old gasket for number of identification holes in one corner of gasket. One hole - 0.053 in. (1.35 mm); 2 holes - 0.058 in. (1.47 mm); and 3 holes - 0.063 in. (1.60 mm).

CAUTION

Ensure that no piston is at TDC when replacing head. Failure to follow this procedure could cause misalignment of the head.

h. Install a new gasket (7) and cylinder head (6) over guide studs. Ensure that pushrod tubes (8) are properly aligned with head.

i. Remove cylinder head guide studs.

NOTE

There are three types of cylinder head bolts used. Install them in their proper locations as noted during removal.

j. Install four bolts (3), four bolts (4), and eight washers (5). Refer to FIGURE 3-278 and install eight bolts (7) and spacers (8). Tighten all bolts finger tight.

k. Tighten all sixteen bolts in three stages and in sequence shown in FIGURE 3-31.

(1) First tighten to 6.2 ft-lbs (8.4 Nm).

(2) Second tighten to 38.5 ft-lbs (52.2 Nm).

(3) Final tighten to 66.6 ft-lbs (90.3 Nm).

l. Install rocker levers and pushrods. Refer to paragraph 3-26.3.

m. Install cylinder covers. Refer to paragraph 3-25.3.

n. Position lifting eyes (2, FIGURE 3-28) on bolts (4) and secure with nuts (1).

o. Install fuel injectors. Refer to paragraph 3-17.4.

p. Install fuel injector pipes. Refer to paragraph 3-18.3.

q. Install exhaust manifold. Refer to paragraph 3-7.3.

r. Install intake manifold. Refer to paragraph 3-6.3.

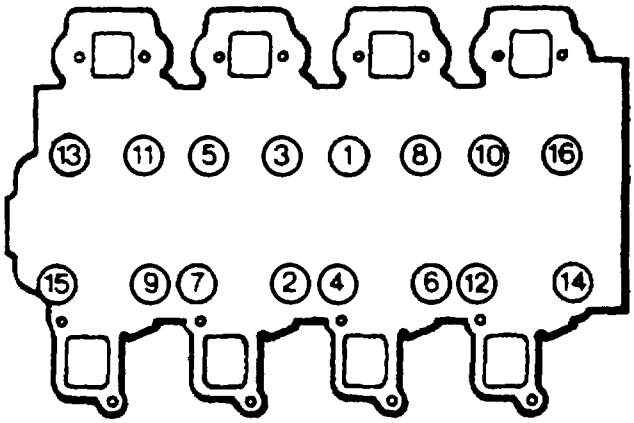


FIGURE 3-31. Cylinder Head Bolt Tightening Sequence

3-28. GEAR END COVER.

3-28.1. Removal.

a. Insert common screwdriver through flywheel housing into flywheel gear ring. Ensure that it is in position by attempting to turn flywheel.
b. Remove fan belt. Refer to end item maintenance manual.

NOTE

Bolt (1, FIGURE 3-32) has left hand threads.

c. Remove bolt (1) securing crankshaft pulley (2) to crankshaft; remove pulley (2).
d. Remove screwdriver.

CAUTION

To avoid possible damage, do not use a screwdriver on cover or crankcase matIng faces to remove gasket.

e. Remove plug (3).
f. Supporting weight of end cover (6), remove seven capscrews (4), washers (5), end cover (6), and gasket (7). Discard gasket.
g. If damaged, use suitable driver and drive oil seal (8) from end cover (6). Discard seal (8).
h. If damaged, remove two dowels (9) from crankcase.

3-28.2. Inspection.

a. Inspect crankshaft front oil seal (8, FIGURE 3-32) for excessive wear, damage, or signs of leakage.
b. Inspect crankshaft pulley (2) for cracks and wear.
c. Inspect end cover (6) for cracks or other physical damage.

3-28.3. Installation.

a. If removed, install two dowels (9, FIGURE 3-32), flat end first into crankcase fully.
b. Install new seal (8) as follows:
   (1) Lightly grease sealing lip of new seal (8) with general purpose grease (630AA).
   (2) Position new seal (8) into outside neck of end cover (6), lip side first, and position it squarely on shoulder of seal boss.
   (3) Using suitable driver, drive seal into position in end cover (6).
c. Clean all traces of old gasket from crankcase and end cover mating surfaces.
d. Install new gasket (7) dry, over two dowels (9), and onto crankcase.
e. Install oil seal tool into outside face of oil seal (8).
f. Install end cover (6), taking care to ensure new gasket (7) is not damaged and cover is correctly installed over dowels (9).
g. Install seven capscrews (4) and washers (5) securing end cover (6) to crankcase. Tighten capscrews to 78 in-lbs (8.8 Nm) in sequence shown in FIGURE 3-33.
h. Install plug (3).
i. Insert common screwdriver through flywheel housing to lock flywheel.

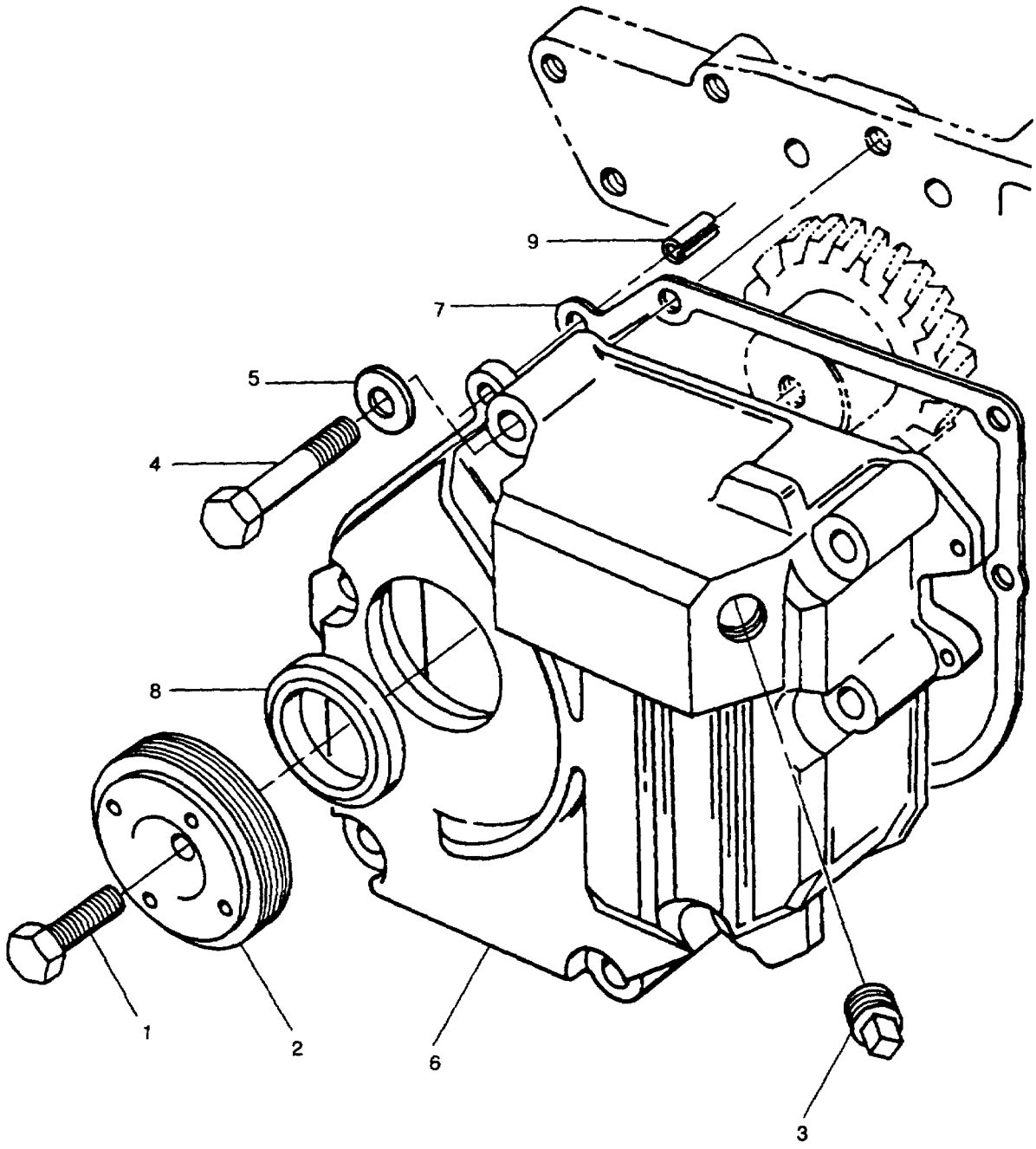


FIGURE 3-32. Gear End Cover

NOTE

Bolt (1) has left-hand threads.

j. Install crankshaft pulley (2) on crankshaft and secure with bolt (1). Tighten bolt (1) to 221 ft-lbs (300 Nm).
k. Remove screwdriver.
l. Install fan belt. Refer to end item maintenance manual.

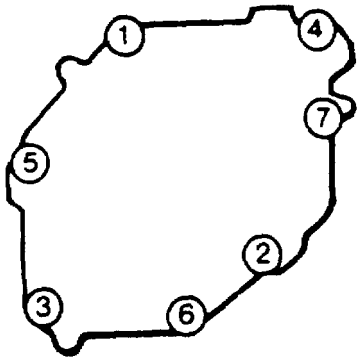


FIGURE 3-33. Gear End Cover Capscrew Tightening Sequence

3-29. CAMSHAFT ASSEMBLY.

