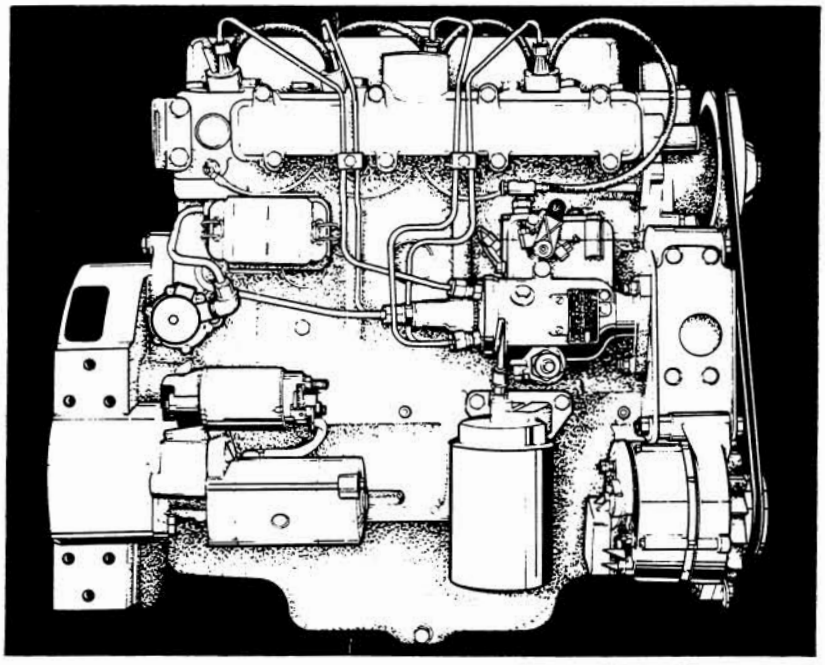
Onan

# Service Manual

## L Series
## Diesel Engine



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# Important Safety Precautions

Read and observe these safety precautions when using or working on electric generators, engines and related equipment. Also read and follow the literature provided with the equipment.

Proper operation and maintenance are critical to performance and safety. Electricity, fuel, exhaust, moving parts and batteries present hazards that can cause severe personal injury or death.

## FUEL, ENGINE OIL, AND FUMES ARE FLAMMABLE AND TOXIC

Fire, explosion, and personal injury can result from improper practices.

- Used engine oil, and benzene and lead, found in some gasoline, have been identified by government agencies as causing cancer or reproductive toxicity. When checking, draining or adding fuel or oil, do not ingest, breathe the fumes, or contact gasoline or used oil.
- Do not fill tanks with engine running. Do not smoke around the area. Wipe up oil or fuel spills. Do not leave rags in engine compartment or on equipment. Keep this and surrounding area clean.
- Inspect fuel system before each operation and periodically while running.
- Equip fuel supply with a positive fuel shutoff.
- Do not store or transport equipment with fuel in tank.
- Keep an ABC–rated fire extinguisher available near equipment and adjacent areas for use on all types of fires except alcohol.
- Unless provided with equipment or noted otherwise in installation manual, fuel lines must be copper or steel, secured, free of leaks and separated or shielded from electrical wiring.
- Use approved, non-conductive flexible fuel hose for fuel connections. Do not use copper tubing as a flexible connection. It will work–harden and break.

## EXHAUST GAS IS DEADLY

- Engine exhaust contains carbon monoxide (CO), an odorless, invisible, poisonous gas. Learn the symptoms of CO poisoning.
- Never sleep in a vessel, vehicle, or room with a genset or engine running unless the area is equipped with an operating CO detector with an audible alarm.
- Each time the engine or genset is started, or at least every day, thoroughly inspect the exhaust system. Shut down the unit and repair leaks immediately.
- Warning: Engine exhaust is known to the State of California to cause cancer, birth defects and other reproductive harm.

*Make sure exhaust is properly ventilated.*

- Vessel bilge must have an operating power exhaust.
- Vehicle exhaust system must extend beyond vehicle perimeter and not near windows, doors or vents.
- Do not use engine or genset cooling air to heat an area.
- Do not operate engine/genset in enclosed area without ample fresh air ventilation.
- Expel exhaust away from enclosed, sheltered, or occupied areas.
- Make sure exhaust system components are securely fastened and not warped.

## MOVING PARTS CAN CAUSE SEVERE PERSONAL INJURY OR DEATH

- Do not remove any guards or covers with the equipment running.
- Keep hands, clothing, hair, and jewelry away from moving parts.
- Before performing any maintenance, disconnect battery (negative [–] cable first) to prevent accidental starting.
- Make sure fasteners and joints are secure. Tighten supports and clamps, keep guards in position over fans, drive belts, etc.
- If adjustments must be made while equipment is running, use extreme caution around hot manifolds and moving parts, etc. Wear safety glasses and protective clothing.

## BATTERY GAS IS EXPLOSIVE

- Wear safety glasses and do not smoke while servicing batteries.
- Always disconnect battery negative (–) lead first and reconnect it last. Make sure you connect battery correctly. A direct short across battery terminals can cause an explosion. Do not smoke while servicing batteries. Hydrogen gas given off during charging is explosive.
- Do not disconnect or connect battery cables if fuel vapors are present. Ventilate the area thoroughly.

## DO NOT OPERATE IN FLAMMABLE AND EXPLOSIVE ENVIRONMENTS

Flammable vapor can be ignited by equipment operation or cause a diesel engine to overspeed and become difficult to stop, resulting in possible fire, explosion, severe personal injury and death. **Do not operate diesel equipment where a flammable vapor environment can be created by fuel spill, leak, etc., unless equipped with an automatic safety device to block the air intake and stop the engine.**

## HOT COOLANT CAN CAUSE SEVERE PERSONAL INJURY

- Hot coolant is under pressure. Do not loosen the coolant pressure cap while the engine is hot. Let the engine cool before opening the pressure cap.

## ELECTRICAL SHOCK CAN CAUSE SEVERE PERSONAL INJURY OR DEATH

- Do not service control panel or engine with unit running. High voltages are present. Work that must be done while unit is running should be done only by qualified service personnel.
- Do not connect the generator set to the public utility or to any other electrical power system. Electrocution can occur at a remote site where line or equipment repairs are being made. An approved transfer switch must be used if more than one power source is connected.
- Disconnect starting battery (negative [–] cable first) before removing protective shields or touching electrical equipment. Use insulative mats placed on dry wood platforms. Do not wear jewelry, damp clothing or allow skin surface to be damp when handling electrical equipment.
- Use insulated tools. Do not tamper with interlocks.
- Follow all applicable state and local electrical codes. Have all electrical installations performed by a qualified licensed electrician. Tag open switches to avoid accidental closure.
- With transfer switches, keep cabinet closed and locked. Only authorized personnel should have cabinet or operational keys. Due to serious shock hazard from high voltages within cabinet, all service and adjustments must be performed by an electrician or authorized service representative.

If the cabinet must be opened for any reason:

1. Move genset operation switch or Stop/Auto/Handcrank switch (whichever applies) to Stop.
2. Disconnect genset batteries (negative [–] lead first).
3. Remove AC power to automatic transfer switch. If instructions require otherwise, use extreme caution due to shock hazard.

## MEDIUM VOLTAGE GENERATOR SETS (601V TO 15kV)

- Medium voltage acts differently than low voltage. Special equipment and training are required to work on or around medium voltage equipment. Operation and maintenance must be done only by persons trained and qualified to work on such devices. Improper use or procedures will result in severe personal injury or death.
- Do not work on energized equipment. Unauthorized personnel must not be permitted near energized equipment. Induced voltage remains even after equipment is disconnected from the power source. Plan maintenance with authorized personnel so equipment can be de-energized and safely grounded.

## GENERAL SAFETY PRECAUTIONS

- Do not work on equipment when mentally or physically fatigued or after consuming alcohol or drugs.
- Carefully follow all applicable local, state and federal codes.
- Never step on equipment (as when entering or leaving the engine compartment). It can stress and break unit components, possibly resulting in dangerous operating conditions from leaking fuel, leaking exhaust fumes, etc.
- Keep equipment and area clean. Oil, grease, dirt, or stowed gear can cause fire or damage equipment by restricting airflow.
- Equipment owners and operators are solely responsible for operating equipment safely. Contact your authorized Onan/Cummins dealer or distributor for more information.

KEEP THIS DOCUMENT NEAR EQUIPMENT FOR EASY REFERENCE.

# Safety Precautions

It is recommended that you read your engine manual and become thoroughly acquainted with your equipment before you start the engine.

**⚠DANGER** ***This symbol if used warns of immediate hazards which will result in severe personal injury or death.***

**⚠WARNING** ***This symbol refers to a hazard or unsafe practice which can result in severe personal injury or death.***

**⚠CAUTION** ***This symbol refers to a hazard or unsafe practice which can result in personal injury or product or property damage.***

Fuels, electrical equipment, batteries, exhaust gases and moving parts present potential hazards that can result in serious, personal injury. Take care in following these recommended procedures. All local, state and federal codes should be consulted and complied with.

**⚠WARNING** ***This engine is not designed or intended for use in any type of aircraft. Use of this engine in aircraft can result in engine failure and causes serious personal injury or death.***

**General**

- Provide appropriate fire extinguishers and install them in convenient locations. Use an extinguisher rated ABC by NFPA.
- Make sure that all fasteners on the engine are secure and accurately torqued. Keep guards in position over fans, driving belts, etc.
- If it is necessary to make adjustments while the engine is running, use extreme caution when close to hot exhausts, moving parts, etc.

**Protect Against Moving Parts**

- Do not wear loose clothing in the vicinity of moving parts, such as PTO shafts, flywheels, blowers, couplings, fans, belts, etc.
- Keep your hands away from moving parts.

**Batteries**

- Before starting work on the engine, disconnect batteries to prevent inadvertent starting of the engine.
- DO NOT SMOKE while servicing batteries. Lead acid batteries give off a highly explosive hydrogen gas which can be ignited by flame, electrical arcing or by smoking.
- Verify battery polarity before connecting battery cables. Connect negative cable last.

**Fuel System**

- DO NOT fill fuel tanks while engine is running.
- DO NOT smoke or use an open flame in the vicinity of the engine or fuel tank. Internal combustion engine fuels are highly flammable.
- Fuel lines must be of steel piping, adequately secured, and free from leaks. Piping at the engine should be approved flexible line. Do not use copper piping for flexible lines as copper will work harden and become brittle enough to break.
- Be sure all fuel supplies have a positive shutoff valve.

**Exhaust System**

- Exhaust products of any internal combustion engine are toxic and can cause injury, or death if inhaled. All engine applications, especially those within a confined area, should be equipped with an exhaust system to discharge gases to the outside atmosphere.
- Do not use exhaust gases to heat a compartment.
- Make sure that your exhaust system is free of leaks. Ensure that exhaust manifolds are secure and are not warped by bolts unevenly torqued.

**Exhaust Gas is Deadly!**

Exhaust gases contain carbon monoxide, a poisonous gas that can cause unconsciousness and death. It is an odorless and colorless gas formed during combustion of hydrocarbon fuels. Symptoms of carbon monoxide poisoning are:

- Dizziness
- Headache
- Weakness and Sleepiness
- Vomiting
- Muscular Twitching
- Throbbing in Temples

If you experience any of these symptoms, get out into fresh air immediately, shut down the unit and do not use until it has been inspected.

The best protection against carbon monoxide inhalation is proper installation and regular, frequent inspections of the complete exhaust system. If you notice a change in the sound or appearance of exhaust system, shut the unit down immediately and have it inspected and repaired at once by a competent mechanic.

**Cooling System**

- Coolants under pressure have a higher boiling point than water. DO NOT open a radiator pressure cap when coolant temperature is above 212°F (100°C) or while engine is running.

**Keep the Unit and Surrounding Area Clean**

- Make sure that oily rags are not left on or near the engine.
- Remove all unnecessary grease and oil from the unit. Accumulated grease and oil can cause overheating and subsequent engine damage and present a potential fire hazard.

# Foreword

*This manual is designed to assist all service personnel with the maintenance and overhaul of Onan L series diesel engines. It presents a description of each systems function together with instructions on servicing and overhaul procedures. A* ***DIMENSIONS AND CLEARANCES SECTION*** *is provided and must be closely followed when overhauling or servicing any part of engine.*

*Unless otherwise specified the information applies to all L diesel engines. Where information applies to a specific engine it is so noted.*

*These engines have a counterclockwise rotation when viewed from the rear, flywheel end of engine. Throughout this manual, "right-hand" and "left-hand" sides are determined by facing the drive end (flywheel) of engine.*

*The manner in which the engine is operated and the maintenance performed on it will determine its performance, safety, and durability. Equally important is the use of proper procedures during engine overhaul. Before operating, servicing, or beginning an overhaul, read this manual carefully to familiarize yourself with the engine procedures involved, and the tools required. Keep this manual handy and refer to it often.*

This manual is divided into ***14 SECTIONS*** *covering the topics listed on the* ***CONTENTS*** *page. At the beginning of each* ***SECTION*** *is an index of the subjects covered. Pages are numbered consecutively, beginning with a new Page 1 at the outset of each* ***SECTION.*** *Each page number is preceded by the appropriate reference number for that* ***SECTION.*** *All illustrations are numbered consecutively, beginning with a new Figure 1 in each* ***SECTION.***

*Always give complete* ***MODEL*** *and* ***SERIAL NO.*** *of engine being serviced when ordering replacement parts.*

# Contents

## SECTION AND TITLE



**⚠WARNING**

***INCORRECT SERVICE OR REPLACEMENT OF PARTS CAN RESULT IN SEVERE PERSONAL INJURY AND/OR EQUIPMENT DAMAGE. SERVICE PERSONNEL MUST BE QUALIFIED TO PERFORM ELECTRICAL AND/OR MECHANICAL SERVICE.***

# 1. Specifications

## INDUSTRIAL ENGINE

| SPECIFICATION | UNIT OF MEASURE | L SERIES | | | |
|---|---|---|---|---|---|
| | | L317 | L423 | L634 | L634T |
| Number of Cylinders | | 3 | 4 | 6 | 6 |
| Diesel Fuel | | ASTM2-D | ASTM2-D | ASTM2-D | ASTM2-D |
| Bore | mm<br>(in) | 89<br>(3.50) | 89<br>(3.50) | 89<br>(3.50) | 89<br>(3.50) |
| Stroke | mm<br>(in) | 92<br>(3.62) | 92<br>(3.62) | 92<br>(3.62) | 92<br>(3.62) |
| Displacement | litre<br>(cu in) | 1.7<br>(105) | 2.3<br>(140) | 3.4<br>(210) | 3.4<br>(210) |
| Compression Ratio | | 21.5 to 1 | 21.5 to 1 | 21.5 to 1 | 21.5 to 1 |
| Rated Speed (Maximum) | RPM | 3600 | 3600 | 3600 | 3600 |
| Power (intermittent) at Rated Speed* | kW<br>(BHP) | 31.3<br>(42.0) | 43.3<br>(58.0) | 65.0<br>(87.0) | 85.8<br>(115.0) |
| Power (continuous) at Rated Speed* | kW<br>(BHP) | 28.5<br>(38.0) | 39.4<br>(52.7) | 59.1<br>(79.1) | 78.0<br>(104.5) |
| Firing Order | | 1 3 2 | 1 2 4 3 | 1 5 3 6 2 4 | 1 5 3 6 2 4 |
| Crankshaft Rotation (viewed from flywheel) | | Counter Clockwise | Counter Clockwise | Counter Clockwise | Counter Clockwise |
| Governor | | Variable Speed Mechanical | | Variable Speed Mechanical | |
| Valve Lash (Spec A to C) + | | | | | |
| Intake | mm<br>(in) | 0.20<br>(0.008) | 0.20<br>(0.008) | 0.20<br>(0.008) | 0.30<br>(0.012) |
| Exhaust | mm<br>(in) | 0.30<br>(0.012) | 0.30<br>(0.012) | 0.30<br>(0.012) | 0.30<br>(0.012) |
| Oil Filter | | Full Flow | Full Flow | Full Flow | Full Flow |
| Crankcase Capacity with filter change | litre<br>(qt) | 5.7<br>(6) | 5.7<br>(6) | 8.5<br>(9) | 11.4<br>(12) |

All dimensions in metric (U.S. customary units of measure in parentheses) unless otherwise specified.

* - Power obtained and corrected in accordance with SAEJ1349 [100 kPa (29.61 inches Hg) barometric pressure at 25° C (77° F) air inlet temperature], without air cleaner, fan, and exhaust muffler on naturally aspirated engines.

Power losses for typical air cleaner and muffler installations included on turbocharged engines.

+ - Beginning Spec D no valve lash adjustment required.

## MARINE ENGINE

| SPECIFICATION | UNIT OF MEASURE | L SERIES | |
|---|---|---|---|
| | | L317D-M | L423D-M |
| Number of Cylinders | | 3 | 4 |
| Diesel Fuel | | ASTM2-D | ASTM2-D |
| Bore | mm (in) | 89 (3.50) | 89 (3.50) |
| Stroke | mm (in) | 92 (3.62) | 92 (3.62) |
| Displacement | litre (cu in) | 1.7 (105) | 2.3 (140) |
| Compression Ratio | | 21.5 to 1 | 21.5 to 1 |
| Rated Speed (Maximum) | RPM | 3600 | 3600 |
| Power (intermittent) at Rated Speed* | kW (BHP) | 32.4 (43.5) | 44.7 (60.0) |
| Power (continuous) at Rated Speed* | kW (BHP) | 29.5 (39.5) | 40.7 (54.5) |
| Firing Order | | 1 3 2 | 1 2 4 3 |
| Crankshaft Rotation (viewed from flywheel) | | Counter Clockwise | Counter Clockwise |
| Governor | | Variable Speed Mechanical | |
| Valve Lash (Spec A to C) + | | | |
| Intake | mm (in) | 0.20 (0.008) | 0.20 (0.008) |
| Exhaust | mm (in) | 0.30 (0.012) | 0.30 (0.012) |
| Oil Filter | | Full Flow | Full Flow |
| Crankcase Capacity with filter change | litre (qt) | 5.7 (6) | 5.7 (6) |
| Coolant Capacity with heat exchanger | litre (qt) | 6.8 (7.2) | 9.1 (9.6) |

All dimensions in metric (U.S. customary units of measure in parentheses) unless otherwise specified.

* - Power obtained with 100 kPa (29 .92 inches Hg) barometric pressure at 16°C (60°F) air inlet temperature without air cleaner or exhaust muffler.

\+ - Beginning Spec D no valve lash adjustment required.

## POWER UNIT

| SPECIFICATION | UNIT OF MEASURE | L SERIES L423 | L634 | L634T |
|---|---|---|---|---|
| Number of Cylinders | | 4 | 6 | 6 |
| Diesel Fuel | | ASTM2-D | ASTM2-D | ASTM2-D |
| Bore | mm (in) | 89 (3.50) | 89 (3.50) | 89 (3.50) |
| Stroke | mm (in) | 92 (3.62) | 92 (3.62) | 92 (3.62) |
| Displacement | litre (cu in) | 2.3 (140) | 3.4 (210) | 3.4 (210) |
| Compression Ratio | | 21.5 to 1 | 21.5 to 1 | 20.5 to 1 |
| Rated Speed (Maximum) | RPM | 2600 | 3600 | 3200 |
| Power (intermittent) at Rated Speed* | kW (BHP) | 33.9 (45.5) | 59.7 (80.0) | 80.2 (107.5) |
| Power (continuous) at Rated Speed* | kW (BHP) | 30.9 (41.4) | 54.2 (72.7) | 72.9 (97.7) |
| Firing Order | | 1 2 4 3 | 1 5 3 6 2 4 | 1 5 3 6 2 4 |
| Crankshaft Rotation (viewed from flywheel) | | Counter Clockwise | Counter Clockwise | Counter Clockwise |
| Governor | | Variable Speed Mechanical | | |
| Valve Lash (Spec A to C) – | | | | |
| Intake | mm (in) | 0.20 (0.008) | 0.20 (0.008) | 0.30 (0.012) |
| Exhaust | mm (in) | 0.30 (0.012) | 0.30 (0.012) | 0.30 (0.012) |
| Oil Filter | | Full Flow | Full Flow | Full Flow |
| Crankcase Capacity with filter change | litre (qt) | 5.7 (6) | 8.5 (9) | 11.4 (12) |
| Cooling System Capacity | | | | |
| Engines without oil cooler | litre (qt) | 13.1 (13.9) | 16.6 (17.5) | |
| Engines with oil cooler | litre (qt) | 13.5 (14.2) | 17.1 (18.1) | 17.1 (18.1) |

All dimensions in metric (U.S. customary units of measure in parentheses) unless otherwise specified.

* - Power obtained and corrected in accordance with SAEJ1349 [100 kPa (29.61 inches HG) barometric pressure at 25°C (77°F) air inlet temperature], with air cleaner and fan.

– - Beginning Spec D no valve lash adjustment required.

## AUTOMOTIVE ENGINE

| SPECIFICATION | UNIT OF MEASURE | L SERIES L634T-A |
|---|---|---|
| Number of Cylinders | | 6 |
| Diesel Fuel | | ASTM2-D |
| Bore | mm (in) | 89 (3.50) |
| Stroke | mm (in) | 92 (3.62) |
| Displacement | litre (cu in) | 3.4 (210) |
| Compression Ratio | | 20.5 to 1 |
| Rated Speed (Maximum) | RPM | 2800 3600 |
| Power at Rated Speed* | kW (BHP) | 83.5 89.5 (112.0) (120.0) |
| Firing Order | | 1 5 3 6 2 4 |
| Crankshaft Rotation (viewed from flywheel) | | Counter Clockwise |
| Governor | | Min.-Max. |
| Valve Lash (Spec A to C) + | | |
| Intake | mm (in) | 0.30 (0.012) |
| Exhaust | mm (in) | 0.30 (0.012) |
| Oil Filter | | Full Flow |
| Crankcase Capacity with filter change | litre (qt) | Refer to Engine Nameplate |

All dimensions in metric (U.S. customary units of measure in parentheses) unless otherwise specified.

* - Power obtained and corrected in accordance with SAEJ1349 [100 kPa (29.61 inches HG) barometric pressure at 25°C (77°F) air inlet temperature], without fan.
Power losses for typical air cleaner and muffler installations included on turbocharged engines.
Refer to engine nameplate for rated speed and power.

+ - Beginning Spec D no valve lash adjustment required.

## STATIC PUMP TIMING SPECIFICATIONS

In February 1983 a change was made in the internal timing of the fuel injection pump and to the pump part numbering system. As a result of these changes, it may be necessary to change the engine static timing when installing a replacement fuel injection pump.

All fuel injection pumps built before February 1983 are marked with a seven digit (Example: 147-*0453*) Onan part number. Fuel injection pumps built after February 1983 are marked with a nine digit (Example: 147-0462-*02*) Onan part number. The Onan part number is stamped on the injection pump name plate. Engine performance is the same for both injection pumps when engine static timing is correctly set.

Find the seven or nine digit Onan part number stamped on the replacement pump and refer to Table 1 for the correct static timing specification.

Refer to *SECTION 10, FUEL SYSTEM* for complete fuel injection pump installation instructions.

## TABLE 1. STATIC PUMP TIMING SPECIFICATIONS

| Replacement Pump | Original Pump | Static Timing | |
|---|---|---|---|
| 9 digit | 7 digit | 15° BTDC* | All Engine applications. |
| 9 digit | 9 digit | 15° BTDC | All engine applications. No change to engine model label required. |
| 7 digit | 9 digit | 14.5° BTDC*<br>15° BTDC*<br>19° BTDC* | 4 cylinder (700-3600 rpm)<br>6 cylinder (700-3600 rpm)<br>4 and 6 cylinder (1500 and 1800 rpm) |
| 7 digit | 7 digit | Refer to engine model label for correct static timing specification. | |

*Change static timing specification on engine model label.

# 2. Dimensions and Clearances

# DIMENSIONS AND CLEARANCES

**All clearances given at room temperature of 21° C (70° F). All dimensions in millimetres (approximate inch dimensions in parentheses) unless otherwise specified.**

**Maximum allowable wear limit of a part is the point at which its proper function becomes impaired. Even though parts are still within the specified wear limits at time of rebuild, other considerations should also be used in evaluating the parts continued use.**

**⚠CAUTION** ***Metric measuring tools, metric dimensions, and clearances must be used when servicing the Onan L Engine. The use of inch measuring tools and approximate inch dimensions and clearances will cause stack up tolerances to be greater than specified.***

| DESCRIPTION | DIMENSION OF NEW PARTS millimetre (inch) | MAXIMUM ALLOWABLE WEAR LIMIT millimetre |
|---|---|---|
| **CYLINDER BLOCK** | | |
| Cylinder Bore Honed Diameter | 88.987-89.013 (3.5034-3.5044) | 89.063 |
| Cylinder Bore Out-of-Round | | 0.04 |
| Cylinder Bore Taper | | 0.08 |
| Main Bearing Bore (Cap in place without bearing, and capscrews properly torqued.) | 80.880-80.906 (3.1843-3.1853) | 80.906 |
| Main Bearing Bore (Bearings installed and capscrews properly torqued.) | 76.040-76.090 (2.9937-2.9956) | See main bearing journal clearance |
| Undersize Main Bearings (Available for N.A. Engines Only) | 0.25 mm, 0.50 mm, and 0.75 mm | |
| Camshaft Bearing Bore (Without bearing) | 53.164-53.188 (2.0930-2.0940) | 53.188 |
| Camshaft Bearing Bore (Bearing installed) | 50.044-50.116 (1.9702-1.9730) | See camshaft bearing clearance |
| Valve Tappet Bore | 26.070-26.100 (1.0263-1.0276) | See valve tappet clearance in bore |
| **CRANKSHAFT** | | |
| Main Bearing Journal Diameter | 75.99-76.01 (2.9917-2.9925) | See main bearing journal clearance |
| Main Bearing Clearance | 0.03-0.10 (0.0012-0.0039) | 0.15 |
| Main Bearing Journal Out-of-Round | 0.007 (0.0003) | 0.010 |
| Main Bearing Journal Taper | 0.005 (0.0002) | 0.007 |
| Connecting Rod Journal Diameter | 55.99-56.01 (2.2043-2.2051) | See connecting rod bearing-to-crankshaft clearance |
| Connecting Rod Journal Out-of-Round | 0.005 (0.0002) | 0.007 |
| Connecting Rod Journal Taper | 0.005 (0.0002) | 0.007 |
| Crankshaft End Play | 0.10-0.33 (0.0039-0.0129) | 0.38 |
| Crankshaft Straightness Runout of Center Main | 0.05-(0.0019) | 0.10 |
| **CONNECTING ROD** | | |
| Large Bearing Bore to Small Bearing Bore (Center-to-Center) | 155.975-156.025 (6.1407-6.1427) | 156.025 |
| Large Bore Diameter (Without bearing installed and rod nuts properly torqued | 59.860-59.875 (2.3567-2.3572) | 59.875 |
| Bearing to Crankshaft Clearance | 0.030-0.091 (0.0012-0.0036) | 0.15 |
| Connecting Rod Side Clearance | 0.05-0.45 (0.0019-0.0177) | 0.45 |
| Piston Pin Bushing Bore (Without bearing) | 35.20-35.23 (1.3858-1.3870) | 35.23 |
| Piston Pin Bushing Bore with Bearing, (Finished bore) | 32.01-32.02 (1.2602-1.2606) | See clearance connecting rod bushing |
| Large Bore Diameter (With bearing installed and rod nuts properly torqued) | 56.040-56.081 (2.2063-2.2079) | See connecting rod bearing-to-crankshaft clearance |
| Undersize Connecting Rod Bearings (Available for N.A. Engines Only) | 0.25 mm, 0.50 mm, and 0.75 mm | |

| DESCRIPTION | DIMENSION OF NEW PARTS millimetre (inch) | MAXIMUM ALLOWABLE WEAR LIMIT millimetre |
|---|---|---|
| **CAMSHAFT** | | |
| Bearing Journal Diameter | 49.988-50.014 (1.9680-1.9691) | See camshaft bearing clearance |
| Bearing Clearance | 0.030-0.127 (0.0011-0.0050) | 0.150 |
| End Play | 0.10-0.50 (0.0039-0.0197) | 0.70 |
| Journal Runout | 0.05 (0.0019) | 0.10 |
| Intake and Exhaust Lobe, Base-to-Tip (Spec A to C) | 42.95-43.15 (1.6909-1.6988) | 42.50 |
| Intake Lobe, Base-to-Tip (Begin Spec D) | 42.56-42.86 (1.6756-1.6874) | 42.20 |
| Exhaust Lobe, Base-to-Tip (Begin Spec D) | 42.86-43.16 (1.6874-1.6992) | 42.50 |
| **PISTON** | | |
| Clearance in Cylinder (Measure 90° to pin, 13 mm below oil ring) | | |
| Naturally Aspirated Engines | 0.145-0.201 (0.0057-0.0079) | 0.273 |
| Turbocharged Engines | 0.137-0.193 (0.0054-0.076) | 0.265 |
| Diameter (Measure 90° to pin, 13 mm below oil ring) | | |
| Naturally Aspirated Engines | 88.812-88.842 (3.4965-3.4977) | See piston to cylinder clearance |
| Turbocharged Engines | 88.820-88.850 (3.4969-3.4980) | See piston to cylinder clearance |
| Piston Pin Bore | 32.003-32.009 (1.2599-1.2601) | See piston pin clearance in piston |
| Ring Groove Width | | |
| Top 1 Compression Ring | 2.04-2.10 (0.0803-0.0827) | 2.15 |
| No. 2 Compression Ring | 2.54-2.56 (0.1000-0.1007) | 2.61 |
| No. 3 Oil Control Ring | 4.04-4.06 (0.1590-0.1598) | 4.11 |
| *Top 1 Compression Ring Groove Dimension over 2.60 mm diameter gauge wire | 88.13-88.33 (3.4697-3.4776) | 87.93 |
| *No. 2 Compression Ring | 2.59-2.61 (0.1019- 0.1028) | 2.66 |
| **PISTON PIN** | | |
| Clearance in Piston | 0.003-0.014 (0.0001-0.0005) | 0.03 |
| Clearance, Connecting Rod Bushing | 0.010-0.025 (0.0004-0.0010) | 0.05 |
| Diameter | 31.995-32.00 (1.2596-1.2598) | See clearance, connecting bushing |
| **PISTON RINGS** | | |
| Clearance | | |
| Top Groove | 0.05-0.13 (0.0019-0.0051) | 0.25 |
| *Top Groove Ring Drop | 0.027-0.52 (0.0011-0.0205) | See piston top groove dimension |
| 2nd Groove | 0.05-0.09 (0.0019-0.0035) | 0.25 |
| *2nd Groove | 0.10-0.14 (0.0039-0.0055) | 0.30 |
| Oil Groove | 0.050-0.095 (0.0019-0.0037) | 0.15 |
| End Gap | | |
| Top 1 Compression | 0.31-0.57 (0.0122-0.0224) | 1.50 |
| No. 2 Compression | 0.31-0.57 (0.0122-0.0224) | 1.50 |
| No. 3 Oil | 0.22-0.58 (0.0087-0.0228) | 1.50 |
| Oversize Pistons and Rings Available for Service | 0.25mm, 0.50mm, 0.75mm, and 1.0mm | |