3-29.1. Removal.

a. Remove end cover. Refer to paragraph 3-28.1.
b. Remove cylinder head. Refer to paragraph 3-27.1.
c. Remove fuel injection pumps. Refer to paragraph 3-13.1.
d. Remove governor system. Refer to paragraph 3-23.1.
e. Rotate camshaft until large holes in gear line up with two capscrews (1, FIGURE 3-34).
f. Remove two capscrews (1) and lockwashers (2) securing thrust plate to crankcase; remove camshaft (3) from crankcase keeping it square at all times. Discard lockwashers.

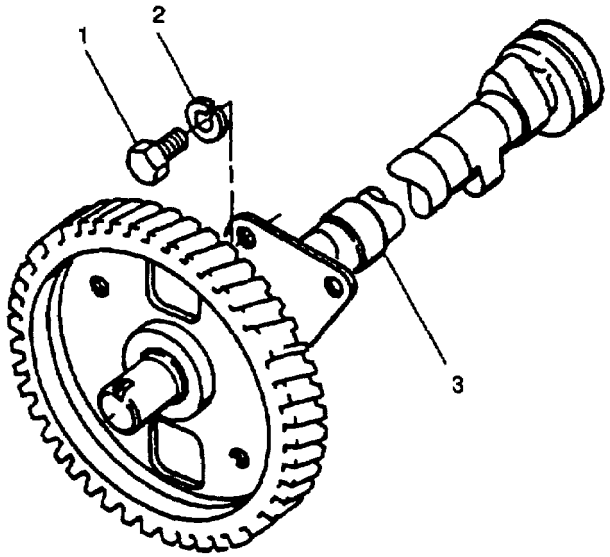


FIGURE 3-34. Camshaft Assembly

CAUTION

No attempt must be made to remove pinion gear from camshaft. Camshaft and gear are supplied as an assembly.

3-29.2. Inspect and Measure.

a. Examine camshaft bushing for scars or wear.
b. Check camshaft gearwheel and crankshaft pinion teeth for wear.
c. Ensure cams are not chipped or damaged.
d. Check tappets for damage to contact face.
e. Using appropriate measuring devices check components listed in TABLE 3-5 for wear. Replace components that exceed maximum clearance.
f. Check gear end of shaft for nicks and burrs.

TABLE 3-5. Camshaft Component Wear Limits

	Initial Dimension		Maximum Clearance	
Components	**inches**	**(mm)**	**inches**	**(mm)**
Gear end camshaft bushing bore	1.378 1.381	(34.990) (35.085)	0.007	(0.17)
Gear end camshaft journal diameter	1.3765 1.3771	(34.965) (34.980)		
Center camshaft bushing bore	1.379 1.381	(35.030) (35.070)	0.007	(0.17)
Center camshaft journal diameter	1.3765 1.3771	(34.965) (34.980)		
Flywheel end camshaft bushing bore	1.379 1.381	(35.030) (35.070)	0.007	(0.17)
Flywheel end camshaft journal diameter	1.3765 1.3771	(34.965) (34.980)		

3-29.3. Installation.

a. Carefully install camshaft (3, FIGURE 3-34) into crankcase keeping it square at all times. Take care to line up '0' timing marks on crankshaft and camshaft gears exactly.
b. Rotate camshaft (3) until large holes in gear line up with bolt holes in thrust plate.
c. Turn thrust plate as necessary to install two capscrews (1) and new lockwashers (2). Tighten capscrews (1) to 75-80 in-lbs (8.4 to 9.0 Nm).
d. Check camshaft end play as follows:
   (1) Push camshaft towards flywheel end.
   (2) Install a dial indicator in position against gear wheel.
   (3) Zero the dial indicator.
   (4) Move camshaft as far as it will go towards gear end. Movement recorded on the dial indicator should be 0.004 to 0.011 in. (0.10 to 0.28 mm).

CAUTION

Excessive camshaft end play affects governing and can cause uneven firing.

e. Measure timing gear backlash as follows. Refer to FIGURE 3-35:

(1) Set a dial indicator on timing gear to be measured.

(2) Hold gear to be checked and adjoining gear stationary.

(3) Move gear tooth side to side in backlash. Record indicated backlash Total Indicator Reading (TIR). Standard TIR is 0.004 - 0.007 in. (0.10 to 0.17 mm) with a limit of 0.012 in. (0.30 mm).

(4) If TIR exceeds limit, replace gear.

f. Install governor system. Refer to paragraph 3-23.4.

g. Install fuel injection pumps. Refer to paragraph 3-13.4.

h. Install cylinder head. Refer to paragraph 3-27.6.

i. Install end cover. Refer to paragraph 3-28.3.

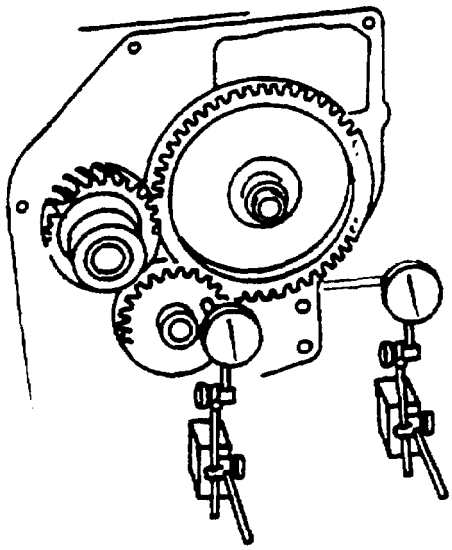


FIGURE 3-35. Measuring Gear Backlash

3-30. PISTON AND CONNECTING ROD ASSEMBLIES.

3-30.1. Removal.

a. Remove crankcase door. Refer to paragraph 3-20.2.1.
b. Remove cylinder head. Refer to paragraph 3-27.1.
c. If number one piston is to be removed, unscrew oil pressure relief valve and oil strainer from oil pump.
d. Rotate crankshaft as necessary to gain access to connecting rod bearing cap capscrews (1, FIGURE 3-36).

WARNING

To avoid possible Injury, due to sharp edges of machined crankcase face, use a drive socket and not a wrench.

CAUTION

Number stamped on connecting rod must correspond with number stamped on end cap. Damage to crankshaft can occur.

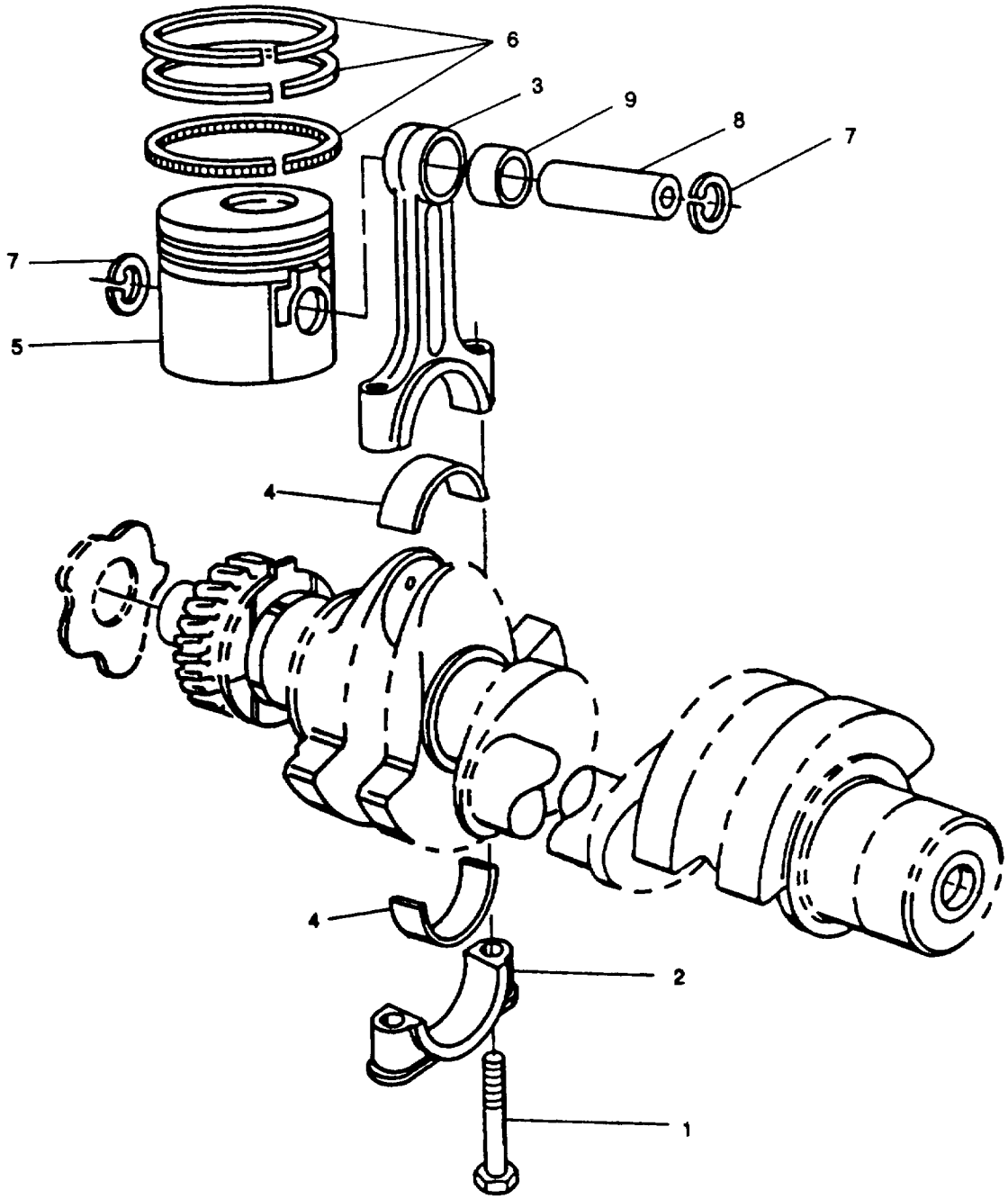


FIGURE 3-36. Piston and Connecting Rod Assemblies

e. Remove two capscrews (1), connecting rod (3), and bearing cap (2).
f. If damaged or worn, remove bearing halves (4).
g. Carefully scrape any build up of carbon from top of cylinder bore.
h. Rotate crankshaft until piston is at TDC.
i. Install (hand-tighten) a capscrew (1) into nearest connecting rod bearing cap bolt hole.
j. Using a suitable lever against crankcase and end of capscrew, press down on end of lever until piston rings are clear of cylinder bore.
k. Lift out piston (5) and connecting rod (3) and tag with corresponding cylinder number.
l. Install bearing cap (2) onto connecting rod (3).

3-30.2. Inspect and Measure.

a. Thoroughly clean cylinder barrel. Check for scoring and wear.
b. Clean piston (5, FIGURE 3-36) by removing all traces of carbon from both upper and underside of crown and ring grooves.
c. Check for correct gap clearance. Refer to TABLE 3-6, with piston rings (6) in an unworn section of cylinder barrel.
d. Clean connecting rod (3).
e. Check bushing (9) for wear. Replace if worn.
f. If big end has been disassembled because of metal failure, oil passages in crankshaft must also be examined for obstruction and fragments of metal.

NOTE

The maximum advisable piston to cylinder clearance given is the clearance between the bottom of the piston skirt, across the faces, and the cylinder bore measured in the region of travel of the piston skirt. The clearance is not to be measured at the top of the bore. When cylinders are rebored, the lower skirt should be etched or painted with the amount of the oversize.

NOTE

The ring gaps given in TABLE 3-6 are those to be anticipated when checking rings in an unworn part of the bore. For every 0.01 mm (0.0004 in.) by which the actual bore size exceeds the initial dimension, the ring gap will increase by approximately 0.03 mm (0.0012 in.) The firing ring side clearance is measured with a new ring flush with the top piston land.

NOTE

Oversize pistons and piston rings, and undersize big end and main bearing shells are available. Nonstandard sizes are marked, by the amount they are under or oversize, as a suffix to the part numbers which can be found in the following locations:

- Piston Rings - stamped on the face of the ring.
- Pistons stamped on the top surface.
- Bearings stamped on the steel outside surface of the bearing.

g. Using appropriate measuring devices, check components listed in TABLE 3-6 for wear. Replace components that exceed maximum clearance.

TABLE 3-6. Piston and Connecting Rod Component Wear Limits

	Initial Dimension		Maximum Clearance	
Components	**inches**	**(mm)**	**inches**	**(mm)**
Connecting rod small end bushing	0.984 0.985	(25.005) (25.017)	0.0019	(0.05)
Piston pin diameter	0.9839 0.9842	(24.9925) (24.9975)		
Cylinder bore	3.386 3.387	(86.000) (86.025)	0.006	(0.40)
Piston diameter - bottom of skirt across thrust face	3.3815 3.3819	(85.891) (85.901)		
Piston ring gaps	0.01 0.02	(0.260) (0.510)	0.055	1.40
Top piston ring width	0.0675 0.0685	(1.715) (1.740)	0.006	(0.16)
Top piston ring groove width	0.0708 0.0718	(1.800) (1.825)		
2nd piston ring width	0.077 0.078	(1.965) (1.990)	0.006	(0.15)
2nd piston ring groove width	0.080 0.081	(2.040) (2.065)		
Oil piston ring width	0.156 0.157	(3.965) (3.990)	0.006	(0.15)
Oil piston ring groove width	0.159 0.160	(4.030) (4.055)		
Connecting rod big end bore (See Note)	2.107 2.108	(53.525) (53.545)		
Bearing shell thickness	0.0685 0.0689	(1.740) (1.750)	0.005	(0.12)
Crankpin diameter	1.968 1.969	(49.985) (50.000)		

NOTE

Torque connecting rod bolts. Refer to paragraph 3-30.4.

3-30.3. Repair.

NOTE

Lay piston rings (6, FIGURE 3-36) out in order of removal to aid in installation.

a. Use a standard ring expander to remove piston rings (6).

b. Remove retaining rings (7) and push pin (8) out of connecting rod (3) and piston (5). Separate piston (5) from connecting rod (3).

c. If necessary, replace bushing (9) from connecting rod (3).

d. Install piston (5) to connecting rod (3)with wording CAMSHAFT SIDE on top of piston to same side as identification marks on connecting rod big end and cap.

e. Insert piston pin (8) and secure with two retaining rings (7).

f. Use a piston ring expander and install piston rings (6) with word TOP facing up as follows. Refer to FIGURE 3-37:

(1) Lower groove-oil control ring.

(2) Middle groove-compression ring.

(3) Top groove - firing ring.

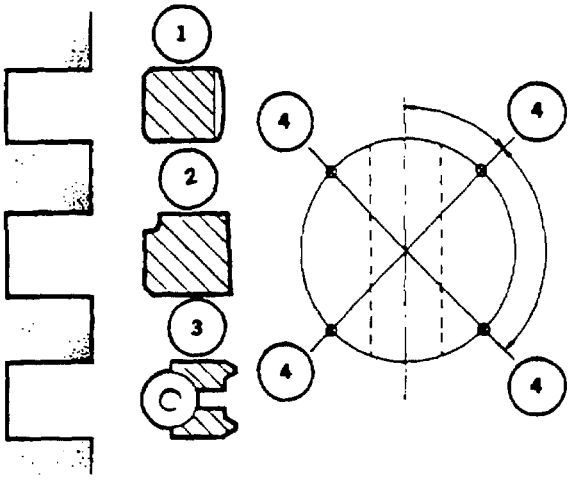


FIGURE 3-37. Piston Ring and Gap Location

3-30.4. Installation.

a. Turn crankshaft journal to TDC.

NOTE

If necessary, separate each bearing cap (2, FIGURE 3-36) and connecting rod (3) as it is installed. Do not mix bearing caps and connecting rods.

b. If damaged, install new connecting rod big end bearing shells (4, FIGURE 3-36) ensuring they are correctly located in both connecting rod and cap.

c. Stagger piston ring (6) gaps so each ring gap is set at 90 degrees to adjacent rings and 45 degrees from piston pin (8) axis.

d. Submerge piston and piston rings in dean engine lubricating oil (MIL-L-2104).

e. Fit piston and rod into cylinder while compressing piston rings using a suitable piston ring compressor.

f. Push down on piston crown and turn crankshaft counterclockwise until big end is almost at Bottom Dead Center (BDC).

g. Ensure identification marks on the cap and rod are identical and on the camshaft side of the engine and replace cap.
h. Install two bolts (1) and tighten them to 222 in-lbs (25 Nm).
i. If removed, attach oil pressure relief valve and oil strainer to oil pump.
j. Install cylinder head. Refer to paragraph 3-27.6.
k. Install crankcase door. Refer to paragraph 3-20.2.4.

3-31. FLYWHEEL HOUSING.

3-31.1. Removal.
a. Remove starter. Refer to paragraph 3-24.1.
b. Remove flywheel. Refer to end item maintenance manual.
c. Scribe a mark on flywheel housing (1, FIGURE 3-38) and crankcase.
d. Support weight of flywheel housing (1) and remove four capscrews (2) securing flywheel housing; remove housing.

3-31.2. Installation.
a. Position flywheel housing (1, FIGURE 3-38) on crankcase aligning scribe marks made during removal and secure with four capscrews (2). Tighten capscrews to 58 ft-lbs (78.6 Nm).
b. Install flywheel. Refer to end item maintenance manual.
c. Install starter. Refer to paragraph 3-24.6.

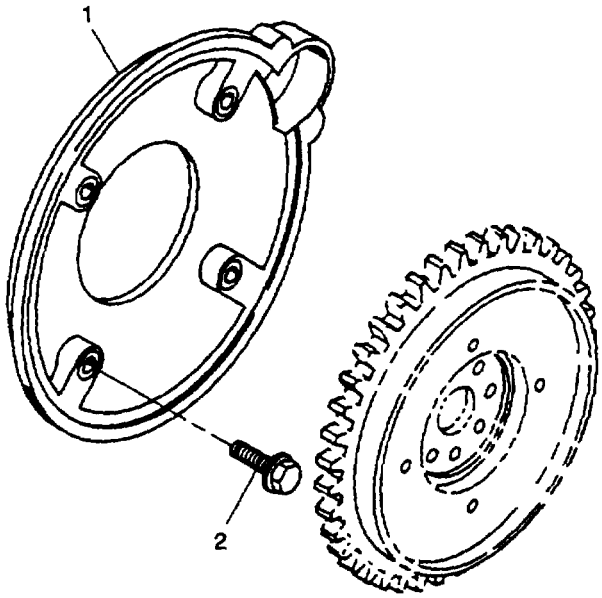


FIGURE 3-38. Flywheel Housing

3-32. MAIN BFARING HOUSING.