* Turbocharged engine.

| DESCRIPTION | DIMENSION OF NEW PARTS millimetre (inch) | MAXIMUM ALLOWABLE WEAR LIMIT millimetre |
|---|---|---|
| **INTAKE VALVE** | | |
| Stem Diameter | 7.93-7.95 (0.3122-0.3130) | See stem to guide clearance |
| *Stem Diameter | 7.95-7.97 (0.3130-0.3138) | See stem to guide clearance |
| Clearance (Stem to Guide) | 0.04-0.08 (0.0016-0.0031) | 0.16 |
| *Clearance (Stem to Guide) | 0.02-0.06 (0.0008-0.0024) | 0.14 |
| Clearance (Lash) (Spec A to C) | 0.20 (0.0078) | Adjustable |
| *Clearance (Lash) (Spec A to C) | 0.30 (0.0118) | Adjustable |
| Top of Valve Recessed Below Cylinder Head Deck | 0.48-1.13 (0.0189-0.0445) | 2.13 |
| Valve Face Angle | 29° | — |
| **INTAKE VALVE SEAT INSERT** | | |
| Seat Insert Cylinder Head Bore Diameter | 40.30-40.32 (1.5866-1.5874) | — |
| Seat Insert Cylinder Head Bore Depth | 8.40-8.50 (0.3307-0.3346) | — |
| Seat Insert Outside Diameter | 40.37-40.40 (1.5894-1.5906) | — |
| Valve Seat Width | 0.88-2.30 (0.0346-0.0906) | — |
| Valve Seat Angle | 30° | — |
| Valve Seat Runout | 0.05 (0.0019) | — |
| Available Insert Sizes | Std., 0.25mm, and 0.50 oversize | — |
| Naturally aspirated engines do not have intake valve seat inserts. | | — |
| **EXHAUST VALVE** | | |
| Stem Diameter | 7.93-7.95 (0.3122-0.3130) | See stem to guide clearance |
| Clearance (Stem to Guide) | 0.04-0.08 (0.0016-0.0031) | 0.16 |
| Clearance (Lash) (Spec A to C) | 0.30 (0.0118) | Adjustable |
| Top of Valve Recessed below Cylinder Head Deck | 0.67-1.33 (0.0264-0.0524) | 2.33 |
| Valve Face Angle | 44° | — |
| **EXHAUST VALVE SEAT INSERT** | | |
| Seat Insert Cylinder Head Bore Diameter | 36.93-36.95 (1.4539-1.4547) | — |
| Seat Insert Cylinder Head Bore Depth | 8.49-8.59 (0.3342-0.3381) | — |
| Seat Insert Outside Diameter | 37.00-37.03 (1.4567-1.4579) | — |
| Valve Seat Width | 0.88-2.30 (0.0346-0.0906) | — |
| Valve Seat Angle | 45° | — |
| Valve Seat Runout | 0.05 (0.0019) | — |
| Available Insert Oversize | 0.25 and 0.50mm | — |
| **VALVE GUIDE** | | |
| Length | | |
| Intake | 56.5-57.3 (2.2244-2.2560) | — |
| Exhaust | 62.5—63.3 (2.4606-2.4921) | — |
| Inside Diameter (after reaming) | | |
| Intake | 7.99-8.01 (0.3146-0.3154) | 8.08 |
| Exhaust | 7.99-8.01 (0.3146-0.3154) | 8.08 |
| Height Above Counterbore | | |
| Without Valve Rotators (Spec A & B) | 15.6-16.4 (0.6142-0.6457) | — |
| Without Valve Rotators (Begin Spec C) | 14.8-15.6 (0.5827-0.6142) | — |
| With Valve Rotators or Spacer (Begin Spec C) | 22.3-23.1 (0.8779-0.9094) | — |
| Valve guides in new and factory service heads do not require reaming. | | |

* Turbocharged engine.

| DESCRIPTION | DIMENSION OF NEW PARTS millimetre (inch) | MAXIMUM ALLOWABLE WEAR LIMIT millimetre |
|---|---|---|
| **TAPPET** | | |
| Body Diameter (Spec A to C) | 26.000-26.015 (1.0236-1.0242) | See tappet clearance in bore |
| Body Diameter (Begin Spec D) | 26.027-26.043 (1.0247-1.0253) | See tappet clearance in bore |
| Overall Length (Spec A to C) | 50.00-50.50 (1.9685-1.9882) | — |
| Clearance in Bore (Spec A to C) | 0.055-0.100 (0.0022-0.0039) | 0.150 |
| Clearance in Bore (Begin Spec D) | 0.043-0.057 (0.0016-0.002) | 0.125 |
| **VALVE SPRINGS INTAKE AND EXHAUST** | | |
| Valve Spring Free Length (Approx.) | 51.0 (2.0) | — |
| Valve Spring Length | | |
| Valve Open | 32.8 (1.29) | — |
| Valve Closed | 42.5 (1.67) | — |
| Spring Load @ 42.5 mm (Valve Closed) | 29.2-31.2 kg (64-69 lb) | 26.3 kg |
| Spring Load @ 32.8 mm (Valve Open) | 62.7-66.7 kg (138-147 lb) | 56.4 kg |
| **GEAR BACKLASH** | | |
| Crankshaft to Idler | 0.050-0.223 (0.0019-0.0087) | 0.30 |
| Idler to Camshaft | 0.045-0.264 (0.0017-0.0104) | 0.30 |
| Idler to Injection Pump | 0.075-0.326 (0.0030-0.0128) | 0.35 |
| Oil Pump Idler to Crankshaft | 0.041-0.256 (0.0016-0.0101) | 0.30 |
| Oil Pump Idler to Oil Pump Drive | 0.044-0.262 (0.0017-0.0103) | 0.30 |
| Oil Pump Element Gears | 0.076-0.430 (0.0029-0.0169) | 0.45 |
| **CYLINDER HEAD** | | |
| Flatness (In 150.0 mm [5.91] of length) | 0.03 (0.0012) | 0.04 |
| **IDLER GEAR ASSEMBLY - OIL PUMP** | | |
| Bearing Bore | 25.030-25.054 (0.9854-0.9863) | See bore to shaft clearance |
| Idler Gear Shaft Diameter | 24.986-25.000 (0.9837-0.9842) | See bore to shaft clearance |
| Bore to Shaft Clearance | 0.030-0.068 (0.0012-0.0027) | 0.100 |
| End Play | 0.05-0.25 (0.002-0.010) | 0.30 |
| **IDLER GEAR ASSEMBLY - CAM AND INJECTION PUMP** | | |
| Bearing Bore | 40.030-40.054 (1.5760-1.5770) | See bore to shaft clearance |
| Idler Gear Shaft Diameter | 39.986-40.000 (1.5742-1.5748) | See bore to shaft clearance |
| Bore to Shaft Clearance | 0.030-0.068 (0.0012-0.0027) | 0.100 |
| End Play | 0.15-0.35 (0.0059-0.0138) | 0.40 |
| **INJECTION NOZZLE** | | |
| Opening Pressure | | |
| New Nozzle Tip and Spring | 13,000-13,800 kPa (1890-2000 psi) | ‡11,000 kPa |
| *Opening Pressure | | |
| New Nozzle Tip and Spring | 17,000-17,800 kPa (2470-2580 psi) | ‡13,800 kPa |

‡ Nozzle opening pressure between cylinders must not vary more than ±600 kPa (87 psi).
* Turbocharged engine

| DESCRIPTION | DIMENSION OF NEW PARTS millimetre (inch) | MAXIMUM ALLOWABLE WEAR LIMIT millimetre |
|---|---|---|
| **OIL PUMP BODY** | | |
| Shaft Bore Diameter | | |
| Idler | 11.918-11.942 (0.4692-0.4702) | — |
| Drive | 11.918-11.942 (0.4692-0.4702) | 11.97 |
| Pump Gear Bore Diameter | 35.69-35.74 (1.4051-1.4071) | See oil pump gear radial clearance in body bore |
| Pump Gear Bore Depth | | |
| L317, L423 | 15.07-15.12 (0.5933-0.5953) | See oil pump gear end clearance to body |
| L634 | 24.07-24.12 (0.9476-0.9496) | |
| L634T | 32.07-32.12 (1.2626-1.2646) | |
| **OIL PUMP SHAFTS** | | |
| Diameter | | |
| Drive-in Body | 11.888-11.902 (0.4680-0.4686) | See drive shaft clearance in body |
| Drive-in Bushing | 15.986-16.000 (0.6294-0.6299) | See drive shaft clearance in bushing |
| Idler | 11.955-11.970 (0.4707-0.4713) | See idler shaft clearance in gear |
| Drive Shaft Clearance in Body | 0.016-0.054 (0.0006-0.0021) | 0.07 |
| Drive Shaft Clearance in Bushing | 0.017-0.103 (0.0007-0.0041) | 0.15 |
| Idler Shaft Clearance in Gear | 0.016-0.045 (0.0006-0.0018) | 0.060 |
| **OIL PUMP GEARS** | | |
| Inside Diameter (Both) | 11.986-12.000 (0.4719-0.4724) | See Idler shaft clearance in gear |
| Outside Diameter (Both) | 35.474-35.500 (1.3966-1.3976) | See clearance in body bore |
| Radial Clearance in Body Bore | 0.095-0.133 (0.0037-0.0052) | 0.175 |
| End Clearance to Body | 0.056-0.134 (0.0022-0.0053) | 0.150 |
| Gear Length (Both) | | |
| 3 and 4 Cylinder N.A. | 14.986-15.014 (0.59-0.5911) | See end clearance to body |
| 6 Cylinder N.A. | 23.986-24.014 (0.9443-0.9454) | |
| 6 Cylinder Turbocharged | 31.986-32.014 (1.2592-1.2604) | |
| **TURBOCHARGER** | | |
| Holset | | |
| End Play | 0.10-0.16 (0.004-0.006) | 0.18 |
| Radial Play | 0.30-0.46 (0.012-0.018) | 0.60 |
| Airesearch | | |
| End Play | 0.03-0.08 (0.001-0.003) | — |
| Radial Play | 0.08-0.15 (0.003-0.006) | — |

# 3. Torques

# ENGINE ASSEMBLY TORQUES

The torque values given in Table 1 have been determined for the specific applications. Standard torque values must not be used where those listed in Table 1 and Figure 1 apply. The engine assembly torques given here will assure proper tightness without danger of stripping threads. All threads must be clean and lubricated with new engine oil before torquing. Proper Joint Design Practices were utilized that do not require lockwashers or gaskets. Do not attempt to use lockwashers with these bolts, it will defeat their purpose. Check all studs, nuts, and capscrews, and tighten as required to keep them from working loose. Refer to the *PARTS MANUAL* for the location of washers and capscrews.

## TABLE 1.

**All torques are in Newton-Metre, Nm (approximate foot-pound torques, Ft.-Lb., in parentheses) unless otherwise specified.**

| DESCRIPTION | SIZE | CLASS | TORQUE SPECIFICATION | |
|---|---|---|---|---|
| | | | Nm | Ft.-Lb. |
| Main Bearing Cap | 12 | 10.9 | 123 | (90) |
| Connecting Rod | 10 | 12.9 | 85 | (63) |
| Rear Seal Plate | 8 | 8.8 | 23 | (17) |
| Backplate (Gearcase) | 8 | 8.8 | 23 | (17) |
| Camshaft Retainer | 8 | 8.8 | 23 | (17) |
| Oil Pump | 8 | 8.8 | 23 | (17) |
| Idler Gear | 10 | 8.8 | 52 | (39) |
| Pump Idler | 8 | 8.8 | 23 | (17) |
| Pump Drive | 8 | 8.8 | 23 | (17) |
| Gearcase | 8 | 8.8 | 23 | (17) |
| Gearcase | 12 | 8.8 | 84 | (62) |
| Front Pulley | 16 | 8.8 | 133 | (98) |
| Flywheel Housing | 12 | 8.8 | 84 | (62) |
| Flywheel | 10 | 10.9 | 68 | (50) |
| Oil Pickup Brace | 8 | 8.8 | 23 | (17) |
| Turbocharger | 10 | — | 52 | (39) |
| Oil Pan | 8 | 8.8 | 11 | (8.3) |
| Cylinder Head | 12 | 10.9 | 129 | (95) |
| Rocker Studs | 10 | 8.8 | 52 | (39) |
| Water Pump Cover | 6 | 8.8 | 11 | (8) |
| Water Pump | 8 | 8.8 | 23 | (17) |
| Water Pump Plugs | — | — | 17 | (12) |
| Thermostat Cover | 8 | 8.8 | 23 | (17) |
| Injection Pump | 8 | 8.8 | 23 | (17) |

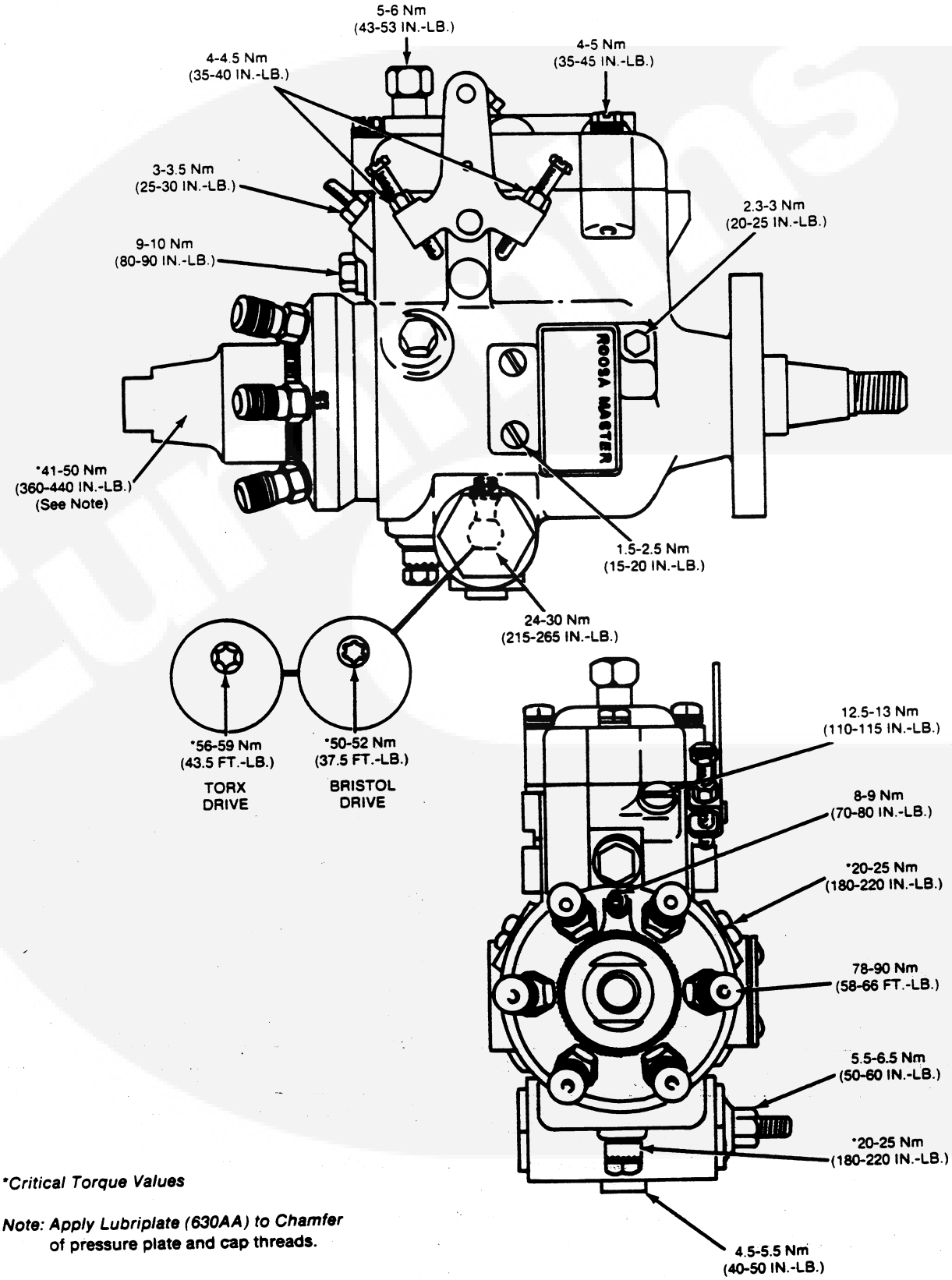
| DESCRIPTION | SIZE | CLASS | TORQUE SPECIFICATION | |
|---|---|---|---|---|
| | | | Nm | Ft.-Lb. |
| Injection Pump Gear | | | | |
| Stanadyne Pump | 14 | — | 52 | (38) |
| Bosch Pump | 14 | — | 80 | (58) |
| Gear Cover | 8 | 8.8 | 23 | (17) |
| Injection Nozzle | | | | |
| Assembly | 22 | — | 69 | (51) |
| Installation | 24 | — | 69 | (51) |
| Intake Manifold | 8 | 8.8 | 23 | (17) |
| Exhaust Manifold* | | | | |
| Capscrew and Flatwasher | 8 | 8.8 | 28 | (21) |
| Flangehead Capscrew | 8 | — | 35 | (26) |
| Exhaust Stack | 10 | 8.8 | 52 | (39) |
| Water Pump Pulley | 8 | 8.8 | 23 | (17) |
| Alternator Bracket | 8 | 8.8 | 23 | (17) |
| Alternator Pivot | 10 | 8.8 | 52 | (39) |
| Alternator Adj. | 8 | 8.8 | 23 | (17) |
| Starter | 12 | 8.8 | 84 | (62) |
| Oil Filter Adapter | 8 | 8.8 | 23 | (17) |
| Fuel Filter Mounting | 10 | 8.8 | 30 | (22) |
| Transfer Pump | 6 | 8.8 | 11 | (8) |
| Glow Plugs | 12 | — | 19 | (14) |
| Injection Line Nuts | 12 | — | 24 | (18) |
| Oil Cooler | 8 | 12.9 | 23 | (17) |
| Rocker Nut Locknut** | 15 | 10.9 | 3.4 | (2.5) |
| Rocker Cover Cap Nut | 10 | — | 18 | (13) |

*Exhaust capscrews must be torqued in the proper sequence to prevent warping of exhaust manifold and possible leakage of exhaust gases.

**This torque is due to friction between the threads only and locks the nut in place. Use the rocker arm, nut to adjust valve lash.

# STANADYNE
# INJECTION PUMP TORQUES

**All torques in Newton-Metre (inch-pound in parentheses) unless otherwise specified.**




**Critical Torque Values*

*Note: Apply Lubriplate (630AA) to Chamfer*
of pressure plate and cap threads.

**FIGURE 1. FUEL INJECTION PUMP TORQUES**

# 4. Special Tools

# SPECIAL TOOLS

The following special tool listing was prepared to aid service and maintenance personnel in obtaining the proper tools to accomplish the various service and maintenance operations described and illustrated in this manual.

The special tools listed below are available from Onan to aid service and repair work.

| | |
|---|---|
| Diesel Nozzle Tester | 420-0184 |
| Diesel Pintle Nozzle Cleaning Tool Set | 420-0208 |
| Deep Socket 27mm 1/2" Drive (Injection Nozzle) | 420-0425 |
| Crowfoot Wrench 17mm 3/8" Drive (High Pressure Line Nuts) | 420-0426 |
| Gear Puller Kit Injection Pump and Front Crankshaft Pulley | 420-0427 |
| Socket, Transfer Pump Removal | 420-0429 |
| Injection Pump Tools, Stanadyne | |
| Shutoff Cam Removal Tool | 420-0430 |
| Throttle Shaft Seal Spreader | 420-0431 |
| Advance Plug Wrench | 420-0432 |
| Socket Driver (End Cap Locking Screw) | 420-0433 |
| Intake Valve Seat Driver | 420-0421 |
| Exhaust Valve Seat Driver | 420-0420 |
| Valve Spring Compressor | 420-0119 |
| Valve Seat Remover | 420-0436 |
| Valve Guide Removal Tool | 420-0443 |
| Valve Guide Installation Tool | 420-0444 |
| Valve Guide Reamer | 420-0439 |
| Valve Seat Concentricity Indicator | 420-0437 |
| Rear Oil Seal Driver-Wear Sleeve Installing Tool | 420-0417 |
| Engine Application Test Kit | 420-0434 |
| Engine Stand Mounting Plate (4-cylinder) | 420-0424 |
| Engine Stand | 420-0441 |
| Front Wear Sleeve - Oil Seal Installing Tool | 420-0418 |
| Cam Bearing Puller | 420-0428 |
| Cam Bearing Puller (Head only) | 420-0422 |
| Cylinder Leakage Tester | 420-0343 |
| Oil Cooler Test Fixture | 420-0435 |
| Fan Belt Tension Tool | 420-0438 |
| Valve Rocker Stud Socket | 420-0423 |
| Onan Tool Catalog | 900-0019 |

# 5. Troubleshooting

Most of the troubles that occur in engine operation can be avoided when those responsible for engine maintenance adhere to an adequate program of lubrication, inspection and maintenance. The time and expense involved in a good maintenance and inspection program is only a small portion of that incurred when poor maintenance practice results in a major malfunction or breakdown.

In most instances, when a problem is detected and fixed immediately, a more expensive, time consuming repair will be avoided. The following list of troubles, causes and remedies is supplied to aid the operator/service person in locating and correcting mechanical and electrical troubles as soon as possible. For specific inspection and service procedures for any given component, refer to that section or subject in this manual pertaining to the part, assembly or system.

## ENGINE

| TROUBLE | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| Engine will not turn or crank | 1. Batteries weak. | 1. Recharge or replace. |
| | 2. Starter or starter switch inoperative. | 2. Repair or replace defective parts. |
| | 3. Engine locked or seized. | 3. This can be due to extended idle or storage periods, or to improper preparation of the engine for storage, in which case the parts may be rusted, corroded or seized. Broken piston rings, gears, etc., may also cause seizing. Repair or replace defective parts. |
| | 4. Hydro-static lock. | 4. This can be due to rain water entering uncovered exhaust pipe, leaking cylinder head gasket, cracked block or cylinder head. Repair or replace defective parts. |
| Engine will not start | 1. Slow cranking speed. | 1. Specific gravity of batteries too low. Charge batteries. Starter not delivering maximum torque. Repair or replace defective parts. Poor connection and/or high cable resistance. |
| | 2. Glow plugs. | 2. Check fuse, glow plugs, and wiring. |
| | 3. Engine controls out of adjustment. | 3. Check all engine controls for proper adjustment and operation. |
| | 4. Insufficient supply of fuel to injection nozzles. | 4. Check fuel system, drain water separator, and replace fuel filter. |
| | 5. Injection nozzles not operating properly. | 5. Test and repair or replace nozzles. |
| | 6. Incorrect valve lash. | 6. Adjust valve clearance. |

| TROUBLE | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| Engine hard to start | 1. Batteries weak. | 1. Recharge or replace batteries. |
| | 2. Insufficient fuel in fuel tank. | 2. Check fuel level in tank. Fill with specified fuel if necessary. |
| | 3. Incorrect grade of fuel. | 3. Drain fuel system. Fill the tank with the specified fuel. |
| | 4. Clogged filter/sediment bowl. | 4. Replace filter, clean sediment bowl, when used. |
| | 5. Injection nozzles not operating properly. | 5. Test and repair or replace nozzles. |
| | 6. Fuel transfer pump not operating properly. | 6. Repair or replace fuel transfer pump. Clean transfer pump filter. |
| | 7. Air in fuel system. | 7. Correct air leaks in low pressure side of fuel system. Prime fuel system. |
| | 8. Insufficient air supply to cylinders. | 8. Clean air cleaner and intake manifold. |
| | 9. Fuel injection pump improperly timed. | 9. Time fuel injection pump. |
| | 10. Valve lash incorrect. | 10. Adjust valve lash clearance. |
| | 11. Piston rings or cylinders worn. | 11. Replace affected parts. Perform cylinder leak down test. |
| | 12. Valves warped or pitted. | 12. Recondition or replace valves and/or guides. |
| Engine stops frequently | 1. Idling speed too low. | 1. Adjust low idle speed. |
| | 2. Restricted fuel supply. | 2. Check fuel system for blockage. |
| | 3. Fuel shut-off solenoid. | 3. Check fuel solenoid. |
| Engine stops suddenly | 1. Out of fuel. | 1. Fill fuel tank with specified fuel and prime fuel system. |
| | 2. Restricted fuel supply or fuel return line. | 2. Check fuel system for blocked lines and clogged filter. |
| | 3. Radiator air passages clogged. | 3. Remove debris from radiator core. |
| | 4. Fan belts loose. | 4. Adjust fan belts to proper tension. |
| | 5. Thermostat inoperative. | 5. Test the thermostat for proper operation. |
| | 6. Malfunctioning fuel solenoid, or safety switch. | 6. Check fuel solenoid, and other safety shutdown switches. |
| | 7. Poor engine lubrication. | 7. Check for proper operation of engine oil pump. |
| | 8. Water pump malfunctioning. | 8. Repair or replace the water pump. |
| | 9. Major engine failure. | 9. Perform cylinder leak down test. |

| TROUBLE | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| Engine shows loss of power | 1. Insufficient supply of air to cylinders. Restricted exhaust system. | 1. Clean air intake system. Clean exhaust system. |
| | 2. Insufficient supply of fuel to injection nozzles. Water in fuel system. | 2. Check fuel system. Drain water separator. |
| | 3. Governor not operating properly. | 3. Check engine operating speed. |
| | 4. Air in fuel system. | 4. Prime fuel system. Check for air leaks on suction side of fuel transfer pump. Check for air in return fuel. |
| | 5. Clogged fuel filter. | 5. Change filter. |
| | 6. Improper valve lash. | 6. Adjust valve lash clearance. |
| | 7. Fuel injection pump improperly timed. | 7. Time fuel injection pump. |
| | 8. Inoperative fuel injection pump or injection nozzles. | 8. Repair or replace affected parts. |
| | 9. Cylinder cutting out. | 9. Locate "missing" cylinder as follows: Run engine at low idle speed and cut out each fuel injection nozzle in turn by loosening the fuel injection line nut attaching line to fuel injection pump. **⚠WARNING** ***Cover fittings before loosening. Fuel under pressure can penetrate the skin and can cause blood poisoning or a serious skin infection.*** A decrease in engine speed with line nut loosened indicates nozzle for that cylinder is functioning properly. If engine speed does not decrease, nozzle is malfunctioning and must be serviced. |
| | 10. Loss of compression. | 10. This may be due to leaking valves or to worn piston rings or cylinder bores. Use a suitable leak down tester and check each cylinder as detailed later in this section. |

| TROUBLE | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| Engine runs unevenly and vibrates excessively | 1. Idle speed. | 1. Adjust idle speed. |
| | 2. Fuel supply erratic or insufficient air intake. | 2. Check fuel system and air intake. |
| | 3. Fuel injection pump malfunctions. | 3. Check fuel injection pump. |
| | 4. Valves in bad condition. | 4. Recondition valves and seats. |
| | 5. Plugged fuel filter. | 5. Replace filter. |
| | 6. Fuel injection nozzle malfunctions. | 6. Repair nozzle. |
| Engine emits black smoke from exhaust | 1. Air system clogged. | 1. Check engine air intake system. |
| | 2. Incorrect injection pump timing. | 2. Check fuel injection pump timing. |
| | 3. Improper fuel. | 3. Drain fuel system and refill with specified fuel. |
| | 4. Lack of good injection nozzle spray pattern. | 4. Clean and adjust nozzles. |
| Engine emits bluish-white smoke from exhaust | 1. Engine operating temperature too low. | 1. Check thermostat operation. |
| | 2. Failed glow plugs(s). | 2. Check continuity. |
| | 3. Clogged injection nozzles. | 3. Clean and adjust nozzles. |
| | 4. Low compression. | 4. Make cylinder leakdown test and necessary repairs. |
| | 5. Early fuel injection pump timing. | 5. Check and adjust timing. |
| Engine detonates or knocks | 1. Fuel pump improperly timed. | 1. Check and adjust. |
| | 2. Loose bearings. | 2. Replace bearings. |
| | 3. Loose piston. | 3. Inspect piston assembly. Replace parts required. |
| | 4. Loose flywheel. | 4. Check tightness of flywheel bolts. Tighten or replace parts required. |
| | 5. Improperly adjusted valve(s). | 5. Check and adjust valve lash clearance. |
| | 6. Foreign material in cylinder(s). | 6. Make necessary repairs. |

## CYLINDER LEAK DOWN TEST PROCEDURE (Using Onan Cylinder Leakage Tester No. 420-0343)

The Cylinder Leakage Tester is used to determine the location and relative amounts of compression losses in an engine. This test can locate leaks at the intake and exhaust valves, head gaskets, and excessive leakage past the rings.

In order to obtain an accurate test, make certain the cylinder leakdown tester has been properly tested and calibrated. Do not rebuild an engine because of high cylinder leakage readings obtained with a leakdown tester unless the unit is known to be accurate.

### Regulator Calibration

The Cylinder Leakage Tester (CLT) requires an outside source of air pressure [483 to 1380 kPa (70 to 200 psi)] to be connected to the air inlet fitting.

1. Before connecting air to the inlet fitting, turn the CLT regulator to the left a couple of turns.
2. Connect air to inlet fitting and turn CLT regulator to the right in small steps until the gauge reads zero.
3. Momentarily depress the valve in the connection end of the outlet to engine hose. The needle should rise, then return to zero.
4. If needle does not return to zero repeat Steps 1,2, and 3. When the Cylinder Leakage Tester reads zero it is properly calibrated and ready to use.