3-32.1. Removal.

a. Drain engine lubrication system. Refer to end item maintenance manual.
b. Remove flywheel housing. Refer to paragraph 3-31.1.
c. Remove crankcase door. Refer to paragraph 3-20.2.1.

CAUTION

Failure to remove a center bearing tube may result in distorting it making it difficult to remove at a later stage.

d. Use an intake manifold bolt to remove center bearing tube (1, FIGURE 3-40). Leave bolt in tube until it is installed to ensure tube is installed correct way. Refer to FIGURE 3-39.

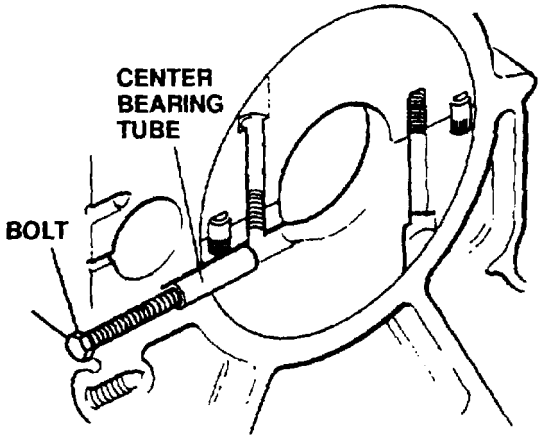


FIGURE 3-39. Center Bearing Tube

e. Remove five capscrews (2, FIGURE 3-40) securing main bearing housing (3).
f. Remove bearing housing (3). If it is tight, use two recesses in 3 o'clock and 9 o'clock positions and pry it off with a suitable screwdriver. Remove and discard shim (4).

NOTE

Thrust bearing (5) will come out with main bearing housing.

g. Remove thrust bearing (5).
h. Clean all traces of old shim and compound from housing and crankcase.
i. Using suitable driver, drive oil seal (6) from housing (3) taking care not to damage bearing (7).
j. Remove bearing (7) from housing (3) as follows:
   (1) Mount housing (3) in a soft-jawed vice.
   (2) Place bolt of main bearing tool (317-50111) through plain dolly. Refer to FIGURE 3-41.
   (3) Install bolt and dolly into bearing (7, FIGURE 3-40) from oil seal side (crankcase outside face).
   (4) Install bridge over bolt threads until two legs are against housing face.
   (5) Install spacer and nut onto bolt.
   (6) Use a suitable wrench to tighten nut until bearing shells (7) are withdrawn.

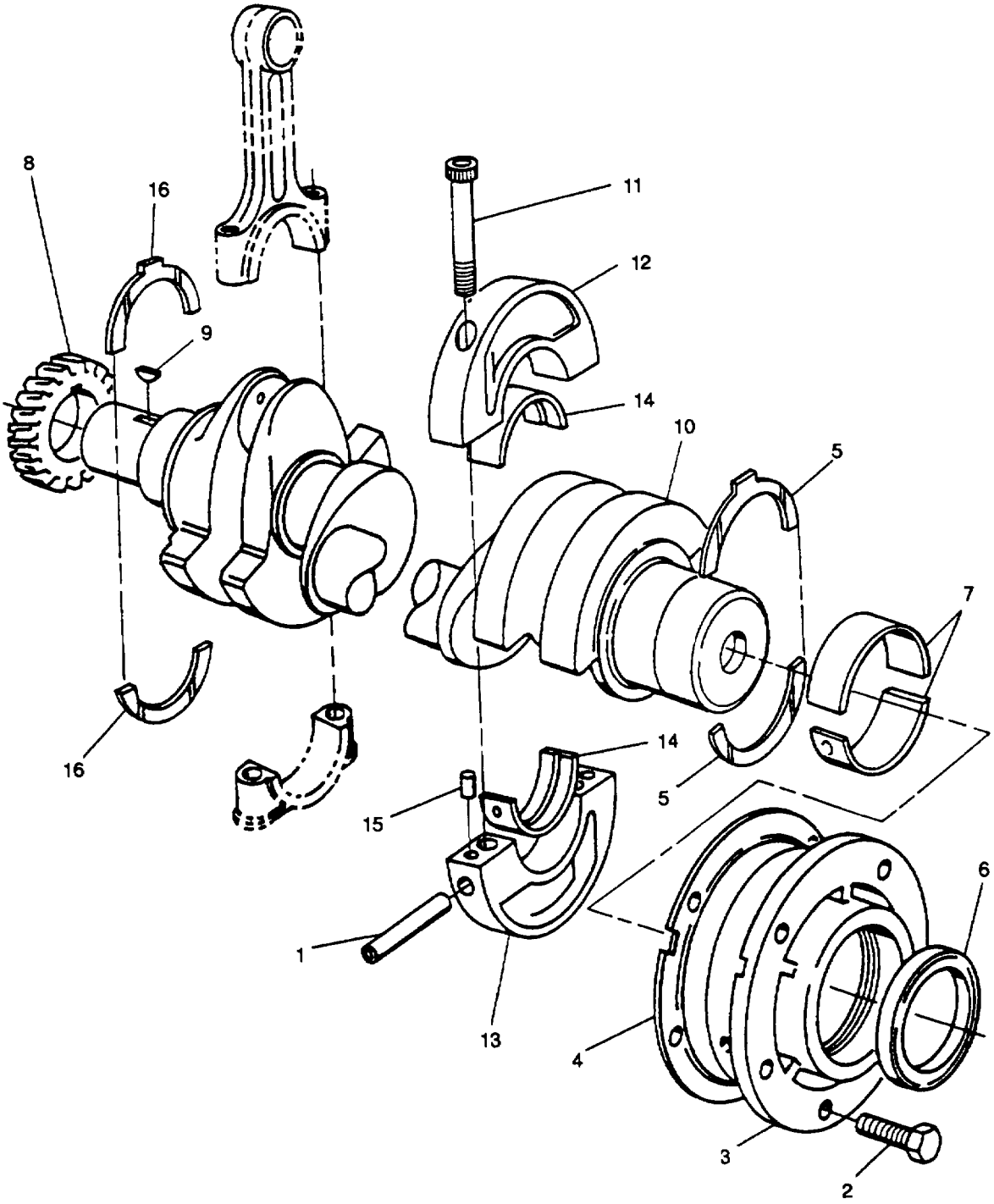


FIGURE 3-40. Crankshaft Assembly

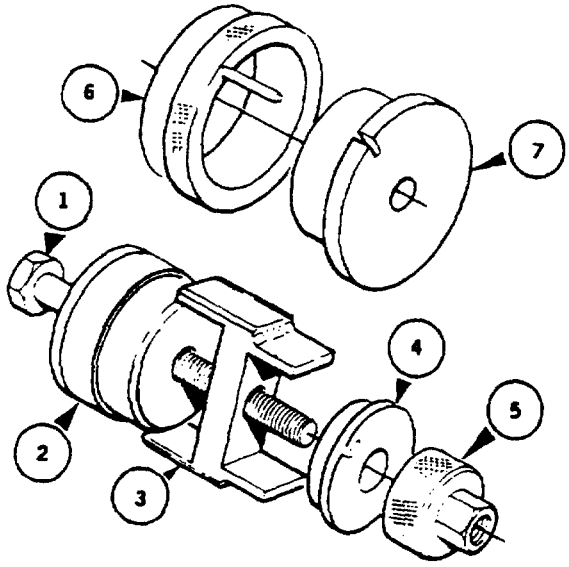


FIGURE 3-41. Main Bearing Tool

3-32.2. Installation.

a. Install bearing (7, FIGURE 3-40) in main bearing housing (3) as follows:
   (1) Mount housing (3) in a soft-jawed vice with small oil feed hole facing up.
   (2) Place large tapered collar of main bearing tool (317-50111) on a bench with pilot facing up.
   (3) Place new bearing shells (7) into collar ensuring one oil feed hole is in line with pilot pin of collar and end of shell is in line with the mark on collar face.
   (4) Place driver onto collar with cutout on driver located over collar pilot pin.
   (5) Push driver sufficiently until bearings (7) come out other side of collar to provide a lead in.
   (6) Install assembly into housing (3) from oil seal side (crankcase outside face) with pilot pin in line with oil feed hole in housing.
   (7) Place bolt through assembly.
   (8) Install bridge, spacer, and nut onto bolt.
   (9) Tighten nut until driver is against face of collar.
   (10) Remove tool.
   (11) Check that oil hole in bearing shell (7) is correctly aligned with oil feed hole in housing (3).

b. Lightly grease steel back of thrust bearing (5) with general purpose grease (630AA) and position it in housing (3). Ensure that tab is correctly located and copper face will be toward crankshaft.

c. Coat both sides of a new main bearing housing shim (4) with sealing compound (MIL-R-46082). Install it to housing (3) with flat side towards crankcase.

NOTE

Two sizes of shim (4) are available; 0.015 and 0.020 in. (0.38 and 0.5 mm). Start with smaller shim and check end play.

d. Position housing (3) with shim (4) on crankcase and secure with five capscrews (2). Tighten capscrews to 240 in-lbs (27.2 Nm) in sequence shown in FIGURE 3-42.

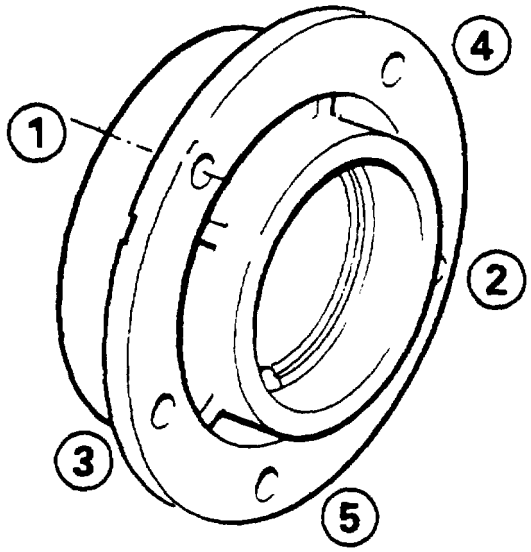


FIGURE 3-42. Bearing Housing Capscrew Tightening Sequence

CAUTION

Striking crankshaft may displace thrust bearings (5) and damage bearing locating tube If It has not been removed.

e. Check crankshaft end play. Refer to paragraph 3-33.2.
f. Install oil seal (6) as follows:
   (1) Place new oil seal (6) squarely into housing (3). Do not use any compound on seal.
   (2) Using a suitable driver against outside face of seal (6), drive seal into bearing housing (3).
g. Install center bearing locating tube (1) with tapped end facing outward.
h. Install crankcase door. Refer to paragraph 3-20.2.4.
i. Install flywheel housing. Refer to paragraph 3-31.2.

3-33. CRANKSHAFT.

3-33.1. Removal.

a. Drain lubrication system. Refer to end item maintenance manual.
b. Remove cylinder head assembly. Refer to paragraph 3-27.1.
c. Remove gear end cover. Refer to paragraph 3-28.1.
d. Remove flywheel housing. Refer to paragraph 3-31.1.
e. Remove camshaft. Refer to paragraph 3-29.1.
f. Remove crankcase door. Refer to paragraph 3-20.2.1.

NOTE
Oil pump does not need to be removed.

g. Remove oil pressure relief valve and strainer. Refer to paragraph 3-21.1.
h. Remove pistons and connecting rods. Refer to paragraph 3-30.1.
i. Using a suitable puller, remove crankshaft pinion gear (8, FIGURE 3-40). Remove key (9) from crankshaft (10).

NOTE
Use two flywheel bolts in end of crankshaft and a bar to hold crankshaft.

j. Remove main bearing housing. Refer to paragraph 3-32.1.
k. Gently withdraw crankshaft (10) through flywheel end of crankcase.
l. Remove two capscrews (11) securing center bearing upper housing (12) to lower housing (13). Remove both housings (12 and 13) and bearings (14).
m. If necessary, remove two dowel pins (15) from lower housing (13).
n. Remove thrust bearings (16) from gear end of crankshaft (10).

3-33.2. Inspect and Measure.
a. Inspect all bearings for scoring or wear.
b. If connecting rod big end has been disassembled because of failure of bearing, oil passages in crankshaft must be examined for obstruction and fragments of metal.
c. Replace thrust bearings if they are damaged or worn.
d. Check center bearing clearance using bearing gage (PLASTIGAGEPR1) as follows:
   (1) Place a piece of correct size bearing gage approximately 0.25 in. (6.35 mm) off center across full width of one bearing shell.
   (2) Install bearing and torque bolts.

CAUTION
Ensure crankshaft is not turned when bearing gage is in place, and all traces of it must be removed before final assembly of bearing to prevent damage to crankshaft and bearings.

   (3) Remove bearing shell. Compare width of bearing gage against scale printed on bearing gage container. Compare with values found in TABLE 3-7.
e. Using appropriate measuring devices, check components listed in TABLE 3-7 for wear. Replace components that exceed maximum clearance.
f. Check crankshaft end play as follows:
   (1) Set a dial indicator so that actuating plunger makes contact with flywheel end face of crankshaft.
   (2) Push crankshaft firmly towards gear end of engine and zero indicator.
   (3) Push crankshaft firmly towards flywheel end of engine and check end play. This should be 0.0071 to 0.0149 in. (0.18 to 0.38 mm). End play is maintained by installing a single 0.0149 or 0.0197 in. (0.38 or 0.50 mm) aluminum shim behind bearing housing flange.

TABLE 3-7. Crankshaft Component Wear Limits

	Initial Dimension		Maximum Clearance	
Components	**inches**	**(mm)**	**inches**	**(mm)**
Flywheel end main bearing housing bore	2.915 2.196	(74.040) (74.065)		
Bearing shell thickness	0.0783 0.0787	(1.990) (2.000)	0.0055	(0.14)
Crankshaft journal diameter	2.755 2.756	(69.985) (70.000)		
Gear end main bearing housing bore	2.305 2.360	(58.535) (58.560)		
Bearing shell thickness	0.0685 0.0689	(1.740) (1.750)	0.053	(0.135)
Crankshaft journal diameter	2.1648 2.1654	(54.985) (55.000)		
Center main bearing housing bore	2.305 2.306	(58.535) (58.560)		
Bearing shell thickness	0.0685 0.0689	(1.740) (1.750)	0.053	(0.135)
Crankshaft journal diameter	2.1648 2.1654	(54.985) (55.000)		
Trust bearing thickness (See Note)	0.091 0.093	(2.310) (2.360)		

3-33.3. Installation.

a. Install new bearing in gear end of crankcase. Refer to paragraph 3-34.4.

b. Position new center bearing shells (14, FIGURE 3-40) on upper and lower housing. If necessary, install two dowel pins (15) in lower housing (13). Install upper housing (12) and lower housing (13) ensuring words FLYWHEEL END are facing flywheel end of crankshaft (10). Secure with two capscrews (11) and tighten to 186 in-lbs (21.0 Nm).

CAUTION

Take special care when passing crankshaft (10) through gear end bearing as it is quite easy to score bearing shell with crankshaft.

c. Install crankshaft (10) into crankcase from flywheel end. Ensure that center bearing locating tube hole is aligned with hole in crankcase.

d. Apply a small amount of general purpose grease (630AA) to steel side of thrust bearings (16) and place them in gear end of crankcase with tab correctly located and copper face toward crankshaft (10).

NOTE

Replace thrust bearing if thickness is less than 0.0394 in. (2.20 mm).

NOTE

Ensure tube is fully seated and not in housing capscrew head recess.

e. With an inlet manifold bolt inserted in center bearing locating tube (1), insert tube through crankcase wall and into center bearing housing (13).
f. Remove bolt from tube.
g. Install rear main bearing housing (3) and oil seal (6). Refer to paragraph 3-32.2.
h. Check that crankshaft (10) is free to rotate.
i. Install key (9) on gear end of crankshaft.

WARNING
Use care to prevent serious bums when handling pinion gear (8).

CAUTION
Insufficient heat or delay In Installation could well cause pinion to become jammed on crankshaft, whereas overheating may cause softening of pinion.

j. Heat crankshaft pinion gear (8) to a straw yellow color (460°F) (238°C) and install it on crankshaft ensuring that '0', mark is facing outward.
k. Install pistons and connecting rods. Refer to paragraph 3-30.4.
l. Install camshaft. Refer to paragraph 3-29.3.
m. Install flywheel housing. Refer to paragraph 3-31.2.
n. Install gear end cover. Refer to paragraph 3-28.3.

3-34. CRANKCASE ASSEMBLY.

3-34.1. Removal. Remove crankshaft. Refer to paragraph 3-33.1.

3-34.2. Repair.
a. If damaged, remove two capscrews (1, FIGURE 3-43) and copper washers (2).
b. If damaged, remove two pivot supports (3).
c. Using camshaft bushing tool (317-50106), remove camshaft bushing (4) as follows:
(1) Install guide into bushing (4) from inside crankcase.
(2) Install slide hammer onto guide threads.

WARNING
Care must be taken to ensure that any part of hand is not likely to become trapped between two parts of slide hammer while it is being used.

(3) Use slide hammer to remove bushing (4).
d. Using main bearing tool (317-50111), remove crankshaft main bearing (5) as follows:
(1) Place bolt through plain dolly. Refer to FIGURE 3-41.
(2) Install bolt and dolly into bearing (5, FIGURE 3-43) from oil seal side (crankcase outside face).
(3) Install bridge over bolt threads until two legs are against crankcase.
(4) Install spacer onto bolt.
(5) Use a suitable wrench to tighten nut until bearing shells are withdrawn.