### Cylinder Leakage Test

With engine at normal operating temperature air pressure is applied when the piston is at TDC of the compression stroke. At this time both valves are closed and except for a small amount of air leaking past the piston ring end gap no air should escape from a good cylinder. Check each cylinder for leakage as follows:

1. Set-up Cylinder Leakage Tester and calibrate.
2. Connect the remote start switch to the start solenoid.
3. Clean area around injection nozzles and remove all nozzles.
4. Remove air cleaner, oil fill cap, and radiator cap.
5. Install Tester in same manner the fuel injection nozzle was installed. Make certain the cylinder being tested is at TDC of the compression stroke.
6. Connect test to adapter. Watch the engine crankshaft. If it turns stop the test. Remove the tester and reposition piston at TDC.
7. Listen for air leakage at exhaust pipe, intake manifold, and from crankcase.
8. Check gauge and record reading. A leakage reading of less than 20% and no "air leaking" heard in exhaust pipe, air intake, or crankcase indicates a good cylinder.

   A leakage reading greater than 20% on a properly broken-in engine or "air leaking" heard at exhaust pipe, air intake, or crankcase indicates a need for service.

   A. Air escaping at air intake indicates a leak at the intake valve.
   B. Air escaping at exhaust pipe indicates a leak at the exhaust valve.
   C. Air escaping at radiator filler cap indicates a blown head gasket or a crack in the water jacket.
   D. Air leaking into crankcase indicates worn or broken rings or scored cylinder walls.

## ELECTRICAL SYSTEM

| TROUBLE | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| Alternator not charging | 1. Alternator drive belt loose or broken. | 1. Adjust or replace drive belt. |
| | 2. Alternator regulator inoperative. | 2. Remove regulator and replace. |
| | 3. Alternator inoperative. | 3. Remove alternator for repairs or replacement. |
| Alternator output low and/or unsteady | 1. Alternator drive belt improperly adjusted. | 1. Adjust drive belt. |
| | 2. Brushes sticking in brush holders. | 2. Free brushes in holders. |
| | 3. Brush spring tension too low. | 3. Replace brush springs. |
| | 4. Slip ring dirty or worn. | 4. Clean slip ring or remove alternator for repair or replacement. |
| | 5. Voltage regulator operating improperly. | 5. Remove regulator and replace. |
| Batteries will not hold charge | 1. Loose terminals or connections. | 1. Tighten affected parts. |
| | 2. Short in electrical system. | 2. Correct short. |
| | 3. Short circuit or bad cell in battery. | 3. Remove and replace battery. |
| | 4. Electrolyte level low (alternator output excessive or cracked battery case.) | 4. Reduce charging rate. Remove and replace battery or add water. |
| | 5. Voltage regulator inoperative. | 5. Remove regulator and replace. |
| Starter will not crank engine. | 1. Batteries weak. | 1. Check batteries. |
| | 2. Cables and/or connections loose or corroded. | 2. Tighten all loose connections and clean corrosion from all terminals. |
| | 3. Starter switch inoperative. | 3. Replace switch. |
| | 4. Starter brushes worn or not contacting properly. | 4. Install new brushes. |
| | 5. Starter brush springs weak. | 5. Check brush spring tension, replace springs if necessary. |
| | 6. Starter commutator dirty or worn. | 6. Clean commutator, machine commutator and under-cut mica if necessary. |
| | 7. Starter armature shaft bearings worn (armature drags on fields). | 7. Replace worn bearings and related items. |
| | 8. Starter armature burned out. | 8. Replace armature. |
| Starter pinion will not engage with flywheel ring gear | 1. Broken or excessively worn parts. | 1. Replace broken or worn parts. |
| | 2. Defective solenoid. | 2. Replace solenoid. |
| | 3. Worn overrunning clutch. | 3. Replace clutch. |

# FUEL SYSTEM

| TROUBLE | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| Insufficient fuel supply to injection nozzles | 1. No fuel in fuel tank. | 1. Fill fuel tank with specified fuel. Prime fuel system. |
| | 2. Inoperative or plugged fuel transfer pump. | 2. Repair or replace transfer pump. Clean inlet filter. |
| | 3. Injection nozzle valve sticking in valve body. | 3. Replace seal and valve assembly in nozzle holder body. |
| | 4. Fuel lines/fuel filter/clogged. | 4. Clean fuel system components, replace fuel filter. |
| | 5. Fuel injection pump malfunctioning. | 5. Remove fuel injection pump for service. |
| | 6. Injection nozzles improperly adjusted. | 6. Adjust injection nozzles. |
| Air in fuel system | 1. Loose fuel line fitting or leak in fuel line on suction side of fuel transfer pump. | 1. Tighten loose fitting or replace damaged line. |
| | 2. Damaged fuel filter. | 2. Replace fuel filter. |
| Insufficient air supply to cylinders | 1. Air cleaner clogged. | 1. Replace air filter element. |
| | 2. Excessive dirt buildup in turbocharger. | 2. Thoroughly clean turbocharger. |
| | 3. Leaks in engine intake and/or exhaust manifolds reducing turbocharger efficiency. | 3. Tighten loose manifold retaining nuts or capscrews. Replace manifold gaskets. |
| | 4. Turbocharger rotating assembly bearing seized. | 4. Overhaul turbocharger. |
| Rapid wear on engine parts | 1. Dirt admitted with intake air. | 1. Inspect air cleaner body, pipe, connecting hoses, gaskets, etc., thoroughly for cracks or openings which would allow air to enter engine without passing through air cleaner. Make necessary repairs. |
| | 2. Dirty crankcase oil. | 2. Change engine oil and the oil filter element at the intervals recommended. Keep oil clean when filling engine. |
| | 3. Improper fuel. | 3. Use the proper fuel. It is important that the fuel be within the specified limits for ash, carbon, sulphur, etc., to prevent excessive wear on engine parts. |
| | 4. Valves hitting pistons. | 4. Check valve recession in head. |

| TROUBLE | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| Engine operating temperature too high with ample coolant in system | 1. Temperature gauge inoperative. | 1. Check gauge. Replace if necessary. |
| | 2. Radiator air passages restricted. | 2. Clean exterior of radiator. |
| | 3. Thermostat inoperative. | 3. Replace thermostat. |
| | 4. Loose or broken fan belts. | 4. Adjust or replace fan belts. |
| | 5. Lime deposits in water passages of radiator, cylinder head and/or cylinder block. | 5. Thoroughly clean affected areas. |
| | 6. Water pump inoperative. | 6. Replace water pump. |
| | 7. Engine pulling excessive load. | 7. Reduce load. |
| | 8. Engine speed set too high. | 8. Adjust speed to within specified rpm limits. |
| Engine operating temperature too high due to loss of coolant | 1. External leaks. | 1. Repair affected parts. |
| | 2. Ruptured oil cooler core (oil in coolant). | 2. Replace oil cooler core. |
| | 3. Engine cylinder head gasket leaking. | 3. Replace gasket and torque cylinder head bolts as specified. |
| | 4. Engine cylinder head cracked. | 4. Replace cylinder head. |
| | 5. Engine cylinder block cracked. | 5. Replace cylinder block. |
| Engine operating temperature too low | 1. Thermostat stuck in open position. | 1. Replace thermostat. |
| | 2. Operating in extremely cold weather. | 2. Provide covers for radiator and engine side openings. |

# OIL SYSTEM

| TROUBLE | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| No oil pressure | 1. Insufficient oil in crankcase. | 1. Fill crankcase to proper level. |
| | 2. Oil pressure gauge inoperative. | 2. Replace gauge. |
| | 3. Oil pickup cracked or clogged. | 3. Remove and clean the screen or replace pickup assembly. |
| | 4. Oil pump inoperative. | 4. Repair or replace oil pump. |
| | 5. Regulating valve stuck open. | 5. Remove and clean. |
| Low oil pressure with proper oil level in crankcase | 1. Oil pressure gauge inaccurate. | 1. Check gauge. Replace if necessary. |
| | 2. Improper crankcase oil or diluted with fuel. | 2. Fill crankcase with specified crankcase oil. |
| | 3. Oil pressure relief valve or regulator valve stuck in open position. | 3. Clean, repair, or replace affected parts. |
| | 4. Main and/or connecting rod bearings worn. | 4. Replace bearings. |
| | 5. Camshaft bearings worn. | 5. Replace bearings. |
| | 6. Oil pump worn. | 6. Repair or replace oil pump. |
| Excessive oil pressure | 1. Oil pressure gauge inaccurate. | 1. Check gauge. Replace if necessary. |
| | 2. Oil pressure regulating valve sticking. | 2. Clean, repair, or replace regulating valve. |
| | 3. Improper crankcase oil. | 3. Fill crankcase with specified oil. |
| Overheating of lubricating oil | 1. Insufficient oil in crankcase. | 1. Fill crankcase to proper level. |
| | 2. Engine oil cooler clogged. | 2. Clean or replace the oil cooler. |
| Excessive oil consumption | 1. External oil leakage (gaskets, etc.). | 1. Correct all external leaks. |
| | 2. Engine oil seals worn or damaged. | 2. Replace oil seals. |
| | 3. Crankcase oil diluted with fuel. | 3. Fill crankcase with specified oil. |
| | 4. Pistons, rings, and/or cylinder bores worn. | 4. Replace or repair affected parts. |
| | 5. Rings stuck in piston ring grooves. | 5. Clean ring grooves and replace rings. |
| | 6. Valve guides and seals worn. | 6. Replace valve guides. Check related parts. |
| | 7. Plugged breather. | 7. Clean breather. |
| Excessive oil consumption during first 250 hours of operation and no indication of improvement | 1. Rings not seated properly. | 1. Allow more time for break-in. Make certain specified crankcase oil is used and engine is at operating temperature. |
| | 2. Pistons or cylinders scored. | 2. Check cylinder leakage. |
| Rapid wear on engine parts | 1. Crankcase oil contaminated. | 1. Fill system with clean engine oil. Replace engine oil filter. |
| | 2. Improper engine lubricating oil being used. | 2. Fill system with crankcase oil of proper specifications. |

## TURBOCHARGER

When operating, each turbocharged engine has its own distinctive sound or noise level. In many instances, malfunctions can be detected when the noise level changes. A change in noise level to a high-pitched screech indicates an air leak between air cleaner and engine or an exhaust gas leak in the exhaust system, between turbocharger and exhaust manifold. Noise level cycling from one level to another is an indication of a plugged air cleaner, a restriction in air intake piping, heavy build up of foreign matter in compressor, or operation at altitudes above 3048 m (10,000 ft). A sudden reduction in noise level and power loss that results in black or blue smoke and excessive oil leakage indicates a turbocharger failure.

A turbocharger cannot correct or overcome engine malfunctions or deficiencies in the fuel and air intake system. If a turbocharged engine has malfunctioned and turbocharger has been inspected and is in good operating condition, proceed with troubleshooting as though engine were not turbocharged.

Simply replacing a good turbocharger with another will not correct engine malfunctions. Too often turbochargers are removed from engines before the cause of a malfunction has been determined. Always inspect and assess turbocharger condition before removal from engine.

Use the troubleshooting list that follows in diagnosing and correcting unsatisfactory turbocharger operation and related engine operation.

## TURBOCHARGER

| TROUBLE | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| Noisy operation | 1. Restricted air intake piping or air cleaner.<br>2. Leak in air intake piping or exhaust system.<br>3. Damaged bearing or other components causing compressor impeller or turbine wheel to rub against housing. | 1. Remove restrictions and clean or replace air cleaner.<br>2. Tighten all connections and replace gaskets as required.<br>3. Remove turbocharger for replacement or repair. |
| Loss of engine power, excess smoke | 1. Leak in air intake piping or exhaust manifold.<br>2. Restricted air intake piping or dirty air cleaner.<br>3. Foreign matter lodged in compressor impeller or turbine wheel. Damaged impeller or turbine wheel.<br>4. Excessive build up of foreign matter in compressor.<br>5. Oil leakage from seals.<br>6. Back pressure on turbo exhaust too high.<br>7. Interference or binding in rotating assembly. Bearing seizure.<br>8. Insufficient fuel supply to engine. | 1. Tighten loose connections or replace exhaust manifold gaskets.<br>2. Remove restrictions and clean or replace air cleaner.<br>3. Clean or replace turbocharger if damaged. Determine source of debris.<br>4. Thoroughly clean compressor assembly. Clean or replace air cleaner and check for leaks.<br>5. Remove turbocharger for replacement or repair.<br>6. Correct restriction in exhaust system.<br>7. Remove turbocharger for replacement or repair.<br>8. Replace fuel filter and inspect fuel system. |
| Oil in intake manifold or exhaust pipe | 1. Seal failure.<br>2. Restriction in air cleaner or air intake creating suction. | 1. Replace or repair turbocharger.<br>2. Remove the restriction. |
| Vibration and noise | 1. Damaged impeller or turbine blades. Worn or damaged bearing.<br>2. Restricted air intake system. | 1. Replace or repair turbocharger.<br>2. Inspect and clean air cleaner and air intake piping. |

# 6. Start-Up

## ENGINE SET-UP

Inspect the engine visually. Check for loose or missing parts and any damage that may have occurred in shipment.

**⚠CAUTION** ***Oil, fuel, and coolant have been drained from the engine prior to shipping from Onan. Severe damage will result if engine is started without oil.***

### Batteries

The batteries and battery cables used for starting the engine should be of sufficient size to provide prompt starting. Undersized batteries will result in poor starter operation and a very short starter service life.

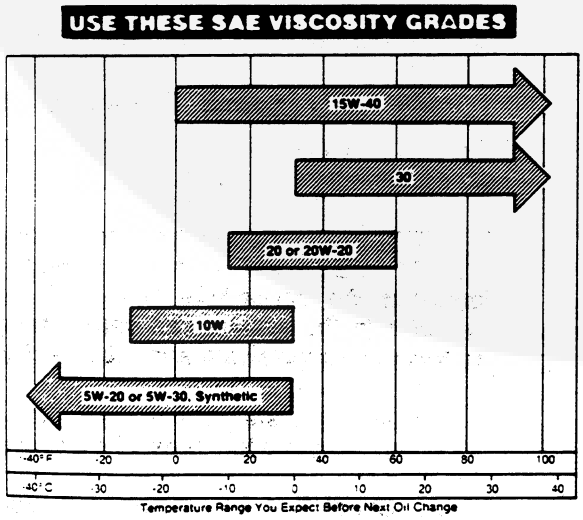
**⚠WARNING** ***Explosive gases are emitted from batteries while charging. Ignition of these gases can result in an explosion and severe personal injury. Do not smoke or allow any spark producing device near batteries while servicing.***

### Crankcase Oil Recommendations

Fill crankcase with correct amount of oil. Refer to *SPECIFICATIONS* section for crankcase capacity. When adding oil between oil changes, it is preferable to use the same brand, as various brands of oil may not be compatible together. Refer to *SECTION 7, MAINTENANCE* for recommended oil change procedures.

**⚠CAUTION** ***Do not overfill crankcase. Excess oil causes foaming and can cause loss of lubrication and higher operating temperatures, resulting in engine damage.***

Recommended L engine oil specifications are 15W-40, 30W, 20W-20, 10W oil meeting the American Petroleum Institute (API) classification CD/SF, CD/SE, or Military Specification MIL-L-2104C. When a 5W-20 or 5W-30 oil is required, it must be a synthetic oil meeting Military Specification MIL-L-46167, MIL-L-2104C, or MIL-L-46152B.




LS-1028

5W-20 and 5W-30 mineral base oils are not recommended for use in the L engine under any condition.

### Fuel Recommendations

Fill the fuel tank with a good quality fuel obtained from a reputable supplier. The quality of fuel used is important in obtaining dependable performance and satisfactory engine life. Fuels must be clean, completely distilled, well refined, and non-corrosive to fuel system parts.

**⚠CAUTION** ***Due to the precise tolerances of diesel injection systems, it is extremely important the fuel be kept clean and free of water. Dirt or water in the system can cause severe damage to both the injection pump and the injection nozzles.***

**⚠WARNING** ***Fuel vapors create fire and explosion hazards which can result in severe personal injury or death. Do not add gasoline, gasohol, or alcohol to diesel fuel. Do not permit any flame, cigarette, or other igniter near the fuel system.***

Use ASTM2-D (No. 2 Diesel), ASTM1-D (No. 1 Diesel) fuel with a minimum Cetane number of 40*. Number 2 diesel fuel gives the best economy and performance under most operating conditons. At temperatures below 0°C (32°F), Number 2-D fuel may pose operating problems. At colder temperatures, use Number 1-D fuel (if available) or use a "winterized" Number 2-D (a blend of Number 1-D and Number 2-D). The blended fuel is normally called Number 2-D also, but can be used in colder temperatures than non "winterized" Number 2-D fuel.

**⚠CAUTION** ***Do not add gasoline, gasohol, or alcohol to diesel fuel. Damage to fuel injection system or engine may result.***

***NOTE: Fuels with Cetane numbers higher than 40 may be needed in higher altitudes or when extremely low ambient temperatures are encountered to prevent misfires and resultant excessive smoke.**

Use low sulfur content fuel having a cloud point of at least 10 degrees below the lowest expected fuel temperature. Cloud point is the temperature at which wax crystals begin to form in diesel fuel.

**⚠WARNING** ***Spilled fuel can ignite and cause serious personal injury or death. Never fill the fuel tank when the engine is running.***

**⚠WARNING** ***Fuel leaks create fire and explosion hazards which can result in severe personal injury or death. Always use a length of flexible tubing between engine and the fuel supply line to avoid line failure and leaks due to vibration. The fuel system must meet applicable codes.***

### Fuel Tank and Lines

When more than one engine share the same fuel tank, do not connect to an existing fuel line at a point above the fuel supply level. Install a fuel shut-off valve in the tank for service convenience.

The engine requires a fuel supply line with a separate return line. Both lines should be connected to standpipes in the tank with the opening for each 2" minimum from the bottom of the tank to allow space for water and sediments to settle and to eliminate siphoning problems.

Install the fuel supply line from tank to the inlet in the fuel pump. Connect fuel return line to tee fitting at injection pump. Use approved flexible fuel lines or connections at the engine to absorb vibration.

**⚠WARNING** ***Do not use dissimilar metal lines, fittings, and fuel tanks in the fuel system. Hazardous fuel leaks may be caused by electrolytic corrosion. An explosion or fire can cause severe personal injury or death.***

### Coolant System

Verify that all drain cocks are closed and all hose clamps secure. **Onan recommends the use of clean ethylene glycol anti-freeze solutions in closed cooling systems during normal operation and storage periods. Be sure anti-freeze solution will protect the cooling system during the coldest winter weather.** Use only a reliable brand of ethylene glycol (permanent type) anti-freeze which contains a rust inhibitor but does not contain a stop-leak additive.

**⚠CAUTION** ***Coolant fill rate must not exceed 11.4 litres (3.0 gallons) per minute. Filling too fast may result in incomplete engine coolant filling and possible engine damage at start-up.***

Use a minimum 50-50 mix of ethylene glycol anti-freeze and soft water to fill the cooling system. Use soft water whenever available. Well water often contains lime and other minerals which eventually may clog the radiator core and reduce the cooling efficiency. Check cooling system for leaks after anti-freeze solution has been added.

Fill cooling system with appropriate mixture of anti-freeze. To assure complete filling of the cooling system the cylinder head and block should be bled to prevent air lock. This can be done by loosening one of the plugs or senders located in the water pump before filling. When coolant appears, retorque plug to 17 Nm (150 in-lb) and finish filling. An additional pocket of air will remain in the cylinder head. Start engine and operate for approximately 10 minutes or until thermostat opens. As coolant circulates, air trapped in the cylinder head will be released.

Fill with additional coolant as required. Coolant level should be maintained at a level midway between top of radiator core and filler neck. If vehicle is equipped with a coolant recovery tank, coolant lever in recovery tank must be between cold and hot marks.

**⚠CAUTION** ***At ambient temperatures below 0° C (32° F), when engine is not in use, sea water side of marine cooling system must be drained. This will prevent cooling system damage caused by freezing.***

### Exhaust System

The exhaust system must efficiently expel all engine combustion products and muffle exhaust noises with minimum back pressure. If back pressure is too high, the volumetric efficiency of the engine is reduced, fuel economy drops, exhaust temperature increases, and valve life is shortened.

Exhaust products of any internal combustion engine are toxic and can cause injury, or death if inhaled. All engine applications, especially those within a confined area, should be equipped with an exhaust system to discharge gases to the outside atmosphere.

**⚠WARNING** ***On service calls, always inspect exhaust systems for possible leaks. Report any exhaust hazards to the owner/operator and warn them of the potential dangers to life if not repaired.***

## PRE-START INSTRUCTIONS

Preparations for the initial start up and each additional start up thereafter should include careful checks of the following:

1. Check all components for mechanical security. If an abnormal condition or defective part is detected, repair or service as required. The engine should be kept free of dust, dirt, and spilled oil or fuel.
2. Check engine crankcase oil level.
3. Check radiator coolant level.
4. Check fuel supply level.
5. Inspect the air cleaner; service if necessary.
6. Inspect exhaust system for possible leakage and cracks.

**Be sure the engine is properly filled with oil, fuel, and coolant.**

## FUEL SYSTEM PRIMING

The fuel system must be primed prior to initial start up or after engine has run out of fuel.

**⚠CAUTION** ***Due to the precise tolerances of diesel injection systems, it is extremely important the fuel be kept clean and free of water. Dirt or water in the system can cause severe damage to both the injection pump and the injection nozzles.***

1. Priming (transfer pump, fuel filter, and injection pump housing) low pressure fuel system.
   A. Check fuel level in fuel tank. Open fuel shut off valve if one is present.
   B. Loosen the fuel filter to injection pump line at the injection pump fitting (Figure 1).

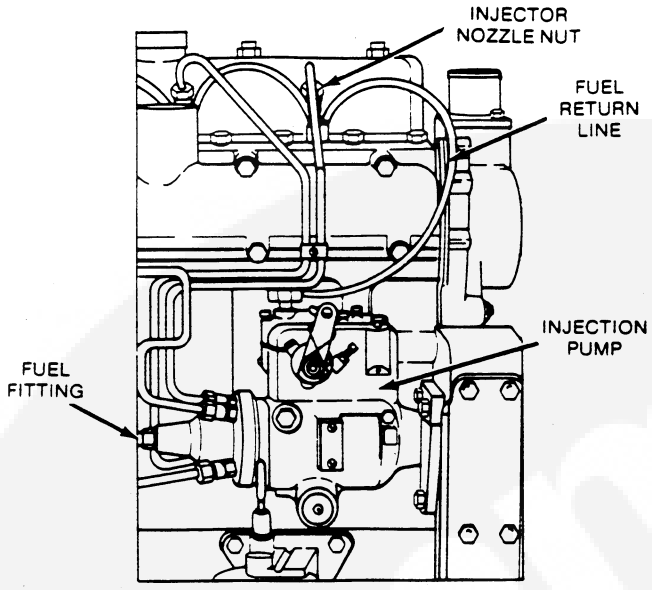



**FIGURE 1. INJECTION PUMP AND NOZZLE**

C. Actuate the priming lever (Figure 2) on the side of the transfer pump until fuel flows from the fitting.

**If resistance is not felt when operating priming lever the camshaft transfer pump lobe is up. Turn engine one revolution to permit hand priming.**

D. Tighten fuel line at the injection pump inlet.

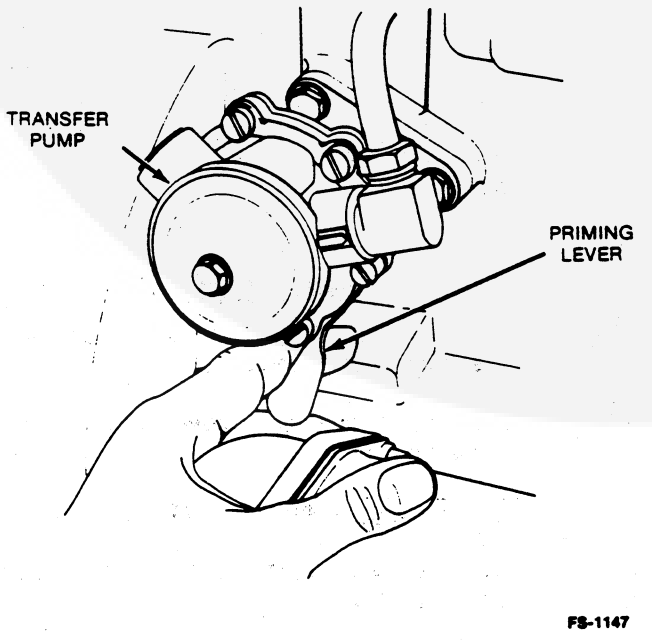



**FIGURE 2. FUEL TRANSFER PUMP**

2. Priming High Pressure Fuel System.

This part of the system is usually self-priming since any trapped air in the injection pump is usually forced out through the injection nozzle. If, however, engine has run out of fuel, been shut down for an extended period, or has had fuel injection lines removed, it may be necessary to prime as follows:

A. Loosen fuel injection line connecting nut (Figure 1) attaching each line to corresponding nozzle holder.

B. Place speed control in high speed position and stop control in RUN position.

C. Energize starting motor. (Do not operate starting motor for more than 30 seconds at a time without pausing two minutes to permit starter to cool.)

**⚠WARNING** ***Fuel penetration of the skin can cause severe personal injury. Do not let the nozzle high-pressure fuel spray against skin surfaces.***

D. When fuel flows from the end of high pressure fuel injection lines, stop starting motor and torque connection nuts.

## PREHEATING AND STARTING

The engine starting procedure depends on the controls and safety shutdown equipment furnished by Onan or the original equipment manufacturer.

When controls are furnished by the original equipment manufacturer (OEM), follow their instructions for stopping, starting, and operating the engine and their equipment.

The following instructions supplement OEM starting instructions and should be followed when controls are furnished by Onan. To aid in starting of all indirect injection L-Series Diesel engines, preheating is required at temperatures below 21°C (70°F).

**⚠CAUTION** ***Do not engage starter for periods longer than 30 seconds without allowing 2 minutes for starter to cool.***

**⚠WARNING** ***Use of ether as a starting aid can cause an explosion resulting in severe personal injury. Heat of compression or hot glow plugs can cause a sudden ignition of the ether vapor. Do not use ether as a starting aid.***

**⚠CAUTION** ***Use of ether as a starting aid can cause an explosion resulting in engine damage. Heat of compression or hot glow plugs can cause ignition of the ether vapor. Do not use ether as a starting aid.***

### Twenty Second Glow Plugs

1. Disconnect load from the engine.
2. Energize fuel solenoid or place all controls in START/RUN position.
3. On engines equipped with a glow plug preheat indicator light, preheat until light goes out indicating engine is ready for starting.
4. On engines equipped with twenty second glow plugs and no preheat lamp energize preheat circuit for specified period of time, determined by ambient temperature.

| Ambient Temperature | Preheat Time |
|---|---|
| Above 21°C (70°F) | 10-20 seconds |
| -18°C to 21°C (0-70°F) | 25-35 seconds |
| Below -18°C (0°F) | 30-45 seconds |

**⚠CAUTION** ***Limit preheating to recommended periods; longer periods can ruin the heater element.***

5. Continue to preheat while energizing the start circuit. De-energize preheat and start circuits when engine will run without the aid of the starter motor.
6. If engine fails to start after 30 seconds, wait two minutes before recranking, and repeat steps 3 and 4 above. Absence of blue/white exhaust smoke during cranking indicates no fuel being delivered. If engine does not start on first attempt, check fuel supply system.
7. Allow engine to warm up before applying load.

### Seven Second Glow Plugs

1. Place transmission in park or neutral position.
2. Turn key switch to engine run position.
3. Wait until glow plug preheat light goes out before cranking engine.
4. Turn key switch to start position to engage starter. On engines equipped with manual cold start advance pull cold start advance knob out at temperatures below 0°C (32°F). Push knob in after engine starts and runs for approximately two minutes.
5. If engine fails to start after 30 seconds, wait two minutes before recranking, and repeat steps 3 and 4 above. Absence of blue/white exhaust smoke during cranking indicates no fuel being delivered. If engine does not start on first attempt, check fuel supply system.
6. Allow engine to warm up before applying load.

Within seconds after starting engine, oil pressure should exceed 60 kPa (10 psi) minimum. After engine has reached operating temperature, oil pressure should be in the range of 207 to 380 kPa (30 to 55 psi) at full load rpm.

**⚠CAUTION** ***Overvoltage will immediately destroy the glow plugs. Do not apply overvoltage to the starting circuit at any time. If it becomes necessary to use an additional source of power to start the engine, use a battery of equal voltage connected in parallel.***

## ENGINE SHUTDOWN

1. De-energize fuel solenoid or turn START/STOP switch to stop position.
2. If stop circuit fails, close manual fuel valve. This manual valve is optional.

**⚠CAUTION** ***Always allow engine to run at idle without load for at least 2 minutes before stopping. This allows engine to cool gradually and uniformly.***

## OPERATION

Operation, following prestart, preheat and starting, involves several checking and servicing procedures that will help the owner-operator extend the engine's life.

### Applying Load

If practical, allow the engine to warm up before connecting a load. Continuous engine overloading causes higher operating temperatures that can damage the engine. The exhaust system may become fouled by combustion deposits during periods of operation at light loads.

### Exercise of Engine on Generator Set Application

A diesel engine on stand-by service that is relied upon to perform under critical conditions, should be exercised at least every 30 days.

Exercise period should be of sufficient duration to allow engine to reach normal operating temperature while carrying at least 50% of normal load.

When the engine is used under conditions of extreme temperatures, humidity, dust, sand, etc., it may be necessary to accelerate maintenance intervals and exercise periods to as often as weekly.

To exercise engine:

1. Before starting, check lubricating oil and coolant levels. Make complete visual check of unit.
2. Start engine and run 15 minutes with speed control at half position.
3. Run engine at rated speed with whatever load is available, up to full load, for the time needed to obtain two consecutive water temperature readings of 71°C (190°F) minimum at 15 minutes. Check and correct any coolant or oil leaks.

   **⚠WARNING** ***Contact with hot coolant might result in serious burns. Do not bleed hot, pressurized coolant from a closed cooling system.***

4. Run engine at half speed with no load for 5 minutes to allow engine to cool evenly.
5. Stop engine.

If accumulated hours of operation during exercise periods do not total 200 hours within a 6 month period, the oil filter and lubricating oil should be changed regardless of hours. If in a 12 month period engine hours do not total 400, replace the fuel filter.