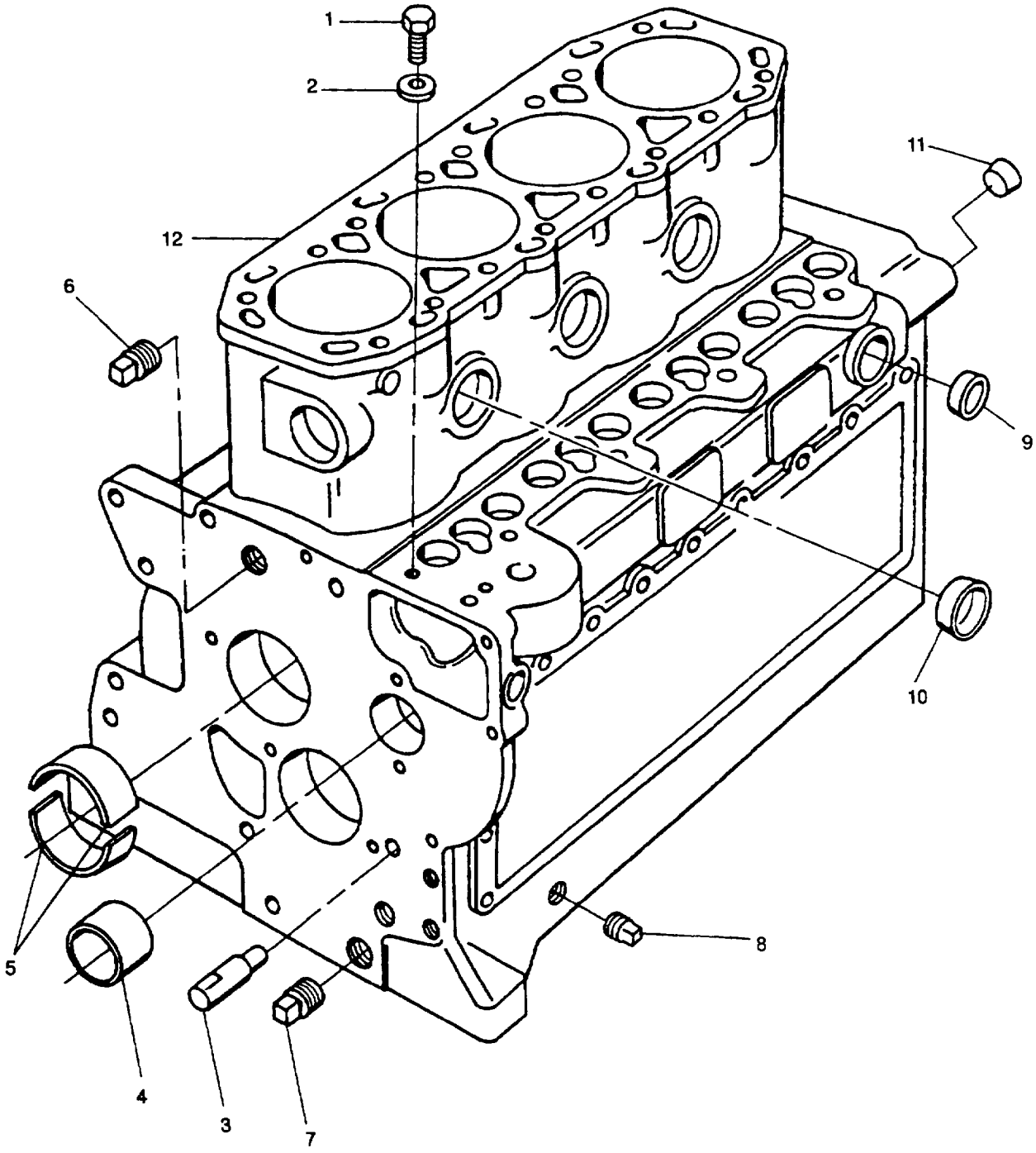


FIGURE 3-43. Crankcase Assembly

e. If damaged, remove pipe plugs (6, 7, and 8) and expansion plugs (9, 10, and 11).
f. If removed, install pipe plugs (6, 7, and 8) and expansion plugs (9, 10, and 11).
g. Using main bearing tool (317-50111), install crankshaft main bearing (5) as follows:
   (1) Place large tapered collar on a bench with pilot pin facing up. Refer to FIGURE 3-41.
   (2) Place new bearing shells (5, FIGURE 3-43) into collar ensuring that one oil feed hole is in line with pilot pin and end of shell is in line with mark on collar face.
   (3) Place driver onto collar with cutout on driver located over collar pilot pin.
   (4) Push driver sufficiently until bearings come out other side of collar to provide a lead in.
   (5) Install assembly into crankcase from gear end with pilot pin in line with the oil feed hole in crankcase.
   (6) Place bolt through assembly.
   (7) Install bridge, spacer, and nut onto bolt.
   (8) Tighten nut until driver is against face of collar.
   (9) Remove tool.
   (10) Check that oil hole in bearing shell (5) is correctly aligned with oil feed hole in crankcase.
h. Using camshaft bushing tool (317-50106), install camshaft bushing (4) as follows:

NOTE
When bushing (4) is replaced split in it must be positioned at top of bushing bore.

   (1) Install new bushing (4) over guide threads.
   (2) Screw on depth plate.
   (3) Install slide hammer onto guide threads.
   (4) Place assembly squarely into crankcase bushing bore from outside of crankcase.
   (5) Use slide hammer to install bushing.
i. If necessary, install two pivot supports (3).
j. If necessary, install two capscrews (1) and copper washers (2).

3-34.3. Inspection.

WARNING

Cleaning solvent is flammable and toxic to eyes, skin, and respiratory tract. Avoid repeated/prolonged contact. Good general ventilation is normally adequate.

NOTE

All components must be removed from engine block for inspection and cleaning.

a. Clean block (12, FIGURE 3-43) thoroughly using dry cleaning solvent (P-D-680), pressure steam, or a hot tank.

CAUTION

If engine block Is cleaned In a hot tank, be sure to remove any aluminum parts (such as nameplates). Aluminum parts can be damaged or destroyed by hot tank solutions.

b. Make sure all passages and crevices are cleared of sludge and grease.
c. All coolant passages must be cleared of any lime deposits and scale.
d. Carefully inspect block for cracks or damage. Replace block if there is evidence of physical damage.

WARNING

Compressed air used for cleaning can create airborne particles that may enter the eyes. Pressure will not exceed 30 psig (207 kPa). Eye protection required.

e. When determined that engine block is serviceable, clean out threads for cylinder head capscrews in top deck of engine block using a M10 x 1.25 sized tap. Use compressed air to remove any debris or fluid which may be present in tapped holes after cleaning.

3-34.4. Installation. Install crankshaft. Refer to paragraph 3-33.3.

APPENDIX A

REFERENCES

A-1. SCOPE.

This Appendix lists all forms, field manuals, technical manuals and miscellaneous publications references in this manual.

A-2. FORMS.

Air Force Reporting of Errors Form ..... AFTO Form 22
Marine Corps Reporting of Errors Form ..... NAVMC Form 10722
Product Quality Deficiency Report ..... SF 368
Recommended Changes to DA Publications ..... DA Form 2028-2
Recommended Changes to Publications and Blank Forms ..... DA Form 2028
Report of Discrepancy (ROD) ..... SF 364
Reporting of Item and Packaging Discrepancies ..... AR 735-11-2
Reporting of Transportation Discrepancies in Shipment ..... AR 55-38
Transportation Discrepancy Report ..... SF 361
Equipment Control Record ..... DA Form 2408-9

A-3. FIELD MANUALS.

First Aid for Soldiers ..... FM 21-11

A-4. TECHNICAL MANUALS.

Destruction of Materiel ..... TM 750-244-3
Repair Parts and Special Tools List, Diesel Engine DN4M-1 ..... TM 9-2815-253-24P

A-5. MISCELLANEOUS PUBLICATIONS.

Maintenance Management Policy (MMP) ..... AFR 66-1
Preservation of USAMECOM Mechanical Equipment for Shipment and Storage ..... TB 740-97-2
Suggestion Program ..... AFR 900-4
The Army Maintenance Management System (TAMMS) ..... DA PAM 738-750
USAF Materiel Deficiency Reporting T0-00-35D54

APPENDIX B

MAINTENANCE ALLOCATION CHART (MAC)

SECTION I.

INTRODUCTION

B-1. GENERAL.

a. This section provides a general explanation of all maintenance and repair functions authorized at various maintenance categories.

b. The Maintenance Allocation Chart (MAC) in SECTION II designates overall authority and responsibility for the performance of maintenance functions on the diesel engine and its components. The application of the maintenance functions to the engine components will be consistent with the capacities and capabilities of the designated maintenance categories.

c. SECTION III lists the tools and test equipment (both special tools and common tool sets) required for each maintenance function as referenced from SECTION II.

d. SECTION IV contains supplemental instructions and explanatory notes for a particular maintenance functions.

B-2. MAINTENANCE FUNCTIONS. Maintenance functions will be limited to and defined as follows:

a. Inspect. To determine the serviceability of an item by comparing its physical, mechanical, and/or electrical characteristics with established standards through examination (e.g., by sight, sound, or feel).

b. Test. To verify serviceability by measuring the mechanical, pneumatic, or electrical characteristics of an item and comparing those characteristics with prescribed standards.

c. Service. Operations required periodically to keep an item in proper operating condition; i.e., to clean (include decontaminate, when required), to preserve, to drain, to paint, or to replenish fuel, lubricants, chemical fluids, or gases.

d. Adjust. To maintain or regulate, within prescribed limits, by bringing into proper or exact position, or by setting the operating characteristics to specified performance.

e. Align. To adjust specified variable elements of an item to bring about optimum or desired performance.

f. Calibrate. To determine and cause corrections to be made or to be adjusted on instruments or Test, Measuring, and Diagnostic Equipment (TMDE) used in precision measurement. Consists of comparisons of two instruments, one of which is a certified standard of known accuracy, to detect and adjust any discrepancy in the accuracy of the instrument being compared.

g. Remove/Install. To remove and install the same item when required to perform service or other maintenance functions. Install may be the act of emplacing, seating, or fixing into position a spare, repair part, or module (component or assembly) in a manner to allow the proper functioning of an equipment or system.

h. Replace. To remove an unserviceable item and install a serviceable counterpart in its place. "Replace" is authorized by the MAC and is shown as the 3rd position code of the SMR code.

i. Repair. The application of maintenance services including fault location/troubleshooting, removal/installation, and disassembly/assembly procedures, and maintenance actions to identify troubles and restore serviceability to an item by correcting specific damage, fault, malfunction, or failure in a part, subassembly, module (component or assembly), end item, or system.

j. Overhaul. That maintenance effort (service/action) prescribed to restore an item to a completely serviceable/operational condition as required by maintenance standards in appropriate technical publications (i.e., DMWR). Overhaul is normally the highest degree of maintenance performed by the Army. Overhaul does not normally return an item to like new condition.

k. Rebuild. Consists of those services/actions necessary for the restoration of unserviceable equipment to a like new condition in accordance with original manufacturing standards. Rebuild is the highest degree of materiel maintenance applied to Army equipment. The rebuild operation includes the act of returning to zero those age measurements (hours/miles, etc.) considered in classifying Army equipment/components.