### Dust and Dirt

1. Keep engine clean.
2. Service air cleaner prior to each start-up.
3. Change crankcase oil every 100 operating hours.
4. Keep oil and fuel in dust-tight containers.
5. Keep throttle linkage clean.

### High Altitude and High Temperatures

Maximum power will be reduced approximately 3 percent for each 304.8 m (1000 ft.) above 90 m (295 ft.) on naturally aspirated engines, and above 1525 m (5000 ft.) on turbocharged engines.

Maximum power will be reduced approximately 1.8% per 10°C (1% per 10°F) above 25°C (77°F).

See that nothing obstructs air flow to and from the engine. Keep cooling system filled to proper level with coolant. Be sure that thermostat and pressure cap function properly. Keep cooling system clean.

If permanent application is expected to exceed 1000 m (3280 ft.) on naturally aspirated engines, 1525 m (5000 ft.) on turbo engines or, if normal air inlet temperature exceeds 40°C (105°F) or if a total power reduction due to both pressure and temperature exceeds 10%, an injection pump change is recommended to reduce the fuel flow rate.

### Low Temperatures

Diesel fuels are sensitive to changes in ambient temperature. All diesel fuels have a certain amount of heavy paraffin-like (wax) components, which are high in energy value and help improve fuel economy. When fuel temperatures fall to less than about -7°C (20°F), the heavy paraffin components begin to solidify into wax flakes. If fuel temperatures become low enough, the flakes can build up in the fuel filters and prevent fuel from reaching the engine.

Number 2-D fuel has a higher level of heavy components and is more subject to waxing than Number 1-D (or a "winterized" 2-D) fuel. When operating at temperatures below 0°C (32°F), use Number 1-D, or Number 2-D that has been blended with Number 1-D for winter use.

To improve cold weather starting and operation, use of an engine block heater is recommended. A fuel heater properly installed helps prevent wax from plugging the fuel filter.

1. Use correct viscosity oil for temperature conditions. Change oil only when engine is warm. If an unexpected temperature drop requires an emergency oil change, move the engine to a warm location or apply heated air (never use open flame) externally to the oil pan until oil flows freely.

2. Use fresh fuel. Protect against moisture condensation. Keep fuel tanks full. Temperature of fuel delivered to engine filter must be above its cloud point to prevent filter blockage.

**⚠WARNING** ***Use of ether as a starting aid can cause an explosion resulting in severe personal injury. Heat of compression or hot glow plugs can cause a sudden ignition of the ether vapor. Do not use ether as a starting aid.***

**⚠CAUTION** ***Use of ether as a starting aid can cause an explosion resulting in engine damage. Heat of compression or hot glow plugs can cause an ignition of the ether vapor. Do not use ether as a starting aid.***

3. Keep fuel system clean, and batteries in a well charged condition.

**⚠CAUTION** ***Overvoltage will immediately destroy glow plugs. Do not apply overvoltage to the starting circuit at any time. If it becomes necessary to use an additional source of power to start the engine, use a suitable battery of equal voltage connected inparallel.***

### Out-Of-Service Protection

The inherent lubricating qualities of No. 2 diesel fuel should protect the cylinders of a diesel engine for at least 30 days when the unit is not in service. To protect an engine that will be out of service for more than 30 days, proceed as follows:

1. Exercise the engine as outlined in *EXERCISE OF ENGINE ON GENERATOR SET APPLICATION* section.
2. Shut down engine and drain crankcase oil while still warm. Refill and attach a warning tag indicating viscosity of oil used.
3. Remove glow plugs and pump 28 grams (1 ounce) of rust inhibitor (or SAE #10 oil) into each cylinder. Use starter to turn engine over three to four revolutions. This will evenly distribute the rust inhibitor in the cylinders. Install glow plugs.
4. Service air cleaner per OEM specifications.
5. Clean throttle linkage and protect with a light coat of oil.
6. Plug exhaust outlet to prevent entrance of moisture, bugs, dirt, etc.
7. Clean and wipe entire unit. Coat parts susceptible to to rust with a light coat of grease or oil.
8. Disconnect battery and follow standard battery storage procedure.

### Returning Unit to Service

1. Remove cover and all protective wrapping. Remove plug from exhaust outlet.
2. Check tag on oil dipstick and verify that oil viscosity is still correct for existing ambient temperatures. Check oil level.
3. Clean and check battery. See *SECTION 7, MAINTENANCE* for instructions.
4. Check that glow plugs are secure, correctly torqued, and electrical leads connected.
5. Connect battery (ground terminal last).
6. Prime fuel system.
7. Refer to starting instructions for start-up.

After engine has started, excessive blue smoke is exhausted until the rust inhibitor has burned away.

**⚠WARNING**

***EXHAUST GAS IS DEADLY!***

***Exhaust gases contain carbon monoxide, a poisonous gas that can cause unconsciousness and death. It is an odorless and colorless gas formed during combustion of hydrocarbon fuels. Symptoms of carbon monoxide poisoning are:***

- ***Dizziness***
- ***Headache***
- ***Weakness and Sleepiness***
- ***Vomiting***
- ***Muscular Twitching***
- ***Throbbing in Temples***

***If you experience any of these symptoms, get out into fresh air immediately, shut down the unit and do not use until it has been inspected.***

***The best protection against carbon monoxide inhalation is proper installation and regular, frequent inspections of the complete exhaust system. If you notice a change in the sound or appearance of exhaust system, shut the unit down immediately and have it inspected and repaired at once by a competent mechanic.***

# 7. Maintenance

## ENGINE INSPECTION

**⚠WARNING** ***Accidental starting of the engine or electrical arcing can cause severe personal injury or death. Disconnect the battery cable when repairs are made to the engine, controls, or associated equipment.***

**⚠CAUTION** ***Onan does not recommend washing the diesel engine. However, if you must wash the engine, do so only when the engine is cold. Never wash a warm, hot, or running engine. Spraying water or cleaning solutions on a warm engine or injection pump can cause serious damage to the engine fuel system.***

After starting the operator should make a complete visual and audible inspection of the engine. Inspect exhaust system for possible leakage and cracks. Locate leaks in muffler and piping while the engine is operating. Repair all leaks immediately after they are detected for personnel safety.

## DAILY CHECKS

Check the following before starting the engine for the first time each day:

1. Check all fuel lines and fittings for possible leakage.
2. Inspect cooling system for possible leaks. Coolant level should be maintained at a level midway between top of radiator core and filler neck. If in a vehicle equipped with a coolant recovery tank, coolant level in recovery tank must be between cold and hot marks. Maintain coolant at a concentration that will prevent freezing and system corrosion.
3. Drain moisture from condensation traps and fuel-water separator (if so equipped).
4. Inspect intake system for leaks. Make certain that all clamps and fittings are tight and free of potential leaks.
5. Check crankcase oil level with the engine off. If oil level is at or below "add" mark on dipstick (Figure 1), add sufficient oil of the proper viscosity as specified in *SECTION 6, START-UP* to bring oil level to the full mark on the dipstick. Do not operate engine with oil level below the "add" mark.

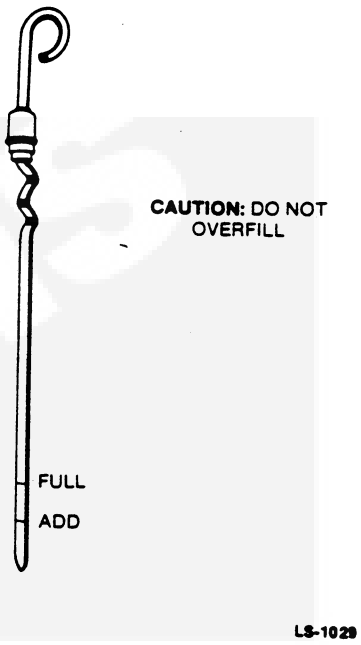



**FIGURE 1. CRANKCASE DIPSTICK**

## OIL AND FILTER CHANGE

Refer to *Periodic Maintenance Schedule* for oil and filter change interval. Change oil and filter more frequently if engine operation includes extended periods of low-speed operation or exposure to extreme dust and dirt.

**⚠WARNING** ***Hot crankcase oil can cause burns if spilled or splashed on skin. Keep fingers and hands clear when removing the oil drain plug and wear protective clothing. Never remove oil drain plug from a hot engine.***

To drain oil, place a pan under the drain outlet, and remove the oil drain plug. After the oil is completely drained, replace the drain plug. Spin off oil filter element and discard it. Thoroughly clean filter mounting surface.

Make sure new gasket is inserted in the element. Apply a thin film of clean oil to the gasket. Spin element down by hand until gasket just touches mounting pad, and then tighten an additional 1/4-3/4 turn. Do not overtighten.

Refill with oil of the correct API classification and appropriate SAE viscosity grade for the anticipated temperature conditions (refer to *SECTION 6, START-UP*). Start engine and run for a short time to check for oil leaks around the drain plug and filter element. Stop engine and check oil level. Oil level should be to the FULL mark on the dipstick.

**Allow a minimum of 10 minutes for the oil to drain down before checking. The best time to check the oil is after an overnight shut-down period.**

Oil level should be to the "full" mark of the dipstick. Start engine and run for a short time to check for oil leaks around the drain plug.

## COOLING SYSTEM

The engine may be equipped with a pressurized cooling system. This system will not operate properly unless it is air-tight, without loose connections or leaks. Otherwise, pressure will not be maintained, and loss of coolant and overheating will result.

Proper operating temperature is maintained by a thermostat located in the water outlet manifold.

**⚠WARNING** ***Contact with hot coolant can result in serious burns. Do not bleed hot, pressurized coolant from a closed cooling system.***

Prior to cold weather and extended storage (30 days or more), drain, flush, and fill the cooling system. Run the engine until it reaches normal operating temperature. This allows the thermostat to open and assures the solution is circulated throughout the entire cooling system.

**⚠CAUTION** ***At ambient temperatures below 0° C (32° F), when engine is not in use, sea water side of marine cooling system must be drained. This will prevent cooling system damage caused by freezing.***

### Cleaning

For efficient operation, the cooling system should be drained, flushed, and refilled once a year.

To drain the system completely, the radiator drain and the cylinder block drain, located on the right side of engine, must be opened.

Clean the cooling system using a good radiator cleaning compound in accordance with instructions furnished with the compound.

To drain sea water side of marine cooling system remove sea water hose from sea water pump outlet or remove drain plug from sea water tube.

Remove front heat exchanger cover to clean debris or sediment from sea water side of cooling system. Refer to *Periodic Maintenance Schedule* for cleaning interval.

After the system is completely drained, close the drains, refill as specified in *SECTION 6, START-UP.*

## BATTERIES

Disconnect negative ground strap from the battery before working on any part of the electrical system or engine.

Disconnect positive terminals before charging batteries to avoid damaging alternator or regulator.

**⚠WARNING** ***Ignition of explosive battery gases can cause severe personal injury. Do not smoke while servicing batteries.***

### Cleaning

Keep the batteries clean by wiping them with a damp cloth whenever dirt appears excessive.

If corrosion is present around the terminal connections, remove battery cables and wash the terminals with an ammonia solution or a solution consisting of 1/4 pound of baking soda added to 1 quart of water.

Be sure the vent plugs are tight to prevent cleaning solution from entering the cells.

After cleaning, flush the outside of the battery, the battery compartment, and surrounding areas with clear water.

Keep the battery terminals clean and tight. After making connections, coat the terminals with a light application of petroleum jelly or non-conductive grease to retard corrosion.

### Checking Specific Gravity

Use a battery hydrometer to check the specific gravity of the electrolyte in each battery cell.

Hold the hydrometer vertical and take the reading. Correct the reading by adding four gravity points (0.004) for every five degrees the electrolyte temperature is above 27° C (80° F) or subtracting four gravity points for every five degrees below 27° C (80° F). A fully charged battery will have a corrected specific gravity of 1.260. Charge the battery if the reading is below 1.215.

### Checking Electrolyte Level

Check the level of the electrolyte (acid and water solution) in the batteries at least every 200 hours of operation.

Fill the battery cells to the bottom of the filler neck. If cells are low on water, add distilled water and recharge. If one cell is low, check case for leaks. Keep the battery case clean and dry. An accumulation of moisture will lead to a more rapid discharge and battery failure.

**⚠CAUTION** ***Do not add water in freezing weather unless the engine is to be run long enough (two or three hours) to assure a thorough mixing of water and electrolyte.***

### Storage

If the engine is to be stored for more than 30 days, remove the batteries. With the electrolyte level at the bottom of the split ring, charge the battery before storing it. After every 30 days the battery is in storage, bring it back up to full charge. To reduce self-discharge, store the battery in as cool a place as possible so long as the electrolyte does not freeze.

## FAN BELT

To adjust, loosen alternator bolt that passes through elongated slot in mounting bracket. Slide alternator until the correct fan belt tension is obtained. See *SECTION 9, COOLING SYSTEM* for belt tension. Tighten alternator mounting bolt to lock alternator in place. Recheck tension; repeat if necessary.

## FUEL SYSTEM

**⚠CAUTION** ***Due to the precise tolerances of diesel injection systems, it is extremely important the fuel be kept clean and free of water. Dirt or water in the system might cause severe damage to both the injection pump and the injection nozzles.***

### Fuel Filter

The combination primary and secondary fuel filter is a disposable type. Any dirt that passes through the primary section is trapped by the secondary section. This prevents dirt from entering fuel injection pump.

The filter replacement interval will vary according to the fuel quality and cleanliness. Using the wrong fuel or dirty fuel will shorten the service life of the filter.

Refer to the *Periodic Maintenance Schedule* for the recommended filter change interval. However, if the engine shows signs of fuel starvation (reduced power or surging), change the fuel filter. Use the following procedures to replace.

1. Close the fuel tank shut off valve.
2. Clean all dirt from around filter, filter base and surrounding area.
3. Disconnect negative battery cable from batteries.
4. Remove filter retaining clip or clips from fuel filter (see Figure 2).
5. Remove old filter and dispose of it properly.
6. Install new fuel filter. Install retaining clip, make sure retaining clip does not contact glow plugs or wiring.
7. Open fuel tank shut off valve, if used.
8. Prime fuel system.

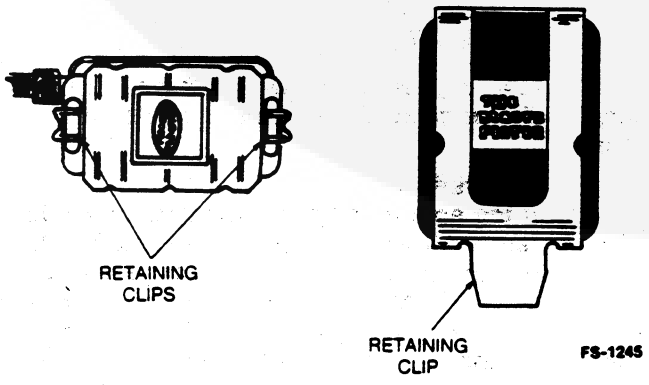



**FIGURE 2. FUEL FILTERS**

### Fuel Injection Pump

**⚠CAUTION** ***Onan does not recommend washing the diesel engine. However, if you must wash the engine, do so only when the engine is cold. Never was a warm, hot, or running engine. Spraying water or cleaning solutions on a warm engine or injection pump can cause serious damage to the engine fuel system.***

Before leaving the factory, all engines are equipped with carefully calibrated fuel injection pumps which have been adjusted to a factory approved power setting. Injection pump and aneroid adjustments are preset and sealed at the factory. Preset adjustments should not be disturbed.

**⚠CAUTION** ***Adjustments to injection pump or aneroid that do not meet specifications may violate Federal, state, and/or local regulations. Emissions and mechanical warranty may also be voided by adjustments made, that do not meet specifications. Adjustments made by non-authorized personnel may void mechanical warranty.***

**⚠CAUTION** ***Do not cut seals on the throttle stop screws. Improper adjustments of throttle stop screws can cause permanent engine damage. Tampering with sealed adjustments will void warranty.***

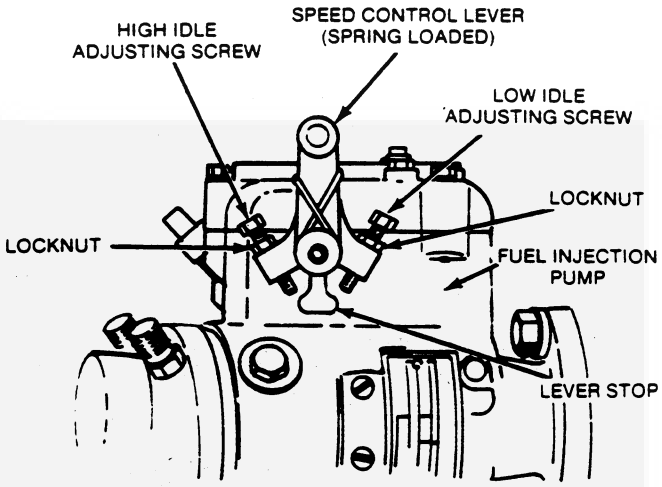



**FIGURE 3. STANADYNE INJECTION PUMP**

**⚠CAUTION** ***All injection pump service and adjustments must be done by qualified injection pump service personnel. To prevent possible equipment damage, it is imperative that service personnel be qualified.***

**⚠CAUTION** ***If engine has been operating while out of time, glow plug damage may result. Reset injection pump timing and check or replace glow plugs.***

No lubrication or regularly scheduled service, checks, are required on the injection pump. If engine speed is irregular, check fuel system and all other engine adjustments before having fuel injection pump settings checked by a qualified service dealer or distributor. Injection pump dealers or distributors are equipped with injection pump test stands, special tools required for repairing, testing, and adjusting the pump. Adjustment of injection pump and aneroid for optimum performance and low exhaust emissions requires highly specialized equipment and special training. If at any time the injection pump needs repair or adjustment, it should be taken to an authorized injection pump service dealer or distributor. It is important that the servicing dealer be furnished with the pump model number, as well as engine model and serial number, to facilitate the repair.

## CRANKCASE BREATHER (Turbocharged Engines)

Clean crankcase breather each time valve clearance adjustments are made. Refer to the *Periodic Maintenance Schedule* for the recommended cleaning interval. Use the following procedure when cleaning crankcase breather.

1. Remove breather cap and lift out the breather element (Figure 4).
2. Clean breather cap and element in cleaning solvent. Dry thoroughly with low pressure (under 241 kPa [35 psi]) compressed air.
3. Install a clean or new breather element in the valve cover. Do not pack element in valve cover.
4. Install clamp, breather cap, and connect breather tube.

**⚠CAUTION** ***Overtightening of the clamp will tear breather cap.***

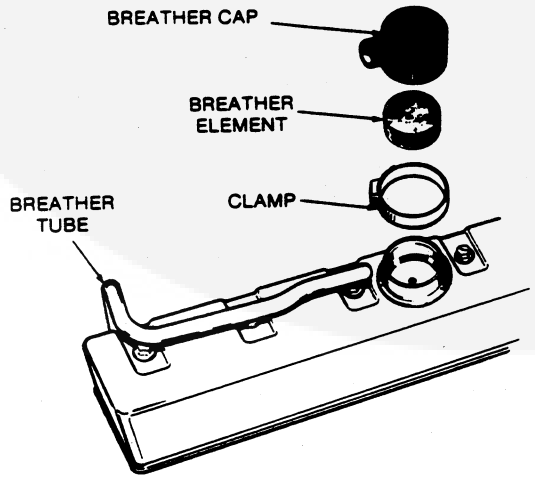



**FIGURE 4. CRANKCASE BREATHER**

## VALVE CLEARANCE

**⚠CAUTION** ***Correct valve clearance is very important in diesel engine performance, because of the high compression developed in the cylinders. Incorrect valve clearance will cause loss of compression, misfiring, noise, and may eventually lead to damaged engine components.***

## PERIODIC MAINTENANCE SCHEDULE

Follow a regular schedule of inspection and servicing, based on operating hours. Keep an accurate logbook of maintenance, servicing, and operating time. Use the factory recommended Periodic Maintenance Schedule (based on favorable operating conditions) to serve as a guide to get long and efficient engine life. Regular service periods are recommended for normal service and operating conditions. For continuous duty, extreme temperature, etc., service more frequently. For infrequent use, light duty, etc., service periods can be lengthened accordingly. Neglecting routine maintenance can result in engine failure or permanent damage. Refer to *OPERATORS MANUAL* for Periodic Maintenance Schedule.

## AIR CLEANER

A variety of air cleaners are available and used on this series of engines. The required service interval, regardless of the type of air cleaner used, depends on the amount of foreign material in the air surrounding the engine.

Inspect the air cleaner body periodically for dents and cracks. Check for damaged gaskets and hoses, loose hose clamps, and for leaks that would allow unfiltered air to enter the engine. Correct any such condition by the immediate repair or replacement of the faulty parts.

Some dry type air cleaners are equipped with a filter service indicator. Service or replace the filter when so indicated. However, if a service indicator is not used, refer to the equipment manufacturer's operators manual for specific air cleaner service instructions.

## TURBOCHARGER

No calibration or adjustment procedures are possible on a turbocharger in-service. Since all lubrication requirements are supplied by the engine, no periodic maintenance in the usual sense is required. Due to the wide variation in operating modes and conditions to which turbochargers are subjected, maintenance procedures based on specific numbers of engine operating hours, vehicle miles, or calendar periods are not practical.

**⚠CAUTION** ***Always allow engine to run at idle speed without load for at least 2 hours before stopping. This allows turbocharger to cool gradually and uniformly, helping to prevent bearing seizure.***

# 8. Oil System

## OIL PRESSURE SYSTEM

Refer to *SECTION 7, MAINTENANCE* for additional information relative to oil system. The lubrication system is designed so that all internal parts are pressure lubricated by a gear type oil pump. The pump is driven by the crankshaft through an idler gear. It is located at the front of engine behind the gearcase backplate. Engines equipped with an oil cooler have an oil pump pressure relief valve located in cylinder block just above the oil pump. This relief valve is set to open when the discharge pressure exceeds 827 kPa (120 psi) and bypasses oil back to the oil pan.

Oil pressure is maintained by an oil pressure regulating valve located in cylinder block main oil gallery at the front. This valve also serves as the pressure relief valve on engines that do not have an oil cooler. Oil pressure at normal operating temperature and full throttle should be 344 to 380 kPa (50 to 55 psi).

A bypass valve is located in the oil filter. If engine oil is too thick to circulate freely through filter, or filter becomes clogged, the bypass valve opens allowing oil to flow directly into main oil gallery.

The oil pump draws oil from engine sump, through suction screen and circulates it under pressure through oil cooler (if applicable), across front of cylinder block to the oil filter (Figure 1). Oil then flows into a main oil gallery running along the block. Oil passages transport oil from the main oil gallery to each main bearing, connecting rod bearing, camshaft bearing and the idler gear bearing. Piston pins and connecting rod bushings are lubricated through a funnel shaped cavity located in the top of each connecting rod. A sufficient quantity of oil splashed in the crankcase catches in each cavity keeping it full and feeding each connecting rod bushing.

On Spec A to C engines an oil line extends along the cylinder head under the rocker arm cover spraying oil onto rocker arms. Oil returning by gravity from valve cover to oil pan lubricates the push rods and tappets.

Beginning with Spec D engines, oil is fed from the third cam bearing to an oil gallery running through the tappet bores. Oil enters the hydraulic tappets where it is pumped through the hollow push rods to the rocker arm assemblies.

On naturally aspirated engines, cylinder walls are lubricated by splash and spray created by the revolving crankshaft and connecting rods. On turbocharged engines, oil is sprayed through nozzles onto the bottom of each piston to cool and lubricate the piston, cylinder walls, and connecting rod bushing. Oil thrown by drive gears lubricates the gear train.

On engines equipped with a turbocharger, oil is suplied to and returned from the turbocharger through external lines.

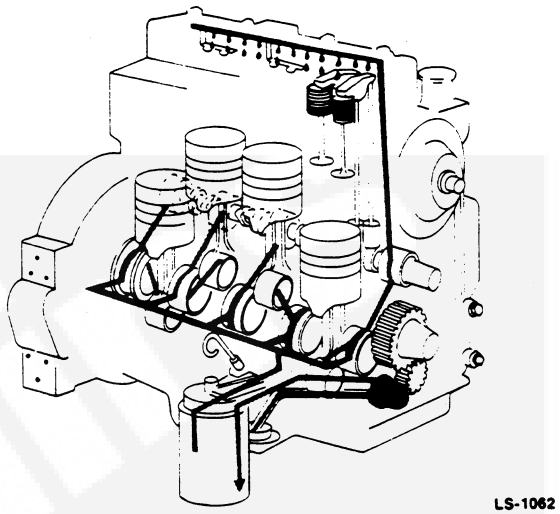



**FIGURE 1. OIL FLOW SCHEMATIC DIAGRAM**

## OIL PAN

The oil pan is the reservoir for engine lubricating oil and has a drain for regular oil draining. Capscrews with Belville washers secure oil pan to engine. A gasket is used to seal the oil pan to cylinder block, gearcover, and rear seal plate.

### Removal and Inspection

1. Remove drain plug from oil pan and allow oil to drain from engine.
2. Remove capscrews and Belville washers securing oil pan to cylinder block, gearcover, and rear seal plate.
3. Tap oil pan loose with a plastic or rubber mallet, and remove oil pan.
4. Wash oil pan in cleaning solvent and clean gasket sealing surfaces on oil pan and cylinder block.
5. Inspect oil pan for cracks or other damage. Inspect drain plug boss for evidence of leakage and damaged threads. Repair or replace oil pan if necessary.

### Installation

1. Place a new gasket on oil pan.
2. Position oil pan on cylinder block and hold it in position by loosely inserting a capscrew and Belville washer in each corner. Install remaining capscrews and Belville washers, but do not tighten them until all capscrews are started, so the oil pan can be shifted if necessary.
3. Tighten all capscrews securely to a torque of 11 Nm (8 Ft.-Lb.) starting at the center and work out to each end.

**⚠CAUTION** ***Do not overtorque oil pan capscrews. Too much torque will distort oil pan causing it to leak.***

4. Install oil drain plug into oil pan and tighten securely.
5. Fill oil pan to proper level with the specified engine oil. Refer to *SECTION 6, START-UP* for correct type and amount. Run engine and check for oil leaks.

## OIL PUMP

A gear type oil pump is mounted on the gearcase backplate. The oil pump (Figure 2) has a helical drive gear that meshes with an idler gear located directly below the crankshaft. The oil pump drive gear is pressed onto a tapered drive shaft and is secured with a flat washer and capscrew. A precision bearing pressed into gearcase backplate supports oil pump drive shaft.

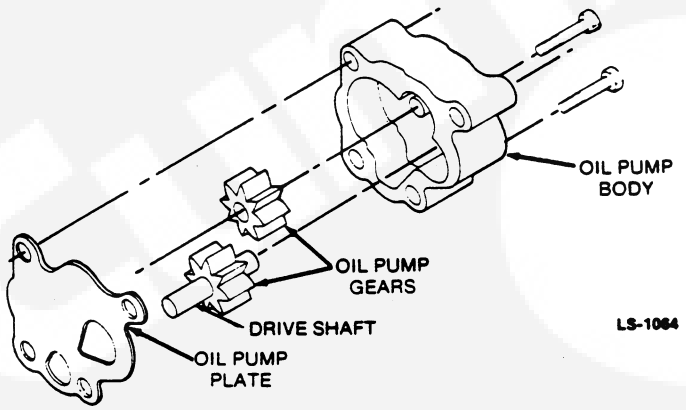



**FIGURE 2. OIL PUMP**

### Removal and Disassembly

1. Drain engine oil and remove oil pan.
2. Remove capscrew that secures oil pickup support to cylinder block.
3. Remove the three capscrews and washers securing oil pickup to oil pump. Note location of the shorter capscrew (Figure 3).
4. Remove remaining two capscrews and washers from oil pump.
5. Remove oil pump housing with pump idler gear.
6. Loosen capscrew that secures oil pump drive gear to input shaft.
7. Tap on capscrew with a soft hammer to free drive gear from the input shaft. Remove capscrew, washer and drive gear.
8. Remove input shaft and oil pump plate.

### Cleaning and Inspection

1. Wash all oil pump components in clean solvent. Inspect all parts before installing pump. The principal wearing parts are the bushings, drive gears, and pumping gears. If dirt and sludge have been allowed to accumulate in the lubricating system, oil pump gear wear may be rather extreme after a short period of time. If oil has been kept clean and oil filter serviced regularly, wear on these parts should be slight.
2. Inspect pump gear teeth, drive gear teeth, pump body (inside), oil pump plate, and drive shaft for wear or scoring. Gear teeth, inside of the pump body, and pump plate must all be smooth and have no scratches, score marks, or rough spots. If worn or damaged parts are found replace the entire pump.

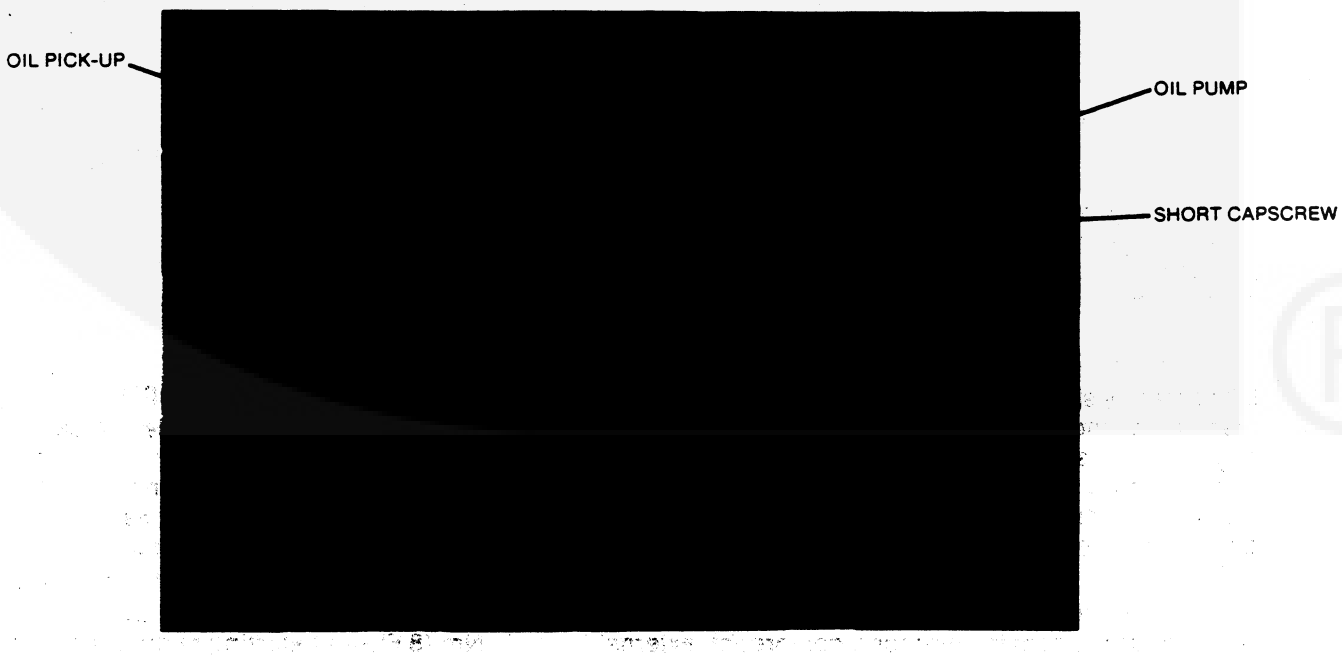



**FIGURE 3. OIL PICK-UP MOUNTING**

3. Check backlash between oil pump element gears. Measure oil pump element gears end clearance to body.
4. Inspect oil pump drive shaft and bearing for excessive wear or scoring and replace as necessary. Use a dial bore gauge or a telescopic gauge and micrometer to measure inside diameter of bearing. Replace bearing if the clearance to oil pump drive shaft is greater than specified. This bearing requires no machining after installation.

**Assembly**

1. Position oil pump plate over pump shaft. Install this assembly with pump shaft through gearcase backplate.
2. Place a 15 mm (0.5906 inch) O-ring over pump shaft, between oil pump drive gear and backplate. Secure gear to shaft with capscrew and washer.
3. Place pump element gear into pump body. Lubricate pump element gears with clean engine oil. Mount pump with two flatwashers and capscrews, placed in top two mounting holes of the pump housing. Do not torque until oil pickup tube is installed.
4. Inspect and thoroughly clean oil pickup screen assembly.
5. Place a new pickup gasket on oil pump, mount oil pickup assembly, and tighten all oil pump mounting screws to the specified torque in two even steps. Make sure oil pump turns freely after torquing.
6. Secure oil pickup support to cylinder block with capscrew and flatwasher.
7. Remove drive gear and O-ring. Make sure oil pump turns freely.
8. Place drive gear on shaft and secure with washer and capscrew.
9. Install oil pan and new oil pan gasket by following the procedure described earlier in this section.
10. Fill engine oil pan to the proper level with the specified engine oil. Check for oil leaks.

## CRANKCASE VENTILATION

During normal operation, unburned fuel and water vapor are formed in the engine. If allowed to condense, these vapors become contaminating liquids that drain into the crankcase. Purpose of the ventilation system is to circulate fresh air through crankcase to carry away these harmful vapors.

If crankcase breather becomes clogged, vapors are trapped within the engine. The resulting pressure build-up will force oil past the crankcase seals, dipstick, and valve cover gasket.

Crankcase ventilation on naturally aspirated engines is achieved through internal breather tubes located under the valve cover (Figure 4). If crankcase shows signs of pressurization, clean breather tubes. Clean the passages in cylinder head that lead to the valve port area. Apply Loctite 325 to breather tubes and install, if removed.

Crankcase ventilation on turbocharged engines is achieved through an external breather, that is a part of the oil fill cap. This crankcase breather must be cleaned after every 400 hours of engine operation. Remove breather assembly, clean breather with cleaning solvent, allow to dry, and replace on engine.


**FIGURE 4. CRANKCASE VENTILATION (N/A ENGINE)**

## IDLER GEAR AND SHAFT (Oil Pump Drive)

The idler gear has a steel backed bronze bearing pressed into it. This bearing is lubricated with engine oil splashed by the rotating gears. The idler gear is secured with a flat washer and capscrew that threads into the idler shaft, which is pressed into gearcase backplate.

### Removal and Inspection

To gain access to idler gear the gearcase cover and oil pan must first be removed from engine. Refer to *SECTION 13, ENGINE DISASSEMBLY, Gearcase Cover Removal* procedure.

1. Remove capscrew and washer from idler gear.
2. Remove idler gear from shaft.
3. Inspect idler gear for nicked, worn, or pitted teeth. Replace if necessary.
4. Measure inside diameter of idler gear bearing. Replace bearing if it is nicked, scored, or worn. After pressing a new bearing into gear, bearing must be reamed to the correct inside diameter.
5. Inspect idler gear shaft. If shaft is worn or scored it must be replaced.
6. To remove a worn idler gear shaft thread a 8 mm adapter into the shaft.
7. Install the end of a slide hammer into adapter and remove idler gear shaft from backplate.

### Installation

1. To install a new idler gear shaft, position it in bore of backplate. Drive idler gear shaft in with a brass hammer until it protrudes 17.1-17.2 mm (0.673-0.677 inch) from the backplate surface.
2. Place idler gear on idler gear shaft and secure with capscrew and washer. Check idler gear end play.
3. Install gearcase cover. Refer to *SECTION 13, ENGINE DISASSEMBLY, Gearcase Cover Installation* procedure.
4. Apply a bead of "RTV" Sealant to the junctions of oil pan, gearcase cover, and backplate.
5. Install oil pan. Refer to procedure outlined earlier in this section.

## OIL COOLER PRESSURE RELIEF VALVE (Engine With Oil Cooler)

A pressure relief valve is located in the cylinder block above the oil pump. This valve bypasses oil back to the oil pan when pump discharge pressure exceeds 826 kPa (120 psi).

When engine is being overhauled or oil pressue is low, remove, clean, and inspect oil pump pressure relief valve parts. To service relief valve gearcase backplate must first be removed. Refer to *SECTION 13, ENGINE DISASSEMBLY, Gearcase Backplate Removal* procedure.

### Removal and Inspection

1. Using a snap ring pliers remove internal retaining ring from relief valve (Figure 5).


**FIGURE 5. REMOVING PRESSURE RELIEF VALVE**

2. Remove relief valve piston and spring.
3. Wash parts in cleaning solvent and inspect carefully. The piston must slide smoothly in bore of valve body.
4. Replace piston if it is scratched or shows any sign of wear.

### Installation

1. Lubricate piston and spring with clean engine lubricating oil.
2. Place piston over spring and insert spring first into cylinder block.
3. Push piston and spring into valve body and hold in place with a screwdriver (Figure 6).
4. Using a snap ring pliers, install retaining ring in cylinder block.
5. Assemble parts removed to gain access to pressure relief valve by a direct reversal of the removal procedure.

## OIL PRESSURE REGULATING VALVE

An oil pressure regulating valve is located in the cylinder block at the front lower right corner of main oil gallery. Purpose of the valve is to maintain a stable oil pressure in the lubrication system. When oil pressure at the regulating valve exceeds approximately 380 kPa (55 psi.), the valve piston is raised off its seat, and oil is bypassed directly from cylinder block oil gallery to oil pan.

The regulating valve may not work properly if sludge is allowed to build-up in the lubrication system. If valve sticks in open position, a sharp drop in oil pressure will occur. If valve sticks in closed position, a sharp rise in engine oil pressure will occur.

Remove, clean, and inspect oil pressure regulating valve whenever engine is being overhauled. To service regulating valve the gearcase backplate must be removed from the cylinder block. Refer to *SECTION 13, ENGINE DISASSEMBLY, Gearcase Backplate Removal* procedure.

### Removal and Inspection

Remove the regulating valve from cylinder block as follows:

1. Using a hammer and punch, drive out regulating valve retaining pin.

   **⚠CAUTION** ***Be careful when removing retaining pin. Driving removal tool into the pin bore too far will damage block.***

2. Remove washer, spring, and piston.
3. Wash valve parts in cleaning solvent and inspect carefully for wear or damage. Replace any worn or damaged parts.
4. Thoroughly clean valve bore in cylinder block.

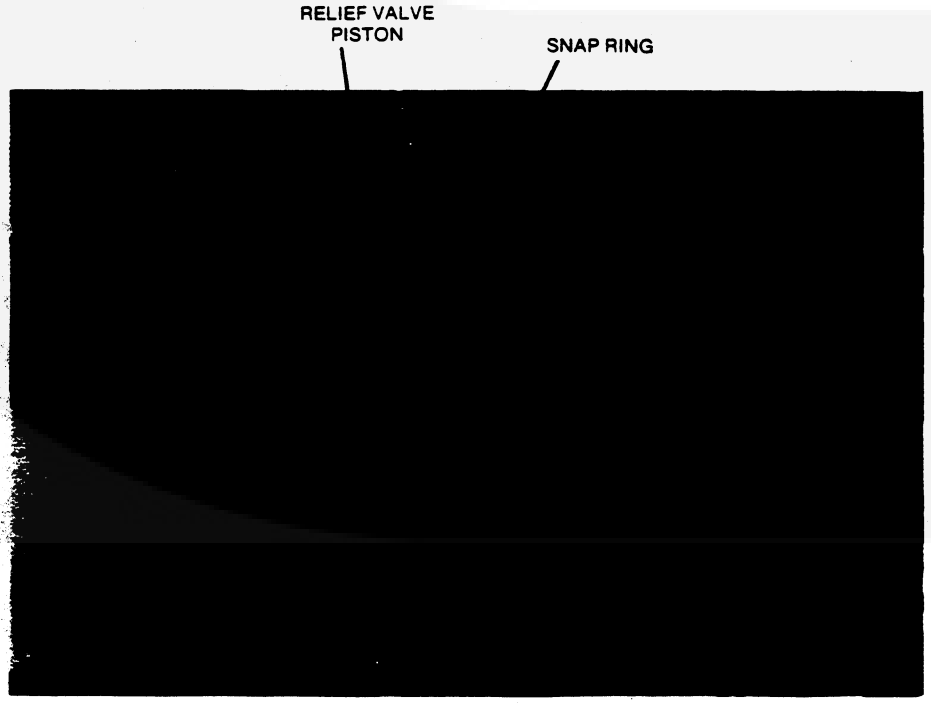



**FIGURE 6. INSTALLING PRESSURE RELIEF VALVE**

## Installation

1. Lubricate valve piston with clean engine oil. Install piston, spring, and washer (Figure 7).
2. Compress spring and washer while driving retaining pin into cylinder block (Figure 8).


**FIGURE 7. REGULATING VALVE INSTALLATION**


**FIGURE 8. RETAINING PIN INSTALLATION**

## OIL COOLER

The engine oil cooler, located on left side of engine, consists of a cooling core and cover, which forms a tank. The engine oil pressure pump circulates oil through the cooling core while coolant circulates through tank, around outside of cooling core, controlling oil temperature.

The cooling core consists of several thin plates which dissipate heat from the oil to engine coolant. If the proper lubricating oil maintenance procedures are not followed, impurities will be depositied in oil cooler that can restrict oil flow through the cooling core plates. A drop in oil pressure due to oil overheating, usually indicates a restricted oil cooler. If this occurs, oil cooler must be cleaned or replaced.

Various sizes of oil coolers are used, depending upon the oil cooling requirements of the engine. The number of plates in the cooling core determines the amount of heat dissipated to the coolant. Baffles are used in some oil coolers to control coolant flow.

### Removal and Inspection

1. Drain cooling system. (Remove drain plug from oil cooler to drain coolant from oil cooler.)
2. Remove socket head screws that secure oil cooler assembly to cylinder block and remove oil cooler assembly.
3. Scrape off any gasket material remnants that remain on block after oil cooler is removed.
4. Clean oil cooler cover and cooling core. Scrape off any gasket material that remains on cover and cooling core.

   Replace the oil cooler when there has been an engine failure and metal paticles may have been drawn into the lubrication system. Do not attempt to clean an oil cooler that has been contaminated with metal particles.
5. Inspect all gasket surfaces for scratches and nicks. Check surfaces of oil cooler for warpage using a straight edge. Pressure test oil cooler core for leaks as follows:
   A. Secure oil cooler test fixture to cooler core with capscrews and hex nuts.
   B. Attach an air hose to regulator in fixture. Submerge cooler in water. Test for leaks with air pressure of not more than 138 kPa (20 psi).
   C. Any air bubbles observed indicate the cooler core has a puncture or may be defective in some other way. If cooler core is faulty it must be replaced.
6. Replace any part that is severely scratched or warped. If oil cooler core is badly clogged, a new core must be installed.

### Installation

When installing the oil cooler use new gaskets, and be sure the socket head capscrews are properly torqued.

1. Position baffles (when used) in oil cooler cover, with notches over cover mounting hole casting bosses. Lower baffle has a hole that lines up with coolant drain.
2. Place cover gasket on cover and set cooler core onto cover.
3. Install gasket onto cylinder block lining up elongated slot in gasket with elongated recess in cylinder block.
4. Using the torque sequence (Figure 9), gradually and uniformly tighten oil cooler sockethead capscrews to a torque of 22 Nm (16 Ft-Lb). Retorque oil cooler sockethead capscrews after two hours of operation.

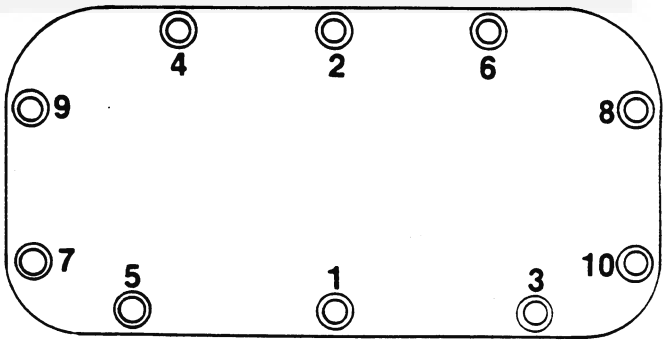



**FIGURE 9. OIL COOLER TORQUE SEQUENCE**

## OIL SPRAY NOZZLE

Oil is sprayed onto the bottom of each piston for cooling and lubrication on all turbocharged engines.

The oil spray nozzle is located in the cylinder block below each cylinder (Figure 10).

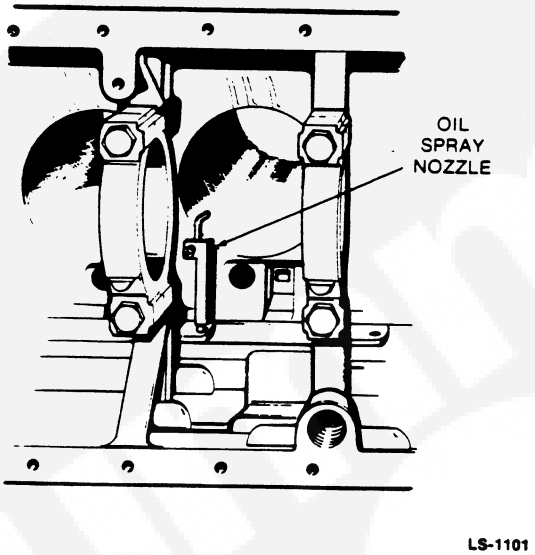



FIGURE 10. OIL SPRAY NOZZLE

### Removal and Inspection

Oil spray nozzles must be removed before doing any cylinder bore refinishing. A dirty nozzle can be cleaned by removing oil gallery plug from side of block and pushing a fine wire through nozzle, without removing nozzle assembly.

1. Remove crankshaft. Refer to *SECTION 13, ENGINE DISASSEMBLY.*
2. Remove special capscrew that secures oil spray nozzle to cylinder block.
3. Remove oil spray nozzle from cylinder block. Remove O-ring from spray nozzle.
4. Clean nozzle jet by passing a fine wire through jet and soaking in solvent.

**⚠CAUTION** ***Oil spray nozzle alignment is critical. If nozzle is bent, crushed, or damaged in any way replace spray nozzle assembly.***

### Installation

1. Install new O-ring on oil spray nozzle.
2. Push nozzle into bore in cylinder block.
3. Secure oil spray nozzle to cylinder block with special socket head capscrew.

**⚠CAUTION** ***Use of the incorrect oil spray nozzle retaining capscrew may result in interference with the crankshaft.***

## OIL LINES (Spec A to C)

When cylinder head is removed for service, the rocker arm oiling tube should be flushed with solvent. Use a fine wire (Figure 11) to clean the small holes.

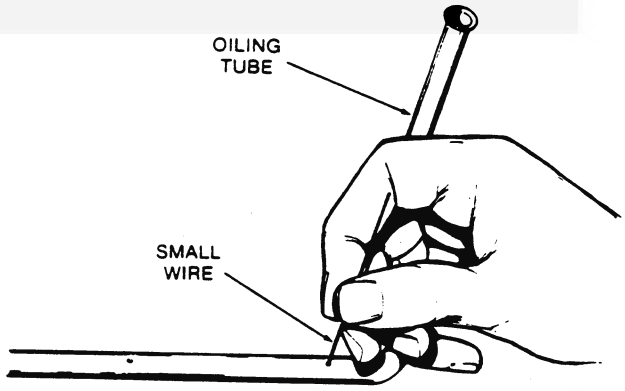



FIGURE 11. ROCKER ARM OILING TUBE

Whenever the engine is disassembled or overhauled, clean all oil galleries and drillings with a solvent and dry with low pressure compressed air.

# 9. Cooling System

## PURPOSE OF COOLING SYSTEM

Purpose of the cooling system is to carry heat away from hot engine components in order to maintain proper running conditions and clearances. Overheating can severely damage engines. The cooling system must carry off the excess heat.

Regulating coolant temperature helps keep the engine at the optimal heat level for each operating condition. After starting, the engine must warm up quickly. During periods of peak output, it must be adequately cooled.

## ANTI-FREEZE AND CORROSION

Corrosion can shorten engine life by plugging the radiator or heat exchanger core, creating hot spots near exhaust valves, and settling in low areas of the block. The corrosive sediment prevents proper heat transfer and holds heat in. Most metals used in cooling systems are susceptible to corrosion damage which can lead to coolant leaks and overheating.

To prevent corrosion, always use a mixture of anti-freeze and water as an engine coolant; even when freezing temperatures are not expected. In addition to lowering the freezing point of water, anti-freeze contains rust inhibitors that prevent corrosion. Most anti-freeze manufacturers recommend a minimum 50-50 mix of ethylene glycol anti-freeze and water for winter and summer in closed water systems, with a complete change every year to prevent corrosion build-up and more extensive damage.

Use soft water whenever available. Well water often contains lime and other minerals which eventually may clog the radiator or heat exchanger core and reduce cooling efficiency.

## HIGH TEMPERATURE CUT-OFF SWITCH

The high temperature cut-off switch shuts down the engine if the coolant reaches a dangerously high temperature. This normally closed switch senses coolant temperature in the engine cooling jacket. When engine temperature rises beyond a specific point the switch opens, breaking the circuit to the fuel solenoid. When coolant temperature falls to a safe operating range the switch closes, permitting engine restarting.

Stopping of the engine due to action of the high temperature cut-off switch is not a normal condition. Examine the cooling system to determine the cause of the overheating and repair as required.

Marine propulsion engines are normally equipped with warning lights or alarms rather than cut-off switches, to alert operator to high temperature conditions.

## MAINTENANCE

The entire cooling system including the block, should be cleaned and flushed out every two years or 3000 hours. This is especially important prior to cold weather conditions and when preparing engine for extended storage (over 30 days). The cooling system can work efficiently only when it is clean. A build-up of rust and scale in cooling system slows down heat transfer and restricts water flow.

### Draining Cooling System

1. If engine is installed in a portable or mobile type of equipment, make certain engine is in a level position to assure complete draining.
2. Remove filler cap and open radiator or heat exchanger drain.

**⚠WARNING** ***Avoid removing the pressure cap until unit has cooled. If this is impractical, the system may be opened while hot if certain precautions are taken. While wearing rubber insulated gloves for protection, slowly open the cap allowing the pressure to vent. This is necessary to avoid personal injury from scalding coolant or steam.***

3. Open block drain located on right side of cylinder block.
4. Remove drain plug from engine oil cooler, if applicable.

### Cleaning and Flushing Cooling System

To clean rust and scale deposits from the cooling system, drain system (as previously described) and then fill with clean water and cleaner solution. Use an approved chemical cleaner (such as type used for cleaning automotive cooling systems) and follow instructions provided by the supplier.

**⚠WARNING** ***Cleaning solutions typically contain strong chemicals that can cause burns or other injury if used improperly. Read all warning labels carefully before using.***

When cleaning is complete, drain cleaning solution and flush system. For best results engine and radiator, or heat exchanger, should be reverse flushed. Allow engine to cool as much as possible before flushing with cold water.

**⚠CAUTION** ***Never pour cold water into a hot engine. Doing so may crack the head or the cylinder block. Do not operate engine without coolant for even a few minutes.***

Flush system if engine operation indicates clogged passages or overheating.

***To Flush Engine:***

1. Drain cooling system, remove thermostats, (re-install water outlet), and disconnect hoses at radiator or heat exchanger.
2. Close all drain plugs and attach flushing gun nozzle to water outlet. Restrict normal engine coolant inlet line opening until system fills with water, then apply air pressure gradually. Repeat the process until water from cylinder block flow is clean.

**⚠CAUTION** ***When flushing the cooling system using a flushing gun and air, do not exceed 50 kPa (7 psi) of air pressure. Excessive air pressure will damage the cooling system.***

3. Remove flushing gun.
4. Reinstall thermostats, hoses, drain plugs, and refill system with proper coolant.
5. When flushing is completed, check system thoroughly for any leaks uncovered by the cleaning operations.

***To Flush Radiator:***

1. Drain cooling system and disconnect radiator hoses at engine.
2. Secure flushing gun in radiator lower hose with a hose clamp.
3. Fill radiator with water. Be sure radiator cap is on tight. Direct upper radiator hose away from engine to minimize collection of water around engine.
4. Apply air pressure gradually to avoid damage to radiator.

**⚠CAUTION** ***When flushing the cooling system using a flushing gun and air, do not exceed 50 kPa (7 psi) of air pressure. Excessive air pressure will damage the cooling system.***

5. Shut off air pressure. Fill radiator with water again and apply air pressure; repeat until water comes out clean.
6. Remove flushing gun.

***To Flush Heat Exchanger:***

1. Drain cooling system and disconnect heat exchanger hoses at engine.
2. Secure flushing gun in lower heat exchanger hose with a hose clamp.
3. Fill heat exchanger with water. Make certain fill cap is on tight.
4. Apply air pressure gradually to avoid damage to heat exchanger.

**⚠CAUTION** ***When flushing the cooling system using a flushing gun and air, do not exceed 50 kPa (7 psi) of air pressure Excessive air pressure will damage the cooling system.***

5. Shut off air pressure. Fill heat exchanger with water again and apply air pressure; repeat until water comes out clean.
6. Remove flushing gun.
7. Disconnect sea water hoses at exhaust elbow and sea water pump.
8. Secure flushing gun in rear hose.
9. Fill heat exchanger core with water. Apply air pressure gradually to avoid damage to heat exchanger.
10. Shut off air pressure. Fill heat exchanger core with water and apply air pressure; repeat until water comes out clean.
11. Remove flushing gun.

### Engine Water Jacket and Cylinder Head

External coolant leakage may occur at any of the joints in the engine water jacket such as the drain plugs, core hole plugs, or cylinder head joint. Since expansion or contraction can aggravate leakage, the block should be inspected both hot and cold while the engine is running.

Internal leakage occurs when coolant passes into the engine oil through a loose cylinder head joint or a cracked or porous casting. The leakage is not visible but may cause extensive damage to the engine. Coolant mixes with the oil to form sludge which causes lubrication failure. Heavy sludge acumulations followed by sticking piston rings, valves, and tappets are symptoms of internal leakage.

Sometimes internal leaks are small enough to prevent coolant leakage but permit exhaust gases to enter the cooling system. The exhaust gases dissolve in the coolant, depleting the rust inhibitors and forming acid which causes corrosion.

## FILLING COOLING SYSTEM

1. Close all drains that were opened to drain system.
2. Fill system with a clean anti-freeze and water solution until level is approximately one inch below bottom of filler neck. To assure complete filling of the cooling system the cylinder head and block should be bled to prevent air lock. This can be done by loosening one of the plugs or senders located in the water pump before filling. When coolant appears, retorque plug to 17 Nm (150 in-lb) and finish filling. An additional pocket of air will remain in the cylinder head.

   In extremely low temperatures, -31°C (-25°F) or lower, it may be necessary to increase the percentage of anti-freeze to provide adequate protection against freezing. Follow suppliers recommendations to determine amount of anti-freeze needed for protection against the lowest temperature expected. Anti-freeze solution must be able to prevent freezing of cooling system during the coldest winter weather.

3. Start engine and operate for approximately 10 minutes or until thermostat opens. As coolant circulates, air trapped in cylinder head will be released.

**⚠WARNING** ***Contact with hot coolant can result in serious burns. Allow cooling system to cool before releasing pressure.***

4. Fill with additional coolant as required, so coolant level is maintained to within one inch of fill opening.
5. Shut down unit and replace pressure cap.

## THERMOSTAT

One or two thermostats may be used, depending on engine cooling requirements. When two thermostats are used, one is a bellows type and the other is a bellows type with bypass. If only one thermostat is used, it is the bellows type with bypass. The bypass thermostat is located in the thermostat housing, directly above the bypass passage.

The bypass thermostat is so positioned in system that when closed, coolant flow from engine to radiator is shut off. During periods of engine warm-up, coolant is directed from engine thermostat housing, through bypass passage in water pump housing, to inlet side of water pump. Coolant then flows through engine water jacket back to thermostat housing. When coolant temperature reaches engine operating temperature the thermostat(s) starts to open. As the thermostat(s) opens allowing coolant to flow through radiator, the bypass closes.

Replace thermostat if it is broken, corroded, or sticks in the open or closed position. If engine overheats or does not reach and maintain a minimum operating temperature, the thermostat should be removed and tested as a possible cause. Engines must not be operated without thermostat(s) or with incorrect thermostat(s) installed.

### Removal

1. Drain cooling system.
2. Remove capscrews that secure thermostat cover to water pump housing.
3. Raise thermostat cover with radiator hose intact and position it to one side.
4. Remove thermostat cover gasket and thermostat.
5. Clean, inspect, and remove any gasket material from the thermostat cover and housing.

### Testing

Nominal operating temperature of the thermostat is stamped on thermostat body. Note this nominal temperature before using.

1. Suspend thermostat in a pan of clean water. Thermostat must be completely immersed but not touching bottom of pan.
2. Heat water gradually and stir so heat is evenly distributed. Check water temperature with a reliable thermometer.
3. Observe thermostat as temperature of water rises. If it is functioning properly, it should begin to open when the water temperature is within plus or minus 3° C (5° F) of the nominal temperature. Thermostat should be fully open at about 12° C (22° F) above the nominal temperature.
4. The thermostat is not adjustable. If it does not operate within the above limits, it must be replaced.

### Installation

1. Install bypass thermostat in thermostat housing so bypass plate is positioned above bypass opening. In large body water pumps, install the other thermostat in housing.
2. Place a new thermostat cover gasket on top of housing.
3. Inspect thermostat cover and clean if necessary.
4. Position thermostat cover on housing and secure with capscrews.
5. Refill cooling system with the appropriate mixture of coolant.

## DRIVE BELTS

The alternator, water pump, and fan (if used) are driven simultaneously by the crankshaft pulley through either a single belt or a matched pair of belts.

### Removal, Inspection, and Installation

1. Remove fan guard or shroud, if applicable.
2. Loosen capscrews that secure alternator to mounting brackets. Push alternator in so fan belt or belts can be removed from alternator pulley. Slip belts from water pump pulley and over fan blades. Remove belts.
3. Inspect fan belts for excessive slickness, oil soak, wear, tear, cracks, and overstretching. Replace belts if they are damaged, badly worn, or soaked with grease and oil. When a matched pair of belts is used and only one needs replacement, both belts must be replaced to assure satisfactory belt performance.
4. Install fan belts by slipping belts over fan blades and into pulley grooves.
5. Adjust belts and replace any parts removed to gain access to belts.

### Adjustment

1. Inspect belts frequently and replace belts if they are oil soaked, damaged, or badly worn.

2. Check tension of fan belts. With engine stopped fan belt tension should be:

| | |
|---|---|
| Single belt | 267 N (60 pounds) |
| Dual belts | 222 N (50 pounds) |

3. To obtain proper belt tension, loosen alternator adjusting bracket and mounting capscrew and move alternator in or out as required (Figure 1).

4. Retighten adjusting bracket and mounting capscrew.

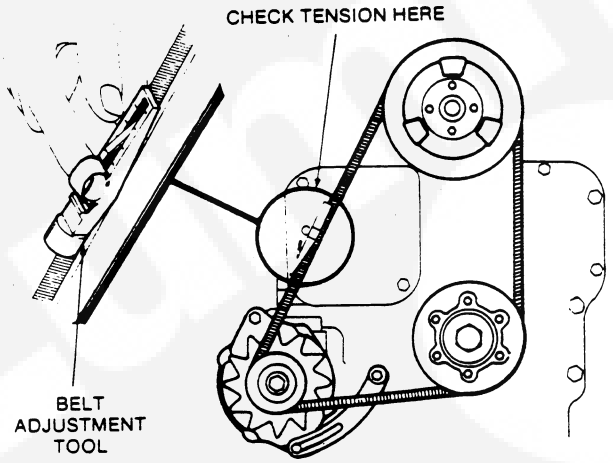



**FIGURE 1. FAN BELT ADJUSTMENT**

## ENGINE WATER PUMP

Two sizes of water pumps along with two different impellers for each pump and a variety of pulleys are used on L engines, depending upon the cooling requirements.

A centrifugal type water pump (Figure 2) circulates coolant through cooling system. The water pump is secured to cylinder block with three capscrews and is belt driven from the crankshaft pulley. Coolant is drawn through pump inlet opening by the impeller and forced through outlet opening in backside of pump into cylinder block. A gasket on water pump outlet assures a leakproof connection. An O-ring is used to seal cylinder head coolant outlet to thermostat housing.

The water pump shaft and bearing assembly is sealed and does not require additional lubrication. A drilled opening in the pump body provides a drain for any coolant which might seep past seal assembly. This prevents coolant from coming in contact with water pump bearing and relieves pressure build-up on seal back. The shaft and bearing assembly is secured in pump body by a press fit. The seal assembly is spring loaded and is pressed into pump body, forming a leakproof seal at this point. Proper positioning of impeller on shaft creates a load on seal assembly, forming a tight seal.