B-3. EXPLANATION OF COLUMNS IN THE MAC, SECTION II.

a. Column 1, Group Number. Column 1 lists functional group code numbers, the purpose of which are to identify maintenance significant components, assemblies, subassemblies, and modules with the next higher assembly. End item group number shall be "00".

b. Column 2, Component Assembly. Column 2 contains the item names of components, assemblies, subassemblies, and modules for which maintenance is authorized.

c. Column 3, Maintenance Function. Column 3 lists the functions to be performed on the item listed in column 2. (For detailed explanation of these functions, see paragraph B-2.)

d. Column 4, Maintenance Level. Column 4 specifies, by the listing of a work time figure in the appropriate subcolumn(s), the level of maintenance authorized to perform the function listed in column 3. This figure represents the active time required to perform that maintenance function at the indicated level of maintenance. If the number or complexity of the tasks within listed maintenance function vary at different maintenance categories, appropriate work-time figures will be shown for each category. The work time figure represents the average time required to restore an item (assembly, subassembly, component, module, end item, or system) to a serviceable condition under typical field operating conditions. This time includes preparation time (including any necessary disassembly/assembly time), troubleshooting/fault location time, and quality assurance/quality control time in addition to the time required to perform the specific tasks identified for the maintenance functions authorized in the Maintenance Allocation Chart. The symbol designations for the various maintenance categories are as follows:

C..... Operator or crew Maintenance
O..... Organizational Maintenance
F ..... Direct Support Maintenance
H..... General Support Maintenance
D..... Depot Maintenance

e. Column 5, Tools and Equipment. Column 5 specifies, by code, those common tools sets (not individual tools), common TMDE, and special support equipment required to perform the designated function.

f. Column 6, Remarks. This column shall, when applicable, contain a letter code, in alphabetical order, which is keyed to the remarks contained in SECTION IV.

B-4. EXPLANATION OF COLUMNS IN TOOL AND TEST EQUIPMENT REQUIREMENTS, SECTION III.

a. Column 1, Reference Code. The tool and test equipment reference code correlates with a code used in the MAC, SECTION II, Column 5.

b. Column 2, Maintenance Category. The lowest category of maintenance authorized to use the tool or test equipment.

c. Column 3, Nomenclature. Name or identification of the tool or test equipment.

d. Column 4, National Stock Number. The National Stock Number of the tool or test equipment.

e. Column 5, Tool Number. The manufacturer's part number of the tool or test equipment.

B-5. EXPLANATION OF COLUMNS IN REMARKS, SECTION IV.

a. Column 1, Reference Code. The code recorded in column 6, SECTION II.

b. Column 2, Remarks. This column lists information pertinent to the maintenance function being performed as indicated in the MAC, SECTION II.

SECTION II. MAINTENANCE ALLOCATION CHART FOR DIESEL ENGINE MODEL DN4M

(1) Group Number	(2) Component/ Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools and Equipment	(6) Remarks
00	ENGINE ASSEMBLY	INSPECT	.2	.5					A
	10KW	TEST			1.5			3	
		SERVICE	.3	.5				4	
		ADJUST		1.0	1.0			4	
		R/I			4.0				B
		REPLACE			8.0				B
		REPAIR		1.0	2.0	2.0			
01	INTAKE & EXHAUST SYSTEM	INSPECT		.1					
		REPAIR		.5					
0101	INTAKE MANIFOLD	INSPECT		.1					
		R/I		2.0				1,4	
		REPLACE		2.0				1,4	C
0102	HEATER PLUG	TEST		.4				1,4	
		R/I		.3				4	
		REPLACE		.3				4	C
0103	EXHAUST MANIFOLD	INSPECT		.1					
		R/I		2.0				1,4	
		REPLACE		2.0				1,4	C
02	COOLING SYSTEM	INSPECT	.1	.1					A
		REPAIR		.5					
0201	THERMOSTAT	INSPECT		.7					
		R/I		.5				4	
		REPLACE		.5				4	C
0202	WATER PUMP	INSPECT	.1	.1					A
		R/I		2.0				1,4	
		REPLACE		2.0				1,4	
03	FUEL SYSTEM	INSPECT	.1	.2					A
		REPAIR		.5	1.0				
0301	PUMP, FUEL	INSPECT	.1						A
		TEST			1.0				
		ADJUST			2.0			2, 4,10	
		R/I			2.0			1,4	
		REPLACE			2.0			1,4	C
0302	FUEL FILTER ASSEMBLY	INSPECT	.1						A
		SERVICE		.2				4	
		R/I		.3				4	
		REPLACE		.3				4	C
		REPAIR		.3				4	
0303	FUEL INJECTOR	INSPECT	.1	.1	.2				
		TEST			2.5			3, 4, 5	
		R/I			2.0			4	
		REPLACE			2.0			4	C
0304	FUEL SOLENOID INSTALLATION	INSPECT	.1						
		ADJUST		.2				4	B
		REPAIR		.2				4	D

SECTION II. MAINTENANCE ALLOCATION CHART FOR DIESEL ENGINE MODEL DN4M

(1) Group Number	(2) Component/ Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools and Equipment	(6) Remarks
04	LUBRICATION SYSTEM	INSPECT	.1						A
		SERVICE		.2					
		REPAIR		.5	1.0				
0401	OIL FILTER	INSPECT	.1						A
		REPLACE		.2				1,4	
0402	CRANKCASE DOOR	INSPECT	.1	.1					
		R/I		1.5				1,4	
		REPLACE		1.5				1,4	C
0403	STRAINER	INSPECT			.1				
		R/I			.2			4	
		REPLACE			.2			4	C
0404	OIL PUMP ASSEMBLY	INSPECT				.1			
		R/I				.5		2, 4	
		REPLACE				,5		2, 4	C
05	GOVERNOR SYSTEM	INSPECT			.2				
		ADJUST		.5	1.5			4, 11	
		REPAIR		.5	1.0			2, 4	
0501	GOVERNOR LEVER & RACK ASSEMBLY	INSPECT			.2				
		R/I			.5			4	
		REPLACE			.5			4	
		REPAIR		.5	.5			4	
06	STARTER ASSEMBLY	INSPECT	.1						
		TEST		.5	1.0			1,4	
		R/T		1.0				4	
		REPLACE		1.0	4				C
		REPAIR		.5	1.0			4	
07	ENGINE SUBASSEMBLY	INSPECT	.1						A
		REPAIR		.5	2.5				
0701	ROCKER LEVER	INSPECT			.1				
		R/I			1.0			1,4	
		REPLACE			1.0			1,4	C
0702	CYLINDER HEAD ASSEMBLY	INSPECT		.2					
		R/I			4.0			2, 4	
		REPLACE			4.0			2, 4	C
		REPAIR			2.0				
070201	VALVE SPRING	INSPECT			.3				
		TEST			.2			4	
		R/I			1.0			2, 3	C
		REPLACE			1.0			2, 3	
070202	EXHAUST & INTAKE VALVES	INSPECT			.5				
		TEST			.4			2	
		R/I			1.0			2, 3	C
		REPLACE			1.0			2, 3	
070203	CYLINDER HEAD	INSPECT			.5				
		TEST			.4			2	
		REPLACE			2.0			3,7,8	

SECTION II. MAINTENANCE ALLOCATION CHART FOR DIESEL ENGINE MODEL DN4M

(1) Group Number	(2) Component/ Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools and Equipment	(6) Remarks
0703	GEAR END COVER ASSEMBLY	INSPECT		.1	.1				
		R/I			1.0			2, 4	
		REPAIR			.5			4	C
		REPLACE			1.0			2, 4	
0704	CAMSHAFT ASSEMBLY	INSPECT				.5			
		TEST				.5		2	
		R/I				4.0		2, 4	C
		REPLACE				4.0		2, 4	
0705	CONNECTING ROD & PISTON ASSEMBLY	INSPECT				.5			
		R/I				1.0		2, 3,4	
		REPAIR				1.0			
070501	CONNECTING ROD ASSEMBLY	INSPECT				.3			
		TEST				.3		2	
		R/I				.5		2, 4	
		REPLACE				.5		2, 4	C
		REPAIR				.5		3, 4	
070502	PISTON ASSEMBLY	INSPECT				.3			
		TEST				.3		2	
		R/I				.5		2	
		REPLACE				.5		2	C
		REPAIR				.5		3	
0706	MAIN BEARINGS	INSPECT				.5			
		TEST				.5		2	
		R/I				1.0		2, 4, 9	
		REPLACE				1.0		2, 4, 9	C
0707	CRANKSHAFT	INSPECT				.3			
		TEST				.3		2	
		R/I				2.0		2, 4	
		REPLACE				1.0		2, 4	C
0708	CRANKCASE ASSEMBLY	INSPECT				.5			
		TEST				.5			
		R/I				8.0		2, 4	
		REPLACE				8.0		2, 4	C
		REPAIR				1.0		2, 4	
070801	CAMSHAFT BEARINGS	INSPECT				.5			
		TEST				.5		2	
		REPLACE				1.0		4, 6	
070802	CRANKCASE	INSPECT				.5			
		TEST				.5		2	