A pulley hub, pressed on front end of water pump bearing and shaft assembly, serves to mount the pulley.

### Service

The water pump is constructed to provide long life with a minimum amount of attention when proper corrosion preventive coolant is used. Care must be taken to keep grit and abrasive material from being circulated through cooling system. Water containing scale-forming materials is especially harmful to pump parts.

### Inspection

The pump cannot be rebuilt and must be replaced as a unit. Check condition of bearing and shaft assembly by turning water pump pulley. If bearing feels rough or binds, seal is leaking, or housing is cracked, the pump must be replaced.

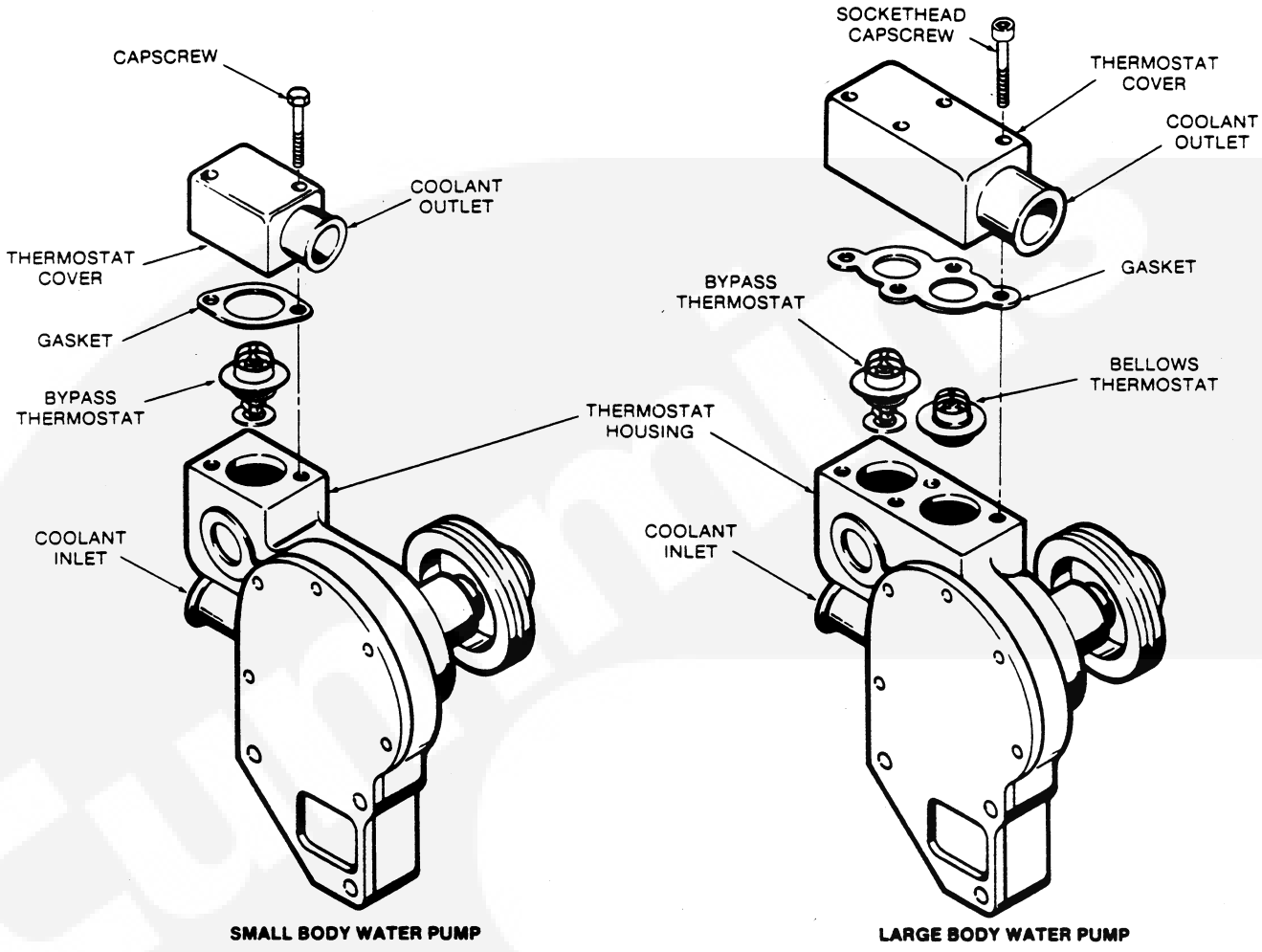



**FIGURE 2. WATER PUMPS**

## Removal

1. Drain cooling system. Refer to procedure outlined earlier in this SECTION.
2. Remove hose clamps and hoses from the water pump inlet and thermostat housing outlet.
3. Determine if radiator must be removed in your application before removing water pump. Remove radiator and fan shroud if necessary.
4. Loosen alternator capscrew at slotted end of mounting bracket. Push alternator in to relieve tension on belts and remove belts.
5. Loosen capscrews that secure fan and pulley to water pump hub.
6. Remove capscrews, fan, and pulley from water pump hub.
7. Remove capscrews and washers that secure water pump to cylinder block and remove water pump.

## Installation

1. Install O-ring and apply a small amount of grease to O-ring and groove in water pump adapter on cylinder head.
2. Place new gaskets on water pump and spacer. Install pump assembly, securing with the three capscrews.
3. Install pulley and fan to pulley hub using capscrews and flat washers.

   **⚠CAUTION** ***Use capscrews of the correct length to mount pulley and fan. Refer to the appropriate PARTS CATALOG for correct capscrew. Capscrews must thread all the way into water pump hub without coming in contact with water pump housing.***

4. Install fan belts. Adjust fan belt tension and tighten capscrew on alternator bracket. Refer to *Fan Belt Adjustment* procedure.
5. Install radiator and shroud if they were removed during the disassembly. Install radiator inlet and outlet hoses and clamps.
6. Fill cooling system. Refer to *Filling Cooling System* procedure.

## RADIATOR COOLED SYSTEM

The radiator cooling system includes the water pump, thermostat housing, engine oil cooler (if applicable), radiator, hoses, cooling fan, pulleys, engine coolant temperature gauge, and water passages in the cylinder block and cylinder head.

A pressure cap pressurizes the cooling system which raises the normal boiling point of clean water at sea level (100° C/212° F) approximately 1.7° C per 6.9 kPa (3° F per psi). Operating temperatures above the coolant's boiling point will cause loss of coolant and result in engine overheating. Altitude also affects the point at which coolant will boil. The higher the altitude, the lower the temperature at which coolant boils. To estimate coolant boiling point at various altitudes above sea level, deduct .8° C per 304.8 m (1.5° F per 1000 ft.) from the boiling point established with a pressure cap at sea level.

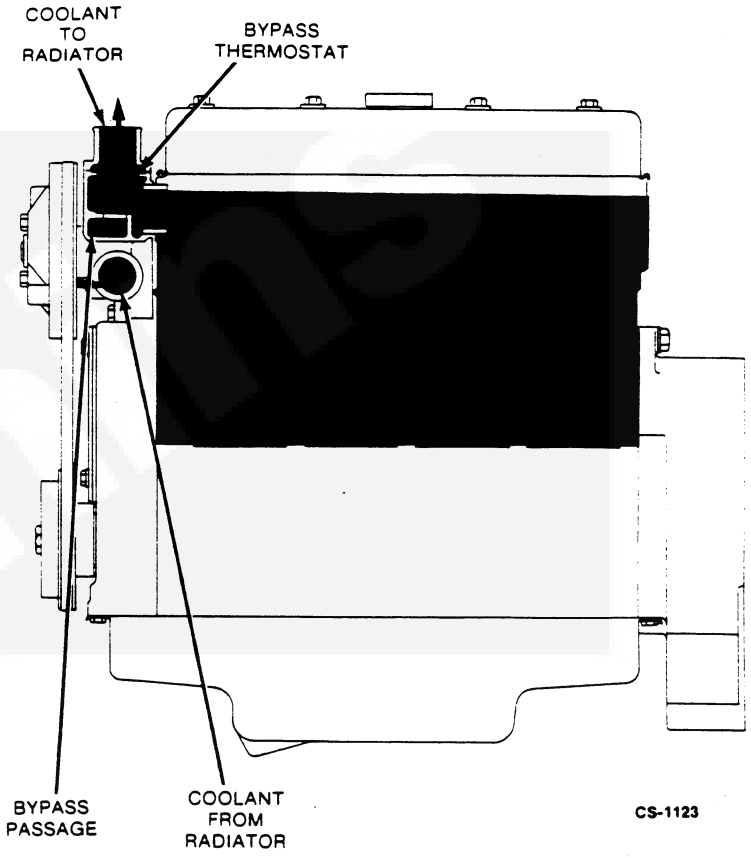



**FIGURE 3. ENGINE COOLANT CIRCULATION**

### Coolant Circulation

The water pump draws coolant from the radiator through lower hose and forces it into the cylinder water jacket. Coolant circulates through cylinder water jacket, cylinder head, and thermostats and flows back into the radiator. Coolant then circulates down through the radiator while the fan blows or draws air across radiator. Coolant is again drawn from the radiator to be recirculated.

During engine warm-up the thermostat is closed, causing coolant to bypass the radiator. Coolant flows through a bypass passage (Figure 3) in water pump housing to the water pump inlet and recirculates through the engine until it reaches normal operating temperature. Recirculation ensures a rapid and even temperature rise of all engine parts durig warm-up. When the thermostat opens, this bypass is blocked. Coolant then circulates through the radiator and engine.

The water pump used on L engines is a cetrifugal type. It mounts on the front of the engine cylinder block and is driven by a belt (or belts). Inlet to the pump is from the lower radiator hose or thermostat bypass passage. Outlet is through the water pump housing into the cylinder water jacket.

## Fan and Pulley

The engine may be equipped with either a pusher type or suction type fan, depending on application. The fan pushes or pulls (depending on type used) air through the radiator. Engine coolant is cooled as it circulates through the radiator core. The fan, fan spacer, and fan pulley are bolted to pulley hub, which is pressed on the water pump shaft.

Fan blades seldom require service unless damaged. Bent blades cause inefficient cooling and affect fan balance. An unbalanced fan mounted on the water pump will damage the water pump bearing. In case of damage, the fan should be removed and replaced with a new fan.

***Removal, Inspection, and Installation:*** The cooling system may have to be drained and radiator removed prior to removing fan and pulley, depending upon clearance between fan and radiator.

1. Loosen fan belts so belts can be removed from water pump pulley.
2. Remove capscrews and washers that secure fan and fan spacer to pulley hub. Remove fan and fan spacer.
3. Slide fan belts off water pump pulley, and remove pulley from water pump hub.
4. Inspect fan for cracks, loose rivets, or bent blades. Replace fan if any of these conditions exist.
5. Inspect fan spacer and water pump pulley for wear or damage. Replace if necessary.
6. Position fan spacer and water pump hub and place fan belts in pulley grooves.
7. Install fan spacer and fan, securing with capscrews and washers.
8. Adjust alternator and fan belts to the proper tension.
9. Install radiator and fan shroud. Refill the cooling system if necessary.

## Radiator

For cooling fan to provide positive air flow through the radiator core, a fan shroud is often used behind radiator to direct air flow. An overflow tube is normally connected to the radiator filler neck.

***Inspection and Repair:***

1. Use a pressure washer to clean radiator exterior and to remove all foreign material from between cooling cores and fins. Be careful not to bend fins. Straighten any that may be bent.
2. Inspect radiator for clogging or leakage. The radiator should be repaired only by qualified personnel. Test radiator under water with compressed air at not more than 50 kPa (7 psi). Note location of any air bubbles and solder leaks.
3. Inspect hoses for any deterioration or damage. Replace as necessary.

***Pressure Cap:*** A pressurized system permits operation of an engine at a higher temperature without boiling off the coolant or losing it by evaporation. A pressure cap permits coolant or steam to escape when system pressure exceeds the pressure cap rating. Boiling point of coolant increases as pressure increases. To prevent damage to the cooling system from either excessive pressure or vacuum, check the cap periodically for proper opening and closing pressures. If pressure cap is defective, replace it. A pressure cap cannot be repaired.

## MARINE COOLING SYSTEM

All Onan L Series Marine Diesel Engines make use of flotation water for exhaust and heat exchanger cooling. Although flotation water may be an ocean, lake, or river, the term "sea water" is used to describe any flotation water that is drawn into the boat for cooling purposes. Engine coolant circulating through a closed system is called "captive" water.

The heat exchanger cooling system was developed to keep sea water, and the resulting sediment deposits (salt, silt, etc.), from the engine cooling jacket. This system has a fixed quantity of captive water in a closed system to cool the engine. Sea water cools the captive water in the heat exchanger. Sea water and captive water are kept separated, so the engine water jacket stays clean.

Because marine engines operate typically in very small compartments, it is important that the heat radiated from the exhaust system be kept to a minimum. To accomplish this, the heated sea water is discharged through the exhaust system. Special mufflers, pumps, and anti-siphon devices are required to avoid interference with the passage of exhaust gases and to prevent entry of sea water into the combustion chamber.

## HEAT EXCHANGER COOLING SYSTEM

Heat Exchanger Cooling has two separate water systems, a captive water and a sea water system. The metal impeller pump (engine water pump) circulates captive water through cylinder head, engine block, heat exchanger shell, water-cooled exhaust manifold, and expansion tank.

A rubber impeller pump circulates sea water through the heat exchanger core (cooling the captive water) and out through the water-cooled exhaust. Figure 4 shows a schematic of a typical marine heat exchanger cooling system.

### Water Flow

During normal operation, marine cooling systems take in more dirt and sediment than a radiator cooled system. This contributes to water pump wear and increases the possibility that water passages will become clogged or restricted. It is very important that water flow be checked frequently to insure that adequate cooling is maintained.

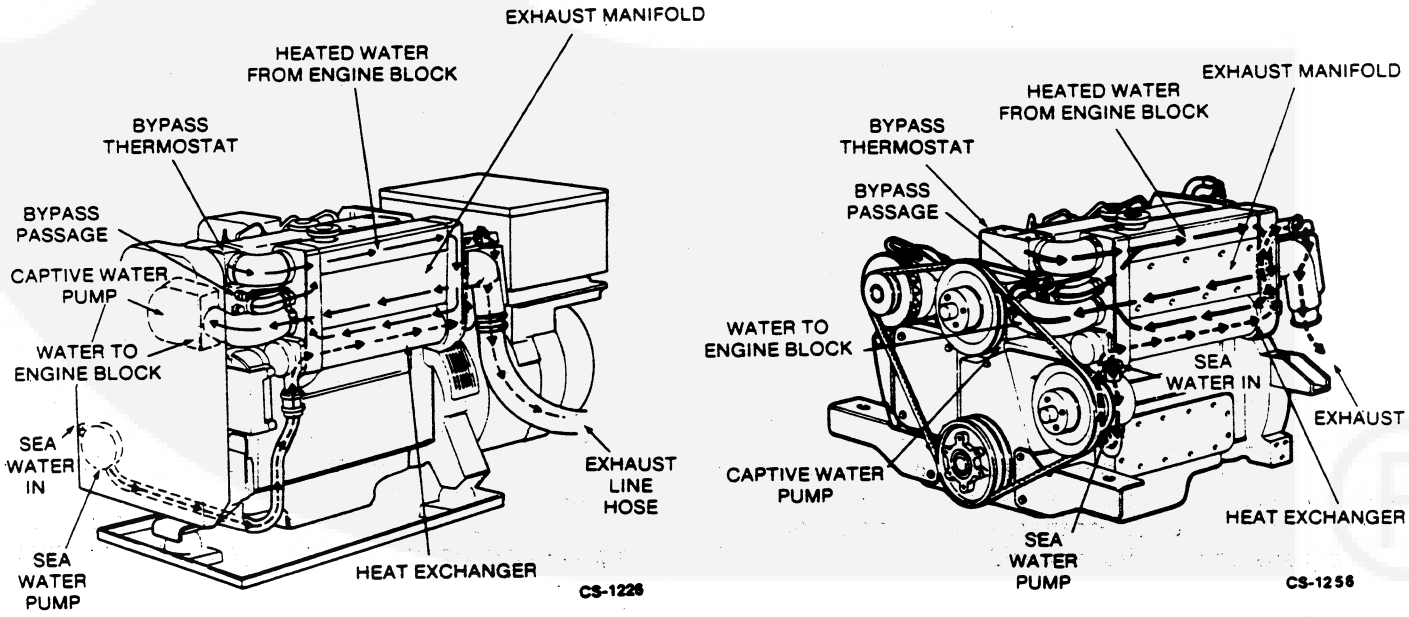



**FIGURE 4. HEAT EXCHANGER COOLING**

### Sea Water

The heat exchanger cooling system requires a continuous flow of sea water for adequate cooling. Anything that reduces or blocks the flow of water in the sea water system may cause overheating. Remove the filter screen from the inlet water filter on a periodic basis and clean away any accumulations of dirt and sediment. Flush clean water through the screen before replacing the filter. Check all hoses and pipes to make sure there are no kinks and bends that could restrict water flow.

When the boat is dry docked, the water inlet strainer (normally located on outside of hull) should also be checked for accumulations of debris and cleaned if necessary. The water inlet should not be directly in line with other water inlets as this could reduce the amount of water received by the unit when the boat is underway. If more than one inlet is present, they should be staggered.

**⚠CAUTION** ***Do not use a scoop-type water inlet fitting. When the boat is underway and the engine is not running, sufficient ram pressure can force water past the sea water pump, flooding the exhaust system, and possibly flooding the engine cylinders.***

Before starting, the sea water pump should be primed and checked for water flow. The pump is primed by removing the outlet hose from the pump connection. Fill the pump and hose with water and replace the components. With the engine running, check the exhaust outlet to verify that the pump is delivering water. An insufficient flow of water indicates that there are obstructions in the system, the water pump belt is loose, or the water pump is faulty. Inspect and replace any hoses or pipes that have become restricted or blocked.

### Captive Water

On marine cooled systems the engine water pump is used to circulate engine coolant continuously through the engine water jacket to heat exchanger. Check all hoses for kinks or bends that could restrict water flow and make any repairs required.

### Water Cooled Exhaust

The marine exhaust system is designed so that a minimum amount of heat is radiated from exhaust system components. This is done to keep the heat build-up in the engine compartment to a minimum. Exhaust heat is dissipated by using a water cooled exhaust manifold and a water injected exhaust pipe and muffler system. The exhaust manifold is encased in a shell through which engine coolant or sea water is circulated. Just beyond the exhaust manifold, a special elbow is fitted which allows the output water from the sea water system to be injected into the exhaust pipe. The injected sea water is carried out through the exhaust system and discharged into the flotation water.

### Marine Water Pumps

Two types of marine water pumps are used: the metal impeller engine (captive) water pump and the neoprene impeller (sea) water pump. Two types of pumps are necessary because the water pumps are used to perform different functions in the cooling system. Metal impeller pumps provide no suction lift but can operate in hot or cold water. Neoprene impeller pumps provide a suction lift but can be used only with clean cool water. Metal impeller pumps are used for the captive water system and neoprene impeller pumps are used for the sea water system. All marine water pumps are driven by a belt from the engine crankshaft.

***Captive Water Pump:*** Check captive water pump for wear or signs of leakage from the shaft seal. Loosen drive belt and move the water pump pulley back and forth. Pulley should be tight on the shaft and only a slight amount of bearing play should be felt. Remove pump if wear is excessive or if the seal leaks. Refer to *Engine Water Pump Removal and Installation* procedures.

***Sea Water Pump:*** The mounting location and size of the sea water pump may vary depending upon the cooling and installation requirements of the application. Check sea water pump for wear or signs of leakage from the shaft seal. Loosen drive belt and move the water pump pulley back and forth. Pulley should be tight on the shaft and only a slight amount of bearing play should be felt. Remove pump for repair or replacement, if leakage or wear is detected.

***Removal and Installation:***

1. Remove capscrew that attaches water pump to adjusting bracket and loosen capscrew that secures water pump to mounting bracket.
2. Remove drive belt from pulley.
3. Loosen clamps and remove coolant hoses from water pump. Remove capscrews attaching pulley to water pump hub.
4. Remove capscrew attaching water pump to mounting bracket.
5. Install water pump by reversing removal procedure.
6. Adjust belt tension. Refer to *Drive Belt Adjustment* procedure.

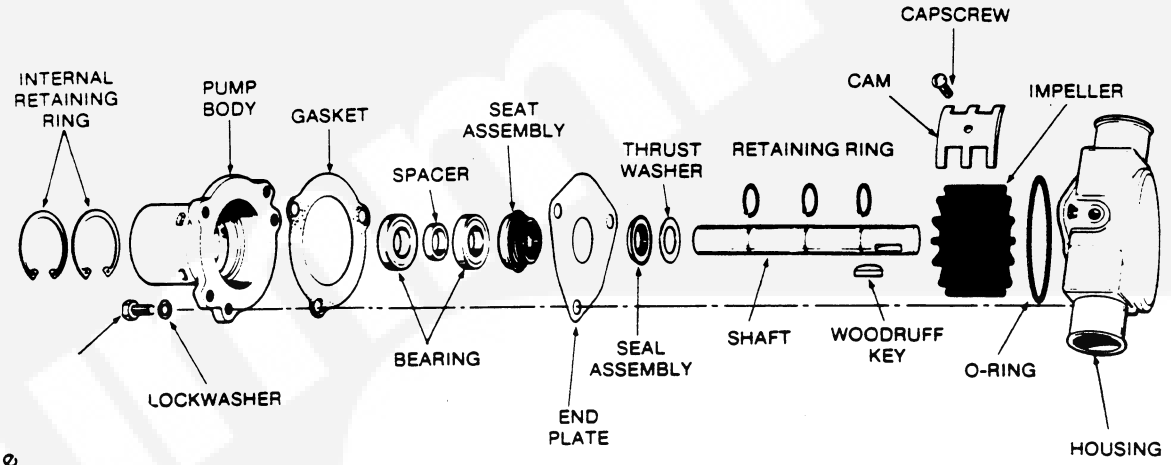



**FIGURE 5. SEA WATER PUMP**

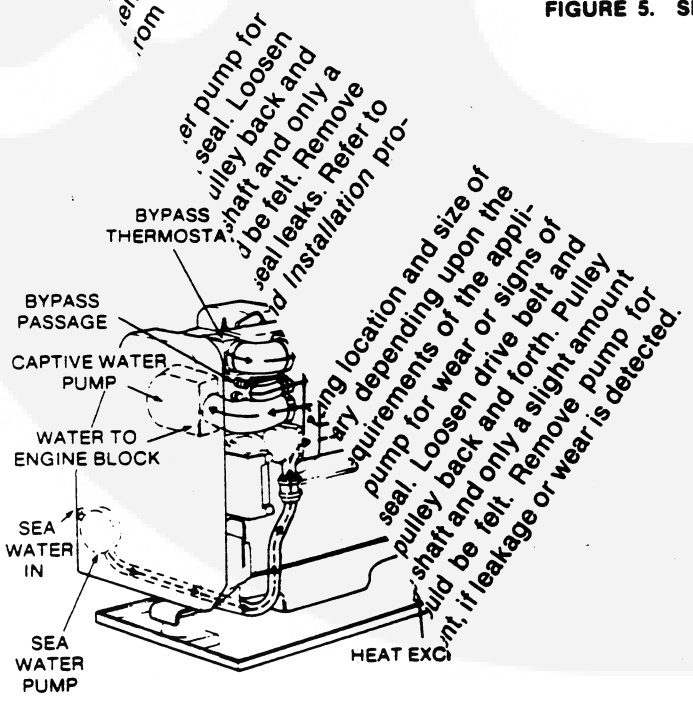



**FIGURE 4.**

***Inspection:*** It may not be necessary to disassemble the pump entirely unless a complete rebuild is required. First determine cause of pump failure.

| TROUBLE | CAUSE |
|---|---|
| ·ump or | Worn or broken impeller, cam, or cover. |
| ·ain | Worn seal. |
| | Worn bearing or shaft. |

·t be replaced together. Do · without the other. Inspect acking and signs of wear. The riorates with time due to contin- g and must be replaced period- npeller blades have broken, locate ove the particles or they will impede ater flow. Particles will normally be d at inlet to heat exchanger.

pect the pump body and housing for wear, ugh surfaces, or pitting and replace if any of these conditions exist. Always use a new end plate gasket and housing O-ring seal when assembling pump.

***Assembly:***

1. Apply Permatex No. 1 on the backside of cam and on cam retaining capscrew threads. Install cam in pump housing. Remove any Permatex that has gotten into impeller cavity.
2. Install a retaining ring on the shaft in the second groove from the keyway.
3. Press a ball bearing onto the shaft. (Push the bearing on from the pulley hub end.) Push bearing up against retaining ring. Press only on the inner bearing race.
4. Place a spacer on the shaft against the bearing. Press the second ball bearing onto the shaft. Install a retaining ring over the shaft against the second ball bearing.
5. If large internal retaining ring has been removed from impeller end of pump body, it must be installed at this time.
6. Press mechanical seal into pump body from the impeller end. Make certain mechanical seal is pressed in straight.
7. Push the bearing and shaft assembly into pump body (impeller end first). Lock the bearing assembly in place by installing the other large internal retaining ring.
8. Install seat assembly, thrust washer, and retaining ring over shaft from the impeller end. Lubricate rubber part of seat with clean engine oil. Install seat assembly with white ceramic surface against the seal.
9. Press brass woodruff key into pump shaft.
10. Install impeller in pump housing. Lubricate impeller with a silicone release agent such as Dow Corning "Slipicone".
11. Place O-ring in groove of pump housing.
12. Position gasket and end plate on the pump body and line up capscrew holes.
13. Install pump housing with impeller, on pump body and secure with capscrews.

## Heat Exchanger

L Series Diesel Engines use a water cooled exhaust manifold with integral heat exchanger and expansion tank. This minimizes the number of hoses and connections required.

The number of tubes in the heat exchanger core will change depending upon the cooling requirements of the application. When replacing heat exchanger core, always replace with one of the same size.

# 10. Fuel System

## ENGINE EXHAUST EMISSION CONTROL INFORMATION LABEL

The Important Engine Information Label is located on the engine valve cover of every EPA certified heavy duty engine produced by Onan Corporation. The label contains important emission specifications and setting procedures.

When servicing the engine or emission system, the Important Engine Information Label should be checked for up-to-date information.

**⚠CAUTION** ***Adjustments made by non-qualified personnel may violate Federal, state, and/or local regulations. Emissions and mechanical warranty may also be voided by adjustments made to injection pump and aneroid by non-qualified personnel.***

## FUEL SYSTEM OPERATION

The fuel system consists of a fuel tank, water separator or fuel sediment bowl, transfer pump, combination primary and secondary fuel filter, fuel injection pump, fuel injection nozzles, and fuel lines. There are two fuel pressure systems, the low pressure and high pressure.

The low pressure system consists of fuel tank, water separator or fuel sediment bowl, fuel filter, transfer pump, fuel lines between fuel tank and injection pump, and fuel return lines.

The high pressure system begins in the fuel injection pump where cam-actuated plungers force fuel into the outlet ports. From the outlet ports fuel travels through the high pressure fuel lines to the injection nozzles.

Fuel is drawn by the transfer pump from fuel tank through the sediment bowl or water separator, then forced through the fuel filter to the injection pump. A vane type transfer pump in injection pump forces fuel to the cam-actuated plungers, which in turn force fuel under high pressure through the fuel lines to the injection nozzles from which fuel enters the combustion chambers in a fine cone shaped spray.

The fuel transfer pump delivers more fuel to injection pump housing than is required for engine operation. A line from the top of fuel injection pump returns surplus fuel back to the fuel tank.

Lubrication for injection nozzles is provided by fuel seepage between the lapped surfaces of each nozzle valve and its body. Leaked fuel accumulates around spindle in the spring compartment of each nozzle holder, and is returned to fuel tank through a fuel return line.

A regulating valve in the injection pump allows a large share of fuel to be bypassed back to pump inlet side. The fuel bypassed increases in proportion to engine speed. The regulating valve is designed so transfer pump pressure increases with engine speed.

Care must be taken in the storage of fuel, transfer of fuel to fuel tank, and in keeping fuel tank full to prevent condensation. Dirt and water entering fuel system will damage fuel injection pump and injection nozzles. The fuel filter is installed in fuel system to clean the fuel before it enters fuel injection pump.

**⚠WARNING** ***Ignition of fuel can cause serious personal injury or death by fire or explosion. Do not permit any flame, cigarette, or other igniter near the fuel system.***

## FUEL FILTER

The combination primary and secondary fuel filter is a disposable type. Any dirt that passes through the primary section is trapped by the secondary section, this prevents dirt from entering fuel injection pump.

### Replacement

1. Close fuel tank shut off valve.
2. Clean all dirt from around filter, filter base, and surrounding area.
3. Remove filter retaining clip or clips from fuel filter.
4. Remove old filter and dispose of it properly.

**⚠CAUTION** ***Due to the precise tolerances of diesel injection systems, it is extremely important the fuel be kept clean and free of water. Dirt or water in the system can cause severe damage to both the injection pump and the injection nozzles.***

5. Install new fuel filter and prime fuel system.

### Fuel System Priming

The fuel system must be primed: (1) whenever filter is changed, (2) if there is air in lines, (3) engine has run out of fuel, or (4) prior to initial start-up. For additional priming information see *SECTION 6, START-UP.*

1. Priming (transfer pump, fuel filter, and injection pump housing) low pressure fuel system.

**⚠CAUTION** ***Due to the precise tolerances of diesel injection systems, it is extremely important the fuel be kept clean and free of water. Dirt or water in the system can cause severe damage to both the injection pump and the injection nozzles.***

A. Check fuel level in fuel tank and open shut off valve.
B. Loosen low pressure injection pump line at injection pump fitting.
C. Actuate the fuel priming lever on side of transfer pump until fuel flows from fitting. If the camshaft transfer pump lobe is up, crank engine one revolution to permit hand priming.
D. Tighten fuel line at injection pump inlet.

2. Priming High Pressure Fuel System

This part of the system is usually self-priming since any air trapped in injection lines is usually forced out through injection nozzles. If, however, engine has run out of fuel, been shut down for an extended period, or has had fuel injection lines removed, it may be necessary to prime as follows:

A. Loosen fuel injection line connecting nut, attaching each line to corresponding nozzle holder.
B. Place speed control in high speed position and stop control in RUN Position.
C. Energize starting motor. (Do not operate starting motor for more than 30 seconds at a time without pausing two minutes to permit starter to cool.)
D. When fuel flows from the end of all high pressure fuel injection lines, stop starting motor and tighten connection nuts.

**⚠WARNING** ***Keep hands away from spray. The discharge pressure can penetrate the skin and can cause blood poisoning or a serious skin infection.***

## FUEL INJECTION PUMP

Purpose of the injection pump is to meter and deliver fuel accurately under high pressure to injection nozzles during the required injection period. The pump is self-lubricating, except for the drive shaft bearing which is splash-lubricated by engine oil.

**⚠WARNING** ***Onan recommends that all aneroid and injection pump service and adjustments be done by qualified injection pump service personnel. From the stand point of possible injury and/or equipment damage, it is imperative that service personnel be qualified.***

Before leaving the factory, all engines are equipped with carefully calibrated fuel injection pumps which have been adjusted to a factory approved power setting.

No lubrication or regularly scheduled service, other than operational checks, are required on the injection pump. If engine speed is irregular, check fuel system and all other engine adjustments before having a factory trained mechanic adjust fuel injection pump settings.

The injection pump is driven by a gear that is secured to the pump drive shaft with a hex nut. The injection pump drive gear is driven by the idler gear, which in turn is driven by the crankshaft gear.

## STANADYNE DB2 INJECTION PUMP

The Stanadyne DB2 fuel injection pump incorporates inlet metering and opposed plungers actuated by an internal cam ring with automatic advance.

To understand the operating principles of the DB2 pump one has to become familiar with the main components and their functions. Refer to Figure 1 for injection pump components.

The main rotating components are the drive shaft, transfer pump blades, distributor head, rotor, and governor.

The pump drive shaft passes through the governor thrust sleeve and washer into the distributor rotor in the hydraulic head. The driven end of the rotor incorporates two pumping plungers.

The plungers are pushed towards each other at the same time by an internal cam ring through rollers and shoes that are carried in slots in the rotor.

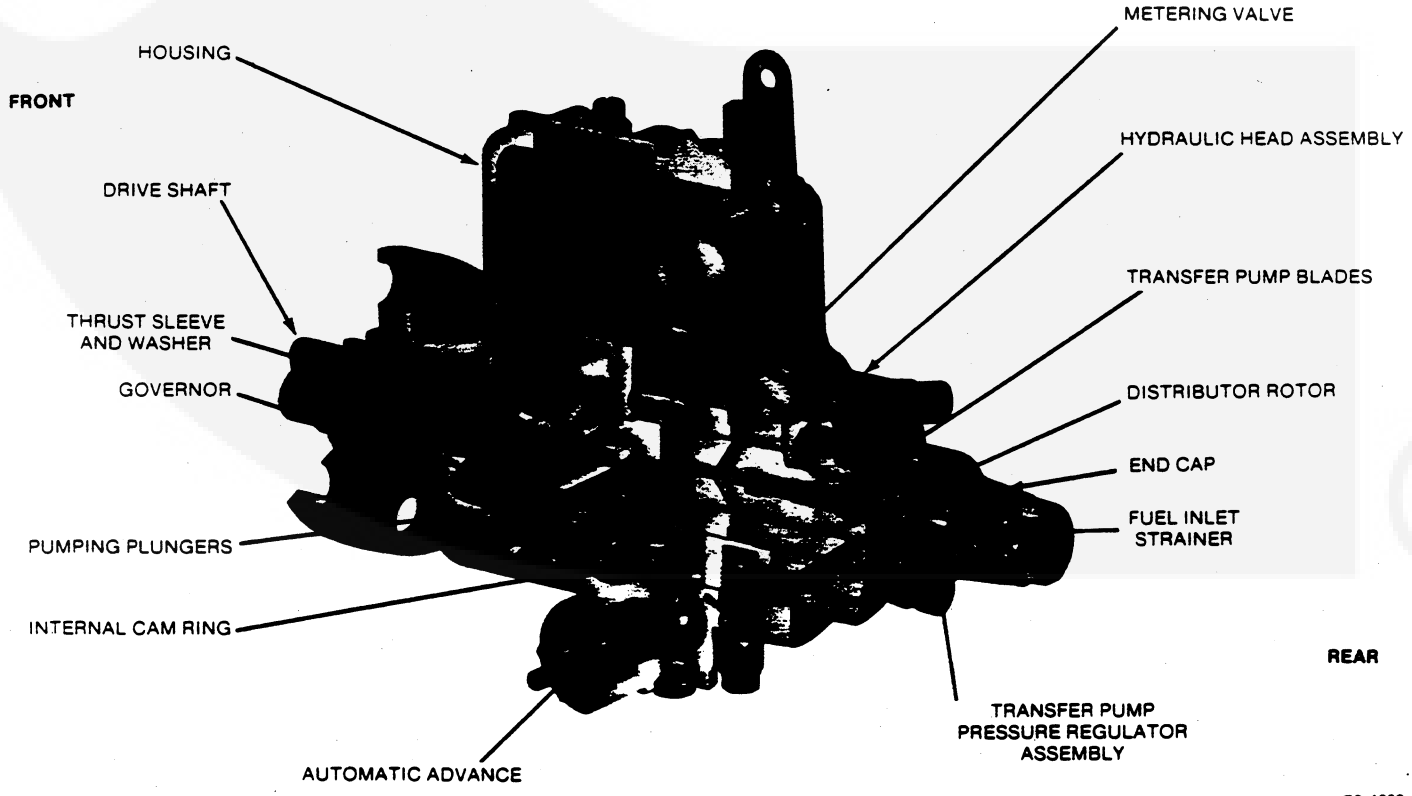



**FIGURE 1. INJECTION PUMP COMPONENTS**

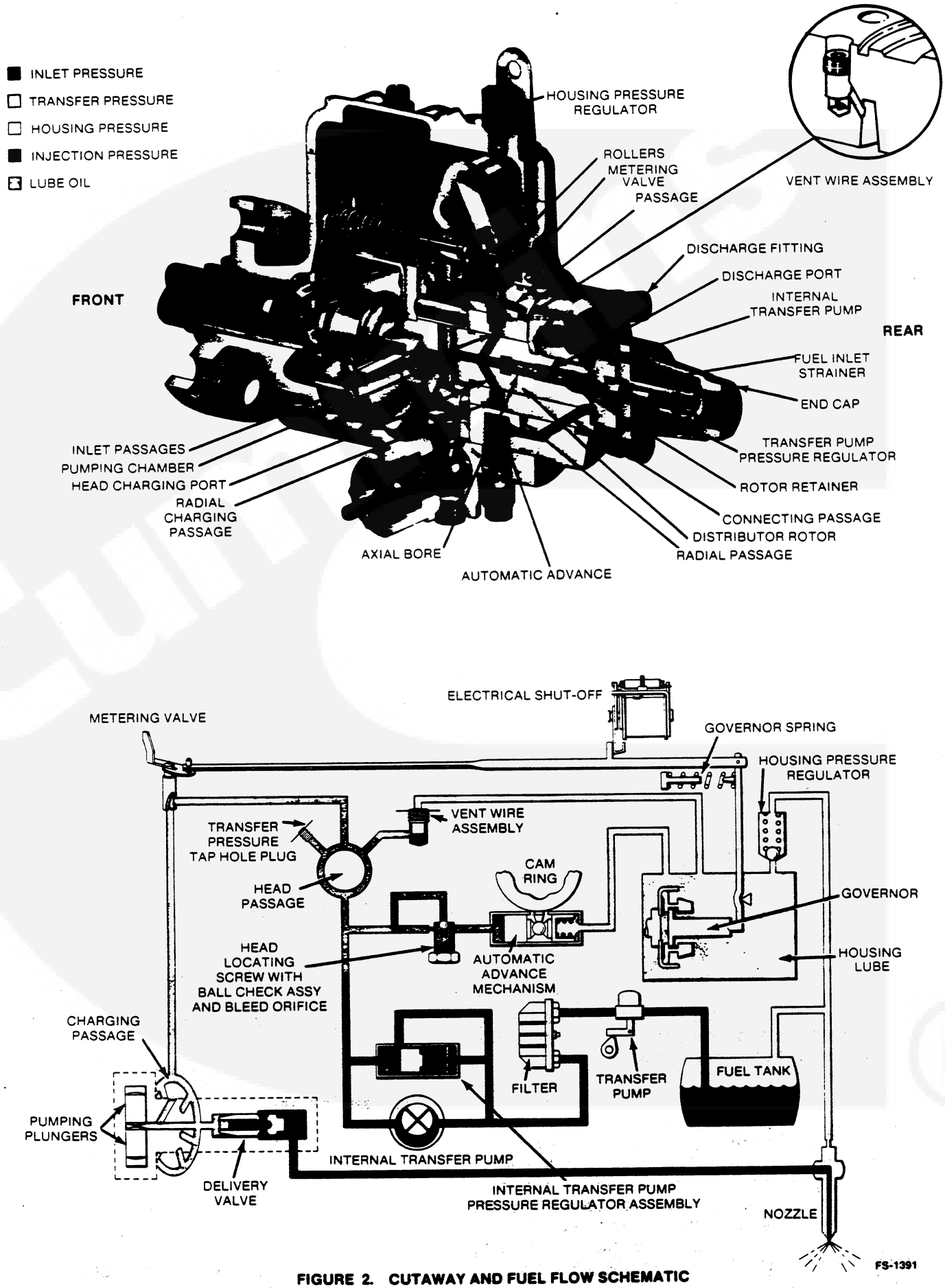



**FIGURE 2. CUTAWAY AND FUEL FLOW SCHEMATIC**

The internal transfer pump (Figure 2) located at the rear of the rotor, is a positive displacement vane type and is enclosed by the end cap. A fuel inlet strainer and transfer pump pressure regulator are also located under the end cap. The distributor rotor has two radial charging passages and a single axial bore with one discharge port to service all discharge fittings to the injection lines.

The hydraulic head assembly (Figure 1) contains the bore in which the rotor turns, metering valve bore, charging passages, and discharge fittings. Injection nozzle high pressure lines are fastened to the discharge fittings.

A mechanical-centrifugal type governor controls fuel delivery and, therefore, maintains the desired engine speed within the operating range under various load settings. The governor is driven directly off the pump drive shaft without gearing. Governor weight centrifugal force is transmitted through a thrust sleeve to the governor arm linkage and metering valve. The metering valve can be closed to shut off fuel supply to the distributor rotor (Figure 6).

The electric solenoid within the injection pump opens or closes the metering valve to permit or stop the flow of fuel. De-energizing the solenoid shuts off fuel delivery and stops engine, since solenoid is of the energized-to-run type (opens metering valve when energized). An optional energized-to-stop fuel solenoid is used in some marine applications.

***Fuel Flow:*** The mechanical or electric transfer pump pulls fuel from the fuel tank (Figure 2). The transfer pump pushes fuel through the filter, where it is cleaned. The fuel is then pushed on to the injection pump where it is pressurized and delivered to each injection nozzle. Injection pump operating principles are better understood by following the fuel circuit during a complete pump cycle (Figure 2). Also, see exploded view of rotor assembly (Figure 3).

Fuel is drawn from the filter through the fuel inlet strainer by the vane type internal transfer pump. Some fuel is bypassed through the pressure regulator assembly to suction side of pump.

Fuel, under transfer pump pressure, flows through the center of transfer pump rotor, past rotor retainers into a circular groove on rotor. Fuel then flows through a connecting passage in pump head to the automatic advance and up through a radial passage to the metering valve. Position of metering valve controlled by the governor, regulates fuel flow into the charging passage, which includes the head charging ports.

As rotor turns, two rotor inlet passages register with the charging ports in pump head, allowing fuel to flow into pumping chamber. With further rotation, inlet passages move out of registry and the discharge port registers with one of the discharge fittings. While the discharge port is open, cam rollers (Figure 5) contact the internal cam ring lobes, forcing plungers together. Fuel trapped between plungers is then pressurized and delivered to the combustion chamber.

Self-lubrication of the pump is an inherent feature of the DB2 design. As fuel at transfer pump pressure reaches charging ports, slots on rotor allow fuel and any trapped air to flow into the pump housing.

A vent wire assembly in the hydraulic head connects outlet side of transfer pump with pump housing. This allows air and some fuel to be bled back to fuel tank through the fuel return line. The bypassed fuel fills pump housing, lubricates internal components, cools, and carries off any small air bubbles in the pump. The pump operates with housing completely full. A housing pressure regulator (check valve) in the fuel return line fitting maintains a housing pressure of 55 to 69 kPa (8 to 10 psi). There are no dead air spaces anywhere in pump.

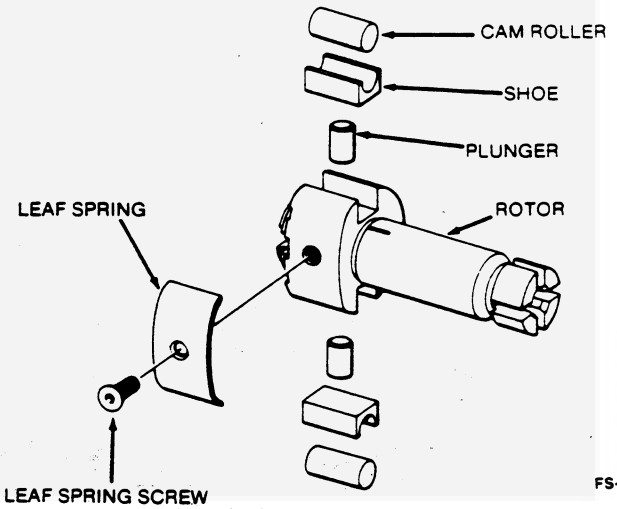



**FIGURE 3. ROTOR ASSEMBLY**

***Charging Cycle:*** As distributor rotor revolves, two inlet passages in rotor line up with the circular charging passages (Figure 4). Fuel controlled by the opening of metering valve, under transfer pump pressure, flows into pumping chamber forcing plungers apart.

The plungers move outward a distance equal to the amount of fuel required for injection on the next stroke. At idle, when only a small quantity of fuel is admitted into pumping chamber, plungers move out a short distance. Maximum plunger travel and fuel delivery is limited by the leaf spring contacting roller shoe edges. When engine is operating at full load the plungers move to the most outward position. Note that while rotor inlet passages are in registry with the ports in charging passage, rotor discharge port is not in registry with a head outlet, also the rollers are off the internal cam ring lobes.

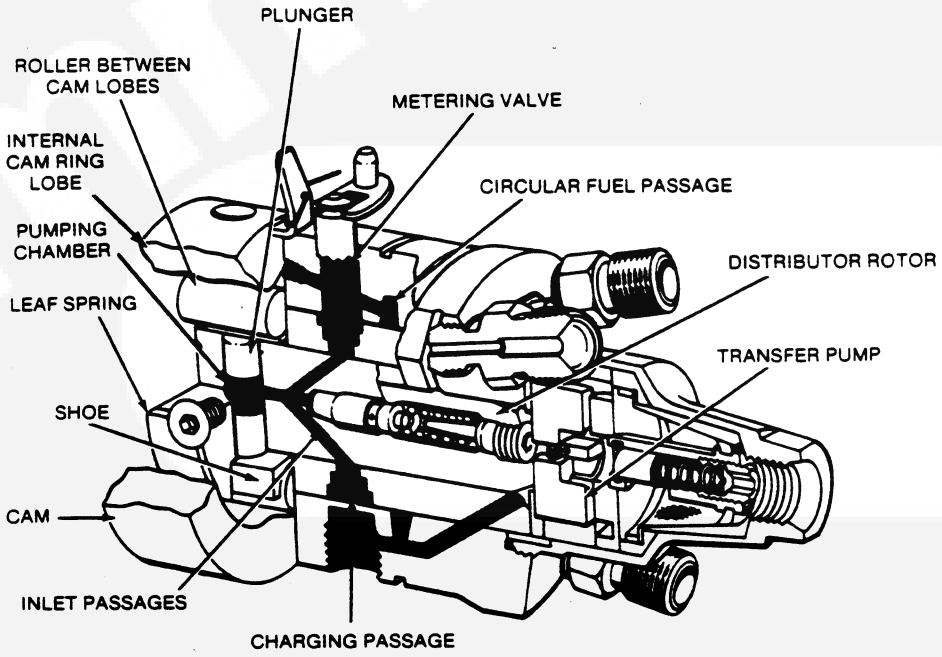



**FIGURE 4. HYDRAULIC HEAD ASSEMBLY-CHARGING CYCLE**

***Discharge Cycle:*** As distributor rotor turns, the inlet passages move out of alignment with charging passages. As rotor discharge port opens to one of the discharge fittings, rollers contact the cam lobes forcing shoes in against plungers and high pressure pumping begins (Figure 5).

The beginning of injection varies according to load (amount of charging fuel). As rotor continues to rotate the rollers move up cam lobes pushing plungers inward. During the discharge stroke fuel pressurized between plungers flows through rotor passage and discharge port to injection line. Fuel delivery to injection line continues until rollers pass the highest point on cam lobe and begin to move outward. As rollers move off cam lobes, pressure in axial passage is reduced allowing injection nozzle to close. This is the end of fuel delivery.

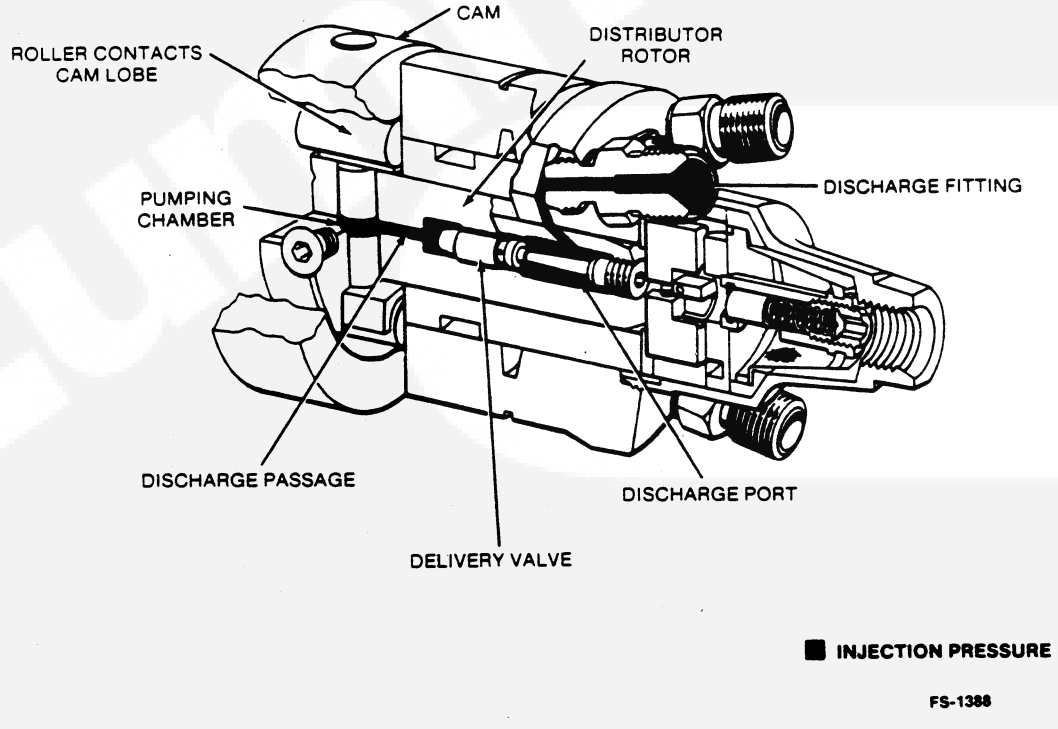



**FIGURE 5. HYDRAULIC HEAD ASSEMBLY-DISCHARGE CYCLE**

***Governor:*** The injection pump has a mechanical flyweight type integral governor which controls the amount of fuel delivered to injection nozzles (Figure 6). By controlling fuel delivered to injection nozzles, the governor maintains the desired engine speed within the operating range under various load conditions.

The governor obtains its energy from weights pivoting in the weight retainer. The weight's movement against governor thrust sleeve rotates metering valve by means of the governor arm and linkage hook. This rotation varies metering valve opening registry with passage to the rotor, controlling fuel flow. Centrifugal force tips the weights outward, moving governor thrust sleeve against governor arm. The force of weights against governor arm is balanced by the governor spring force, which is controlled by the manually positioned throttle lever for the desired engine speed.

On highway applications, direct control from the accelerator to the metering valve is desired. For this type of application a min-wax governor is used. A min-max governor typically governs only in the engine low idle speed range and at the maximum rated speed. At speeds between the idle speed range and maximum rated speed, the throttle lever directly controls metering valve position.

A speed increase due to a load reduction, increases centrifugal force on the governor weights rotating metering valve, reducing fuel flow. This limits the speed increase (within engine operating range) to a value determined by the governor spring rate and throttle setting.

As load on engine is increased, the speed tends to fall. Lower speed reduces force generated by the weights permitting spring force to rotate metering valve increasing fuel flow. Engine speed at any point within the operating range is dependent upon the combination of load on engine, governor spring rate, and speed setting established by throttle position. A light idle spring is provided for more sensitive regulation when the weight energy is low in the lower speed ranges. The limits of throttle travel are set by high idle and low idle adjusting screws.

A light tension spring on the linkage assembly takes up any slack in linkage joints allowing metering valve to close without having to overcome governor spring force. Only a very light force is required to rotate metering valve to the closed position.

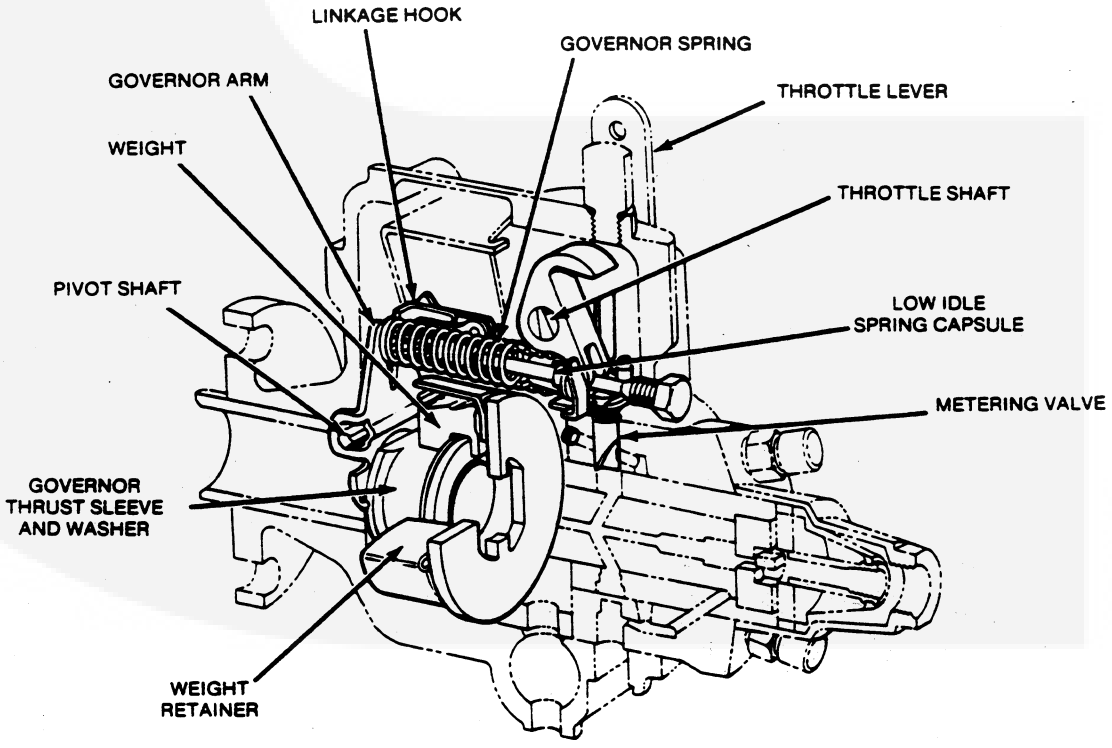



**FIGURE 6. MECHANICAL GOVERNOR**

***Automatic Advance:*** The DB2 injection pump design permits the use of a simple, direct acting hydraulic mechanism, powered by fuel pressure from the integral transfer pump. This feature is standard on all L engine variable speed pumps. The hydraulic mechanism rotates cam slightly and varies fuel delivery timing.

Fuel delivery timing will normally retard with increasing speed due to the length of time required for fuel to travel to injection nozzles. Use of an advance mechanism allows earlier fuel delivery to injection nozzles to insure optimum performance at higher speeds and loads.

1. Speed/Light Load Advance (Hydraulic)
   To obtain optimum performance both speed and load timing is needed on some engines. This advance gives normal advanced timing in the full load speed range as well as further advance at reduced engine loads.
2. Speed/Light Load Advance (Mechanical)
   This advance reduces emissions by increasing injection timing at low throttle settings. Consequently this improves combustion efficiency at lower engine speeds. This advance is used only on injection pumps equipped with min-max type governors.

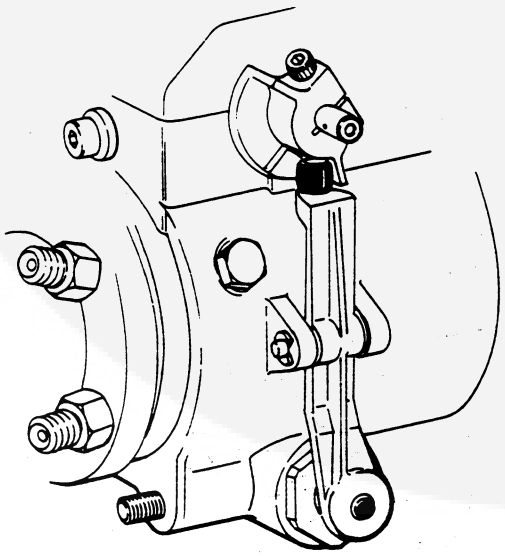


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**FIGURE 7. MECHANICAL SPEED/LIGHT LOAD ADVANCE**

***Cold Start Mechanical Advance:*** Cold starting of some variable speed turbocharged engines is improved by advancing the timing at cranking speeds. This is done by extending the advance range above the optimum timing required for operating speeds below 2200 rpm.

The cold start advance is operated by a lever located on the injection pump (Figure 8). Cold start advance is obtained by rotating the lever in a counter clockwise direction.

When installing and timing injection pump, engine cold start mechanical advance lever must be in the off position.

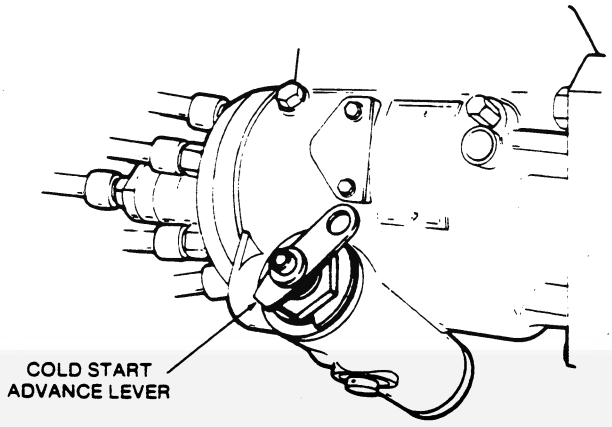


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**FIGURE 8. COLD START ADVANCE**

***Housing Pressure Cold Advance (HPCA):*** The HPCA located under the governor cover provides cold cranking speed advance, as well as reduced white smoke and hydro carbon emissions during warm-up. By unseating the housing pressure regulator the HPCA solenoid allows additional advance throughout the advance range. A thermo sensor located in water pump housing controls HPCA solenoid operation.

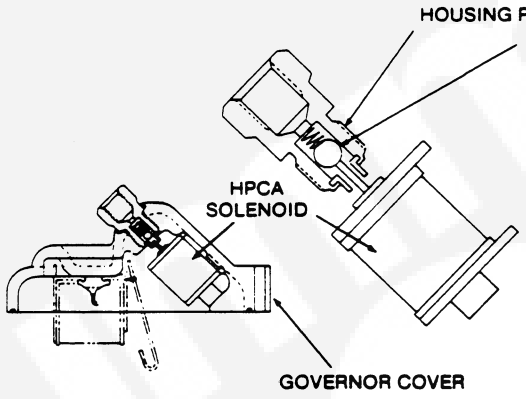


FIGURE 9. HOUSING PRESSURE COLD ADVANCE

***Aneroid (Acceleration Smoke Control):*** This is a pressure sensitive fuel reduction control used on most variable speed turbocharged engine applications. The aneroid matches injection pump fuel delivery quantity to engine intake manifold pressure during periods of acceleration.

During the acceleration period the injection pump delivers full load fuel quantity while the turbocharger speed lags behind engine speed. Until full turbo speed is attained, insufficient air is supplied to the combustion chambers for complete combustion of full load fuel quantity. To prevent overfueling and excessive smoke, a reduction in the full load fuel quantity delivered during acceleration is needed. The aneroid senses intake manifold pressure and reduces fuel quantity until turbocharger gains speed and is able to provide sufficient air for efficient combustion.

When manifold pressure is at its peak, engine at rated speed and load, the aneroid piston is pushed out positioning its operating rod and pump shut-off lever in the RUN position. A reduction in intake manifold pressure allows the spring loaded piston to pull the lever toward the shut-off position. As the lever is moved forward, shut-off cam pushes linkage hook slightly to the rear, reducing fuel flow past the metering valve (Figure 10).

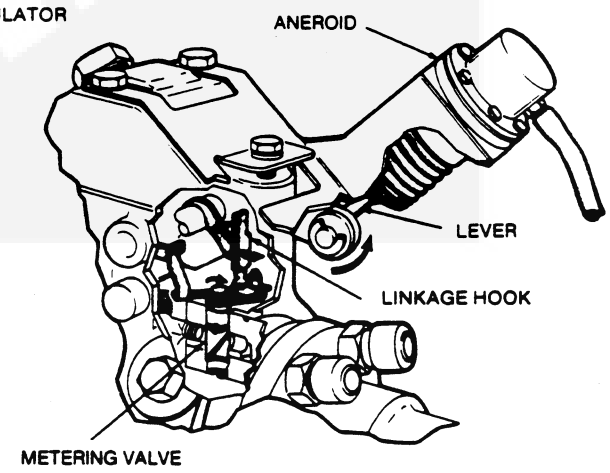


FIGURE 10. ANEROID OPERATION

As turbocharger speed increases intake manifold pressure increases overcoming aneroid spring force. The piston then pushes the shut-off lever to the full RUN position allowing full load fuel delivery.