SECTION III. TOOL AND TEST EQUIPMENT REQUIREMENTS FOR DIESEL ENGINE MODEL DN4M

Tool or Test Equipment Ref Code	Maintenance Category	Nomenclature	National/NATO Stock Number	Tool Number
1	O	SHOP EQUIPMENT, AUTOMOTIVE MAINTENANCE AND REPAIR: ORGANIZATIONAL MAINTENANCE COMMON NO. 1, LESS POWER	4910-00-754-0654	SC 4910-95-CL-A74
2	F, H	TOOL SET, BASIC, FIELD MAINTENANCE CL-A31	4910-00-754-0705	SC 4910-95-
3	F, H	SHOP EQUIPMENT, AUTOMOTIVE MAINTENANCE AND REPAIR: FIELD MAINTENANCE, SUPPLEMENTAL SET NO. 2, LESS POWER	4910-00-754-0707	SC 4910-95-CL-A63
4	O, F, H	TOOL KIT, GENERAL MECHANIC'S CL-N26	5180-00-177-7033	SC 5180-90-
5	F	SHOP EQUIPMENT, FUEL AND ELECTRICAL SYSTEM ENGINE, FIELD MAINTENANCE BASIC, LESS POWER	4940-00-754-0714	SC 4940-95-CL-B20
6	H	TOOL, BUSHING, CAMSHAFT	---	317-50106
7	F	STOP, VALVE GUIDE DEPTH	---	317-50108
8	F	TOOL, VALVE GUIDE REPLACEMENT	---	317-5033
9	H	TOOL, MAIN BEARING		317-50111
10	F	TOOL, FUEL PUMP RACK	---	317-50114
11	O, F	GAGE, GOVERNOR RACK	---	317-50115

SECTION IV. REMARKS FOR DIESEL ENGINE MODEL DN4M

Reference Code	Remarks
A	Refer to end item operator's manual.
B	Refer to end item maintenance manual.
C	Replace function is identical to remove/install function.
D	Repair is limited to replacement of damaged parts (refer to remove/install function).

APPENDIX C

EXPENDABLE/DURABLE SUPPLIES AND MATERIALS LIST

SECTION I. INTRODUCTION

C-1. SCOPE.

This appendix lists expendable supplies and materials you will need to operate and maintain the engine. These items are authorized to you by CTA 50-790, Expendable Items (except Medical, Class V, Repair Parts, and Heraldic Items).

C-2. EXPLANATION OF COLUMNS.

a. Column (1) - Item Number. This number is assigned to the entry in the listing.

b. Column (2) - Level. This column identifies the lowest level of maintenance that requires the listed item.

c. Column (3) - National Stock Number. This is the national stock number assigned to the item; use it to request or requisition the item.

d. Column (4) - Description. Indicates the Federal item name and, if required, a description to identify the item. The last line for each item indicates the Commercial and Government Entity (CAGE) code in parentheses ( ) followed by the part number.

e. Column (5) - Unit of measure (U/M). Indicates the measure used in performing the actual maintenance function.

EXPENDABLE SUPPLIES AND MATERIALS LIST

(1) Item Number	(2) Level	(3) National Stock Number	(4) Description	(5) U/M
1	Unit/ DS/GS	7920-01-338-3329	Cloth, Cleaning, TX-1250	
2	DS/GS	5210-00-640-6178	Gage, Bearing Clear, PLASTIGAGEPR1	BX
3	Unit/ DS/GS	9150-00-663-1770	General Purpose Grease, 630AA	TU
4	Unit/ DS/GS	9150-00-152-4117	Lubricating Oil, Eng 15/40W, MIL-L-2104	QT
5	Unit/ DS/GS	5350-00-224-7201	Paper, Abrasive, #400	SHT
6	DS/GS	8030-00-891-8358	Sealing Compound (LOCTITE 609), MIL-R-46082	TU
7	DS/GS	3439-00-974-1873	Solder, Tin Alloy Compound, SN60WRAP2	OZ
8	Unit/ DS/GS	6850-00-264-9038	Solvent, Dry Cleaning, P-D-680, 5 Gal. Can	GL

Appendix D. MAINTENANCE PROCEDURE AND AUTHORIZED LEVEL OF MAINTENANCE

Section I. INTRODUCTION

SCOPE. This appendix shall be used when a Commercial Off The Shelf (COTS) manual is used by the Military services. This appendix is divided into three sections. Section I gives a brief description of the sections within this appendix. Section II list the paragraphs to the associated maintenance level. Section III list the maintenance level to the associated paragraphs.

Section II. PARAGRAPH TO MAINTENANCE LEVEL

Paragraph	Maintenance Level
3-3	ALL
3-4	ALL
3-5	ALL
3-6	O
3-7	O
3-8	O
3-9	C, O
3-10	C, O
3-11	ALL
3-12	ALL
3-13	C, F
3-14	F
3-15	O
3-16	O
3-17	C,O, F
3-18	O, F
3-19	C, O
3-20	C, O
3-21	F, H
3-22	O
3-23	O, F
3-24	O, F
3-25	F
3-26	F
3-27	F
3-28	O, F
3-29	H
3-30	H

Section II. PARAGRAPH TO MAINTENANCE LEVEL - Cont.

Paragraph	Maintenance Level
3-31	H
3-32	H
3-33	H
3-34	H

Section III. MAINTENANCE LEVEL TO PARAGRAPHS

Maintenance Level	Paragraphs
ALL	3-3, 3-4, 3-5, 3-11, 3-12
C	3-9,3-10, 3-13, 3-17, 3-19, 3-20
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APPENDIX E

TORQUE CHART

Torques are given as wet torques, hardware should be lightly oiled before installing. To ensure the component is pulled down correctly the sequences shown throughout this manual must be followed.

TABLE E-1. TORQUE SPECIFICATIONS

	ft - lbs *		
Description	**min.**	**nom.**	**max.**
Stop/run control assembly screw	4.5	5.0	5.5
Crankcase door bolts End cover bolts Manifold bolts or nuts Oil pump bolts Camshaft thrust plate screws Governor weight plate screws Rocker cover nut	5.9	6.5	7.1
Connecting rod bolts	18.1	18.5	18.9
Fuel swivel union plug	13.5	15.0	16.5
Fuel lift pump/blanking plate Injector clamp bolt Fuel line bracket bolt Water pump bolts Center bearing housing bolts	14.0	15.5	17.0
Flywheel end bearing housing bolts	18.0	20.0	22.0
Injector pipe nuts	18.9	21.0	23.1
Radiator fan nut (left hand thread)	19.8	22.0	24.2
Fuel pump clamp nut Valve rocker nut	22.5	25.0	27.5
Starter motor screw	27.0	30.0	33.0
Fuel pump delivery valve holder Injector nozzle nut	31.5	35.0	38.5
Flywheel bolts	50.1	51.3	52.5
Flywheel housing screws	52.2	58.0	63.8
Cylinder head bolts			
stage one	6.1	6.2	6.3
stage two	35.0	38.5	36.8
stage three	65.0	66.6	68.2
Crankshaft pulley bolt (left hand thread)	198.9	221.0	243.1

* Metric Conversion: Nm = ft-lbs x 1.3558

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The Metric System and Equivalents

Linear Measure

1 centimeter = 10 millimeters = .39 inch
1 decimeter = 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

Weights

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = .035 ounce
1 decagram = 10 grams = .35 ounce
1 hectogram = 10 decagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

Liquid Measure

1 centiliter = 10 milliters = .34 fl. ounce
1 deciliter = 10 centiliters = 3.38 fl. ounces
1 liter = 10 deciliters = 33.81 fl. ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 26.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

Square Measure

1 sq. centimeter = 100 sq. millimeters = .155 sq. inch
1 sq. decimeter = 100 sq. centimeters = 15.5 sq. inches
1 sq. meter (centare) = 100 sq. decimeters = 10.76 sq. feet
1 sq. dekameter (are) = 100 sq. meters = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47 acres
1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

Cubic Measure

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. centimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

Approximate Conversion Factors

To change	*To*	*Multiply by*	*To change*	*To*	*Multiply by*
inches	centimeters	2.540	ounce-inches	Newton-meters	.007062
feet	meters	.305	centimeters	inches	.394
yards	meters	.914	meters	feet	3.280
miles	kilometers	1.609	meters	yards	1.094
square inches	square centimeters	6.451	kilometers	miles	.621
square feet	square meters	.093	square centimeters	square inches	.155
square yards	square meters	.836	square meters	square feet	10.764
square miles	square kilometers	2.590	square meters	square yards	1.196
acres	square hectometers	.405	square kilometers	square miles	.386
cubic feet	cubic meters	.028	square hectometers	acres	2.471
cubic yards	cubic meters	.765	cubic meters	cubic feet	35.315
fluid ounces	milliliters	29,573	cubic meters	cubic yards	1.308
pints	liters	.473	milliliters	fluid ounces	.034
quarts	liters	.946	liters	pints	2.113
gallons	liters	3.785	liters	quarts	1.057
ounces	grams	28.349	liters	gallons	.264
pounds	kilograms	.454	grams	ounces	.035
short tons	metric tons	.907	kilograms	pounds	2.205
pound-feet	Newton-meters	1.356	metric tons	short tons	1.102
pound-inches	Newton-meters	.11296			

Temperature (Exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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