Aneroid operation may be checked with engine stopped by connecting a regulated air pressure source to the aneroid (boost pressure) inlet fitting. Because operating pressures are very low, a mercury manometer is required to measure the air pressure applied to the aneroid.

Increase air pressure and observe pump shut-off lever (Figure 11). Clearance between pump shut-off lever, forward screw, and stop is preset at the factory to 0.006 to 0.010 inch (0.15 to 0.25 mm) at 5 inches of mercury on automotive engines, or 4 inches of mercury on industrial engines. Full pump shut-off lever travel should occur at 24 to 28 incyes of mercury. If pump shut-off lever does not move, or an air leak is noted, aneroid must be replaced as an assembly. Aneroid can be disassembled, but internal parts are not serviceable.

**NOTE: Adjustments to injection pump that do not meet specifications may violate Federal, state, and/or local regulations. Emissions and mechanical warranty may also be voided by adjustments that do not meet specifications. Adjustments made by non-authorized personnel may void mechanical warranty.**

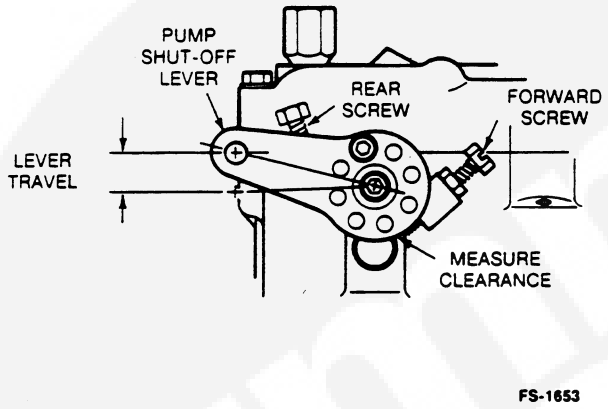


**FIGURE 11. PUMP SHUT-OFF LEVER**

IF PAINT SEAL ON ADJUSTMENT SCREWS IS NOT BROKEN, ANEROID CAN BE REPLACED WITHOUT REMOVING INJECTION PUMP FROM THE ENGINE. IF ADJUSTMENT SCREWS ON PUMP SHUT-OFF LEVER HAVE BEEN TAMPERED WITH (PAINT SEAL BROKEN) SINCE CALIBRATION BY AN AUTHORIZED SERVICE CENTER, INJECTION PUMP MUST BE REMOVED AND CALIBRATED AT AN AUTHORIZED STANADYNE SERVICE OUTLET.

**⚠CAUTION** ***Never submerge the aneroid assembly in oil or solvents. A dry lubricant is used on the internal diaphragm. Washing of the assembly will remove the lubricant and possibly damage the diaphragm.***

## Injection Pump Adjustments

Fuel injection pumps are adjusted at the factory for a governor breakpoint of 40 to 60 rpm above rated speed with a high idle setting of 7 to 10 percent greater than the specified speed. The high idle adjusting screw is locked and sealed at the factory. Pump adjustment is seldom necessary. Low idle speed is factory set at 775 to 825 rpm. The low idle adjusting screw is not sealed; adjustment is permissible to achieve a suitable low idle speed.

**It is not recommended to make injection pump adjustments in the field. It must be clearly understood by the owners and by Onan service personnel that tampering or inept repair attempts can cause irrepairable damage to pumps that will not be covered by the manufacturers warranties or exchange agreements. Contact an authorized injection pump service dealer or distributor for expert repair service on injection pumps.**

**⚠CAUTION** ***Adjustments made by non-qualified personnel may violate Federal, state, and/or local regulations. Emissions and mechanical warranty may also be voided by adjustments made to injection pump and aneroid by non-qualified personnel.***

Injection pump dealers are equipped with injection pump test stands, special tools required for repairing, testing, and adjusting the pump. If at any time the injection pump needs repair or adjustment, it should be removed and taken to an authorized injection pump service dealer or distributor. It is important that the servicing dealer be furnished with the pump model number, as well as engine model and serial number, to facilitate the repair.

The repair service should include cleaning, part replacement, static pressure tests for internal and external leaks, internal pump timing, and calibration and adjustment to the manufacturer's specification.

***Checking Engine Speed:*** Engine speed may be checked with a panel mounted tachometer if unit is equipped with one. If unit does not have a panel mounted tachometer a strobe light tachometer can be used.

1. Start engine and run until minimum operating temperature is obtained.

**⚠WARNING** ***Rotating machinery can cause serious personal injury or death. Stay clear of rotating equipment and ensure that protective shields and guards are in place.***

2. Move throttle control to both low and high speed positions. Make sure control moves speed control level on injection pump through its full arc of travel.

3. Move throttle control to low idle position and check engine speed. Make sure engine rpm is within the normal range 775 to 825 rpm. Low idle speed varies depending upon engine application.

4. Move throttle control to high idle position. Check engine speed. High idle speed should be 7 to 10 percent greater than speed stamped on injection pump nameplate.

5. If engine speed is not within the specified ranges, governor (speed control adjustment screws) must be adjusted.

***Speed Control Adjustments - Standard 10 Percent Regulation:***

1. Remove throttle control cable from fuel injection pump speed control lever so lever can be moved by hand.

2. With engine running at operating temperature, loosen locknut (Figure 12) on low idle adjusting screw. Push speed control toward front (fan end) of engine so low idle adjusting screw touches lever stop. Turn low idle screw in to increase speed or out to decrease speed. When low idle rpm is obtained, hold adjusting screw and tighten locknut.

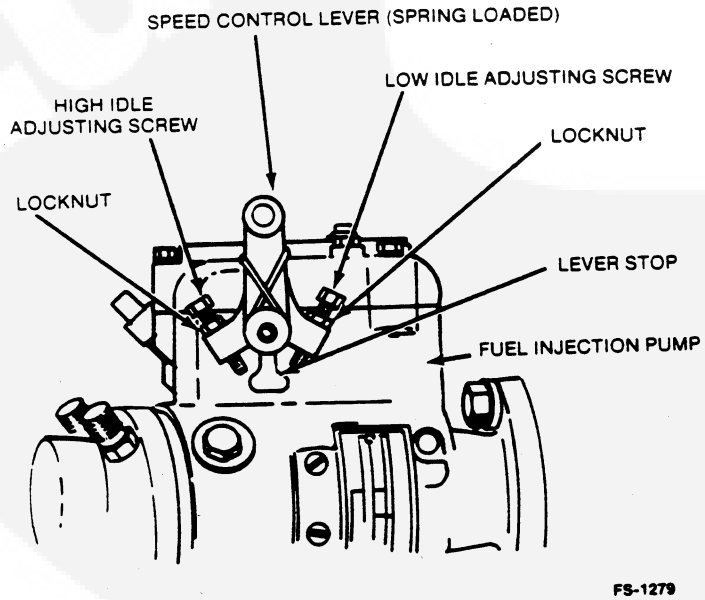


**FIGURE 12. SPEED ADJUSTMENT**

3. With engine running at operating temperature remove seal and loosen locknut (Figure 12) on high idle adjusting screw. Push speed control lever toward rear (away from fan) of engine so high idle adjusting screw touches lever stop. Turn high idle screw in to decrease or out to increase engine speed. After correct high idle speed is obtained, hold adjusting screw and tighten locknut.

**⚠CAUTION** ***High idle screw is factory set and sealed. Only authorized Onan service personnel are permitted to make pump adjustments and re-seal the injection pump.***

4. Connect throttle control cable to speed control lever on injection pump. Make sure that when throttle is in the idle position, the control lever low idle adjusting screw contacts pump housing lever stop. When throttle is in the fast (high idle) position the high speed adjusting screw must contact lever stop.

***Speed Control Adjustments - Optional 4.5 Percent Regulation (Generator Application):*** An external speed droop adjustment screw located at rear of injection pump housing, controls governor sensitivity. The droop screw adjustment varies the governor regulation by changing the effective spring rate. This adjustment will affect both full load and no load frequency settings and may require that the high speed stop screw be reset.

After each adjustment of the droop screw, engine must be shut down briefly in order to allow the governor spring to unload and the adjusting mechanism to seek its final position in the spring. Turning screw in shortens control spring making it less sensitive and increases speed droop. Turning adjusting screw out has the opposite effect. Speed droop is the injection pump's ability to respond to changing engine loads. Adjust governor as follows:

1. Check engine operating speed. Adjust as outlined in preceding procedure for standard governor.
2. To adjust speed droop:
   A. Run engine until normal operating temperature is obtained.
   B. Apply full rated load. With engine running at rated speed, droop is determined by removing load and noting the no-load speed. In the case of a generator set note the difference in frequency.
   C. Turn adjusting screw, at back of injection pump (Figure 13), clockwise to increase speed droop or counterclockwise to decrease speed droop. A small correction in throttle positon may be necessary. Re-seal adjusting screws.

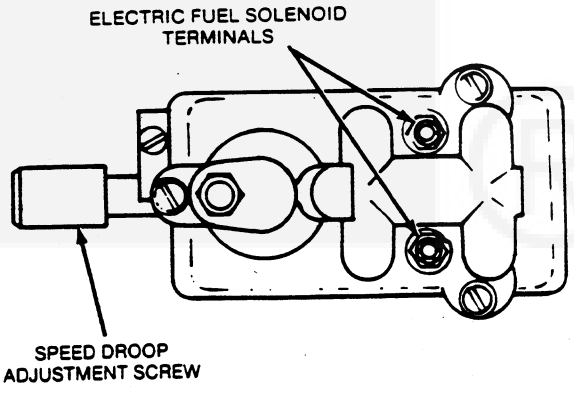


**FIGURE 13. SPEED DROOP ADJUSTMENT**

## BOSCH VE INJECTION PUMP

In contrast to the Stanadyne DB2 injection pump the Bosch VE injection pump has only one pump barrel and one pump plunger. Fuel delivered by the injection pump is distributed via a distribution groove in the plunger to the discharge fittings. The Bosch VE pump is of a modular design and can be equipped with various additional modules. This allows for greater versatility in matching the pump to the engine.

To understand the VE pump one has to become familiar with the main components and their functions. Refer to Figure 14 for VE injection pump components.

The drive shaft is supported by the pump housing and drives the vane-type fuel supply pump. The cam plate rides against the cam roller ring producing a rotating stroke motion that is transferred to the distributor-pump plunger. Distributor-pump plunger is guided by the hydraulic head, which is secured to pump housing with screws. Hydraulic head assembly also contains the fuel solenoid for interrupting the fuel supply, delivery-valve assemblies, and delivery-valve holders.

A governor drive gear located on the drive shaft drives the flyweight assembly. This assembly is equipped with flyweights and a sliding sleeve.

The governor assembly consisting of the adjusting lever, starting lever, and tensioning lever is mounted in the pump housing. Governor assembly changes the position of the control collar thereby controlling fuel delivery.

A hydraulic timing device is located on the underside of the pump and is controlled by fuel housing pressure.

The pump housing is enclosed at the top by a governor cover containing the control lever, speed adjusting screws, and full load-delivery adjusting screw.

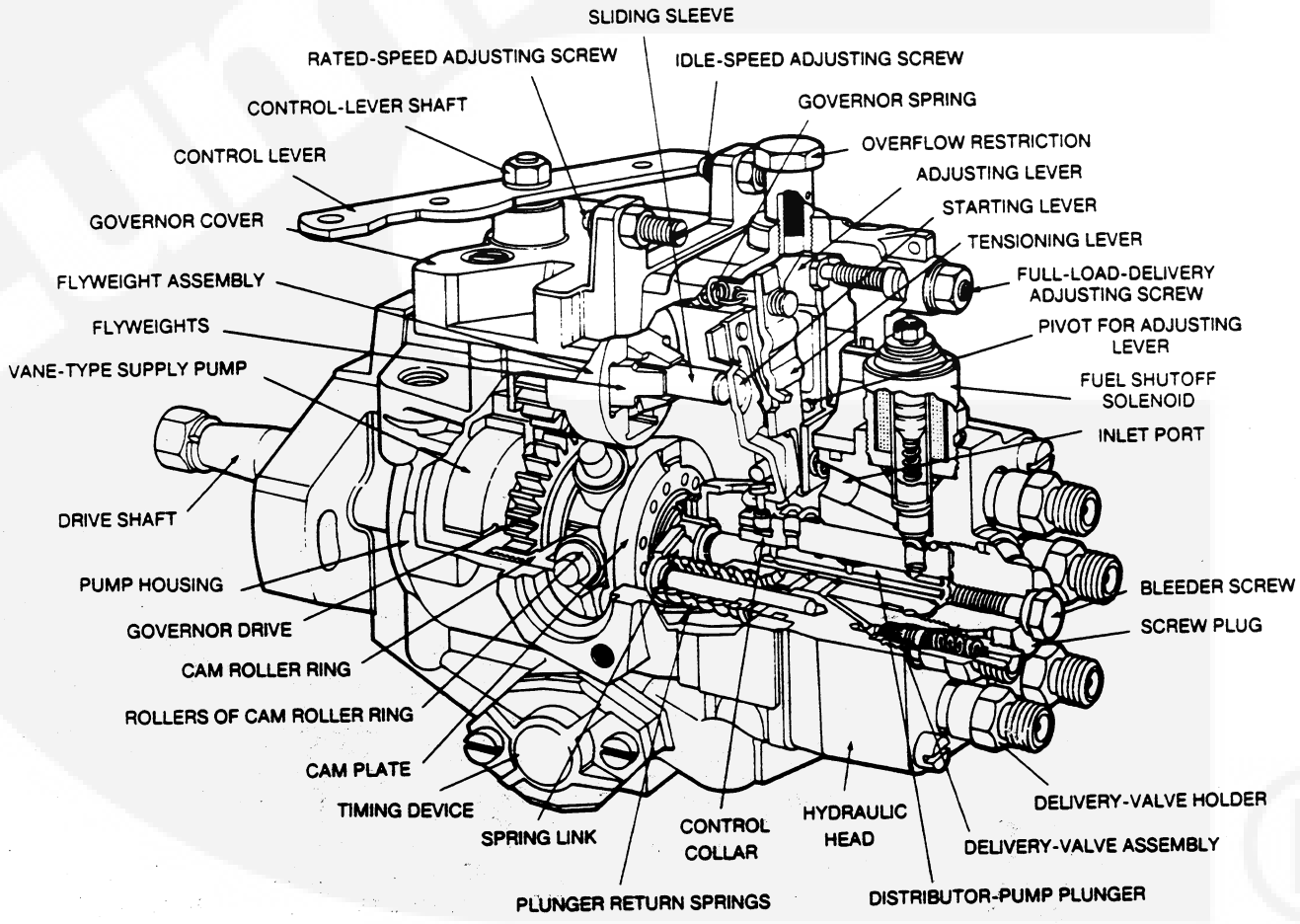


**FIGURE 14. VE INJECTION PUMP COMPONENTS**

***Fuel Flow:*** The mechanical or electric transfer pump pulls fuel from the fuel tank (Figure 15). The transfer pump pushes fuel through the filter, where it is cleaned. The fuel is then pushed on to the injection pump where it is pressurized and delivered to each injection nozzle. Injection pump operating principles are better understood by following the fuel circuit during a complete pump cycle (Figure 15).

With each pump drive shaft revolution the integral vane-type supply pump, pumps a constant amount of fuel from the fuel tank into pump interior. Pump interior pressure is maintained by a pressure-regulating valve. Interior pressure rises in proportion to engine speed. To cool and automatically bleed the injection pump a certain amount of fuel flows back to the fuel tank through the overflow restriction located on the governor cover.

Fuel flows from the pump interior through the inlet port and metering slit in distributor pump plunger into the high pressure chamber situated above distributor pump plunger. As cam plate turns, riding over the cam rollers in the cam roller ring, a rotating stroke motion is transferred to the distributor pump plunger. The rotating motion produces an opening and closing of the metering slits and spill ports located in the distributor pump plunger and hydraulic head assembly.

Pressure is produced by the stroking motion of the distributor pump plunger after inlet port closes. Fuel is delivered and distributed through the distribution groove to the individual outlets. As the distribution groove lines up with the outlet port high pressure lifts the delivery valve assembly off its seat and fuel is forced through a fuel injection line to the injection nozzle.

As distributor pump plunger spill port reaches control collar edge fuel delivery is terminated. From this instant on the high pressure chamber is connected to pump interior through the internal port. During the remaining plunger stroke excess fuel is forced back into pump interior.

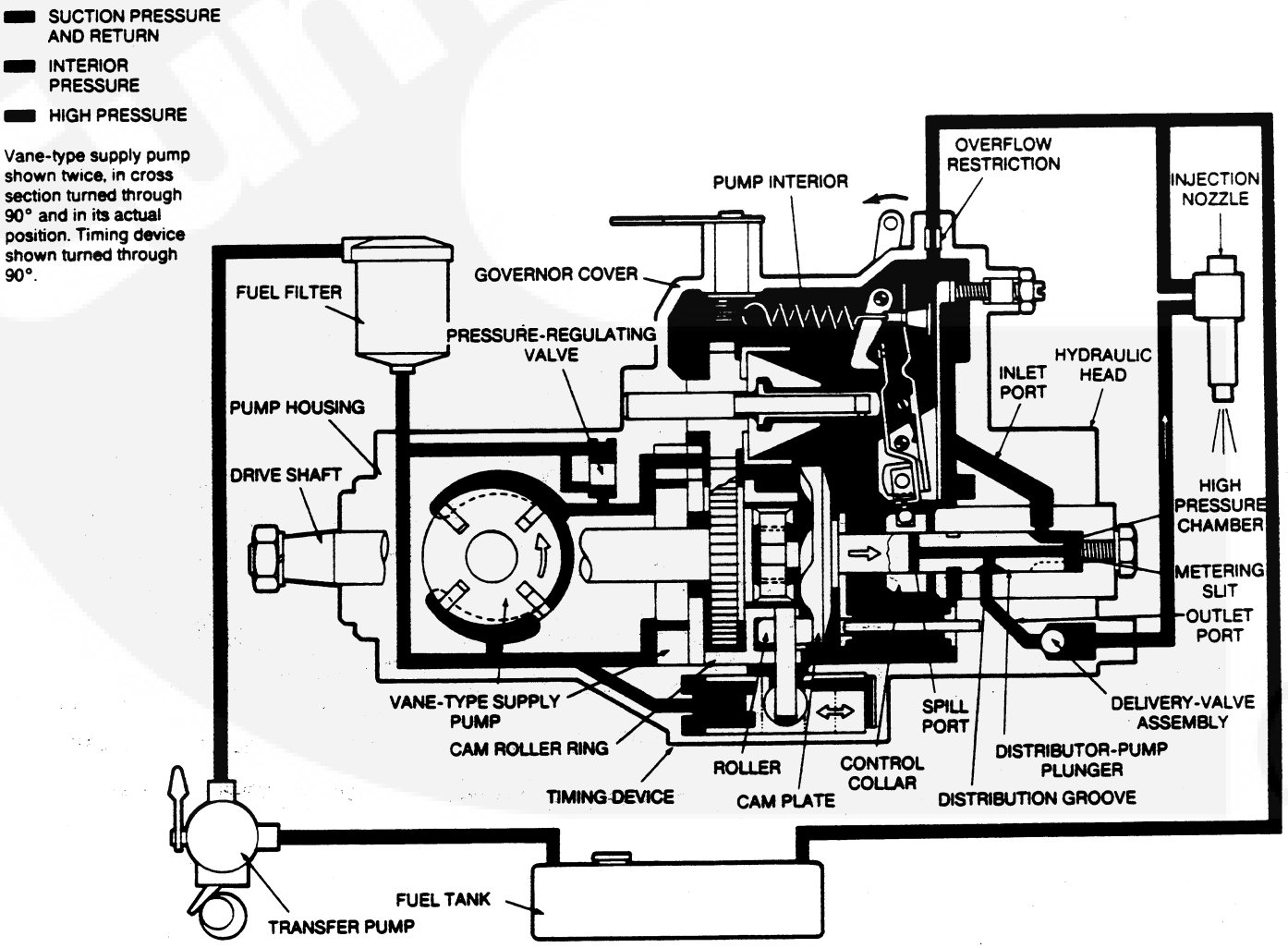


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**FIGURE 15. VE FUEL FLOW SCHEMATIC**

***Governor:*** The centrifugal governor is a integral part of the distributor type fuel injection pump that controls the amount of fuel delivered to the injection nozzles.

Direct control from the accelerator to the control collar is required for most vehicle applications. For vehicle applications a minimum-maximum governor (Figure 16) is used. With the minimum-maximum governor only idle speed and maximum full load speed are governed. Intermediate speed and load ranges are controlled directly by the accelerator through the governor mechanism.

Engine speed is transmitted from injection pump drive shaft through gears to the governor flyweights. As engine speed increases centrifugal force moves the flyweights outwards. The flyweights rotate around the knife-edge bearing and move the axially displaceable sliding sleeve. The sliding sleeve transfers the centrifugal force through a lever arrangement until the system is in equilibrium against the force of various springs.

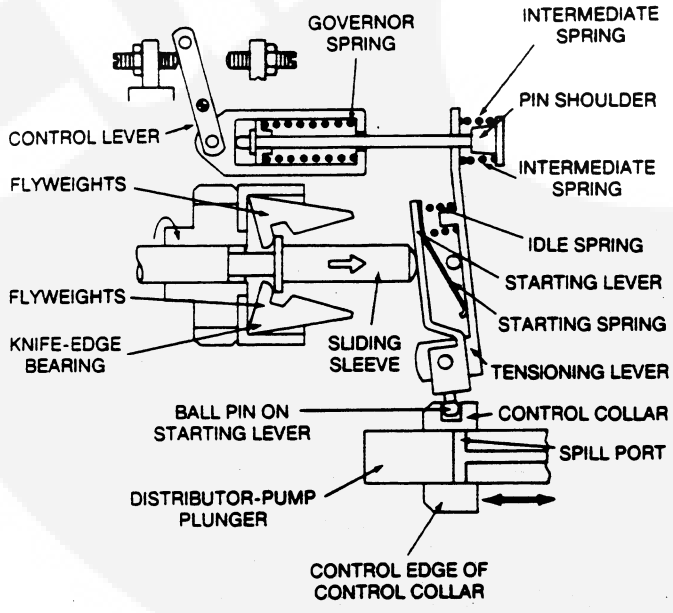
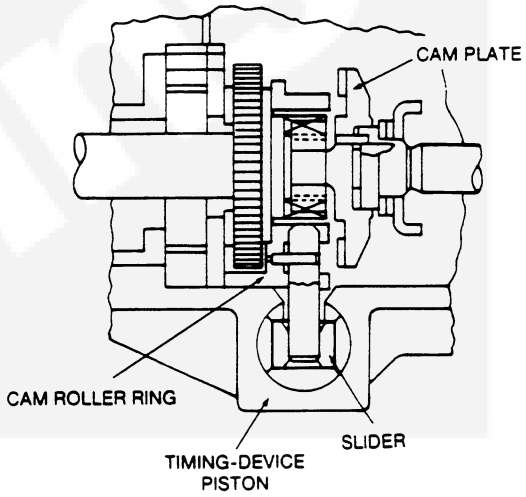



**FIGURE 16. MINIMUM-MAXIMUM GOVERNOR**

Starting and tensioning lever movement is transmitted through a ball pin to the control collar which slides on the distributor pump plunger. Control collar end face in conjunction with the spill port controls the end of the effective stroke and the quantity of fuel injected.

***Automatic Advance:*** To obtain optimum combustion, maximum power, minimum fuel consumption, and clean exhaust injection timing must be varied on diesel engines operating over a wide speed range. This is accomplished by the timing device which advances injection timing as engine speed increases (Figure 17.)



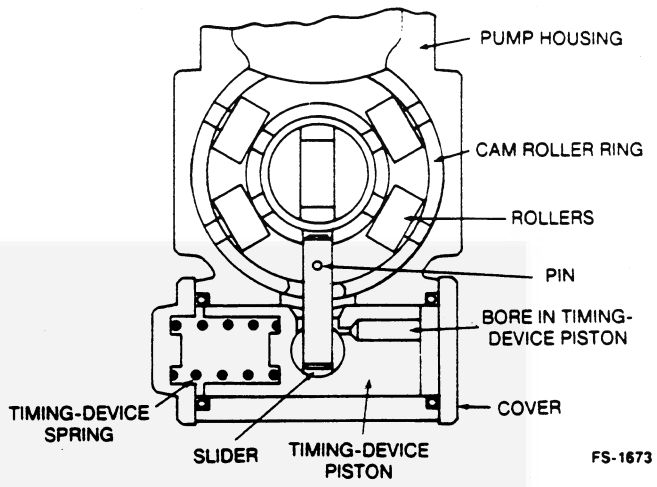




**FIGURE 17. AUTOMATIC ADVANCE**

When engine is stopped injection pump timing device piston is held in the basic position by a preloaded timing device spring. During operation pump interior fuel pressure is regulated in proportion to engine speed by the pressure regulating valve in conjunction with the overflow restriction.

At a given engine speed interior pump pressure overcomes the spring force and moves the timing device piston to the left. Axial piston movement is transferred through the slider and pin to a rotatable cam roller ring. This changes the respective positions of the cam plate and cam roller ring causing the rotating cam plate to be lifted earlier by the rollers.

Advance at the start of injection is accomplished by the load dependent start of pump delivery (LFB). Purpose of the LFB is to vary the beginning of pump delivery as a function of engine load. The load dependent start of pump delivery is designed so that when there is a drop in load (full load to part load) injection timing is retarded. As the load increases there is a reduction in engine speed and the load dependent start of pump delivery advances injection timing. The LFB is used to achieve smoother engine running, reduce noise, and exhaust emissions.

***Cold Start Accelerator:*** The cold start accelerator advances the start of injection by a specific amount. This operation is performed by the driver from the passenger compartment via a cold start advance cable.

When the cold start cable is pulled the cold start accelerator control lever and shaft are turned together with the ball pin. This turning motion changes the position of the cam roller ring with respect to cam plate and advances injection timing.

***Manifold Pressure Compensator (LDA):*** This device reduces the full load fuel delivery in the lower engine speed range starting at a specified charge air pressure. Fuel quantity in turbocharged engines is matched to the increased air charge required during middle and upper engine operating speed ranges (when turbocharger is in operation). When the turbocharged engine is operating in the lower engine speed range, the air charge is smaller and fuel quantity must be adapted to this reduced air quantity.

During lower engine speed operation, the manifold pressure compensation is inoperative until the charge air pressure is sufficient to overcome the spring force. As engine speed increases charge air pressure applied to the diaphragm increases and the diaphragm and sliding bolt with control cone are moved against the pressure spring force. When the sliding bolt moves vertically the stop lever rotates moving the control collar allowing more fuel to be delivered to match the increased air quantity. At low engine speed or if turbocharger fails the manifold pressure compensator returns to its basic position and limits full load fuel delivery so that smokeless combustion is ensured.

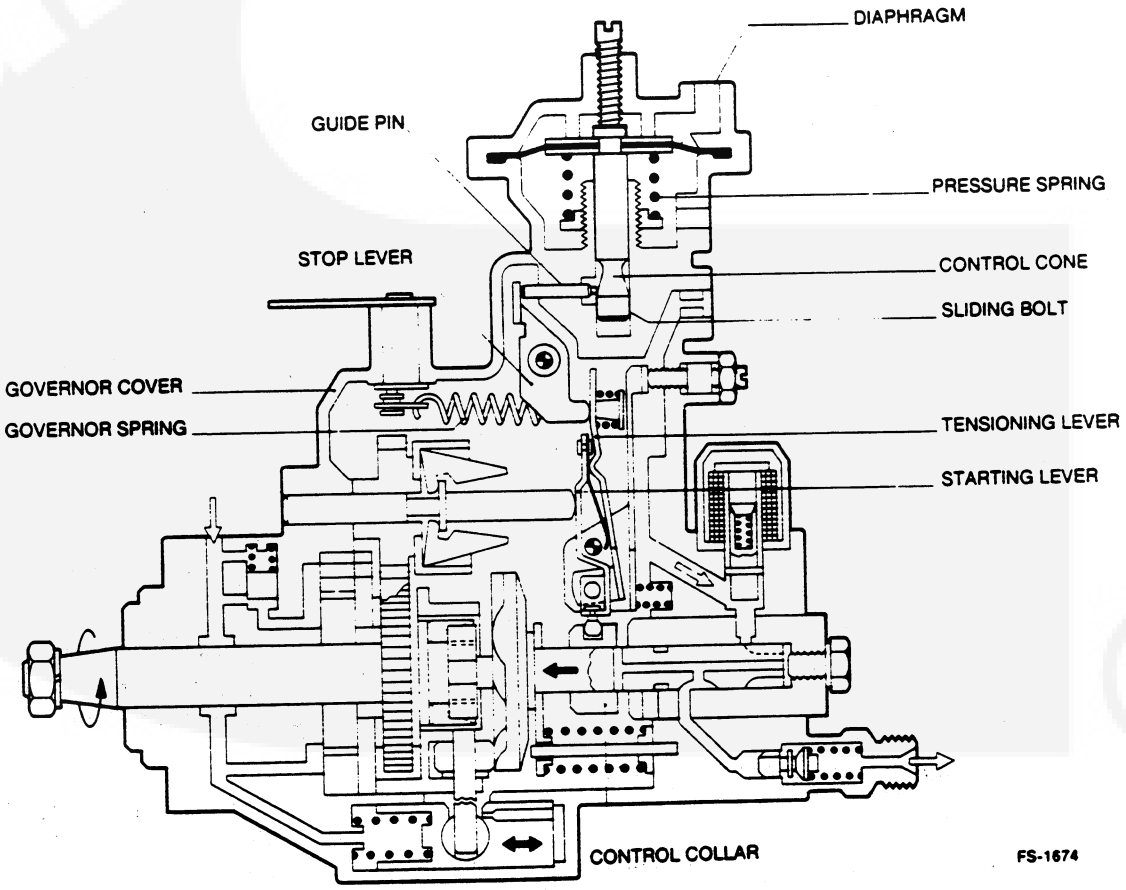



**FIGURE 18. MANIFOLD PRESSURE COMPENSATOR (LDA)**

## INJECTION PUMP REPAIR

Before leaving the factory, all injection pumps are carefully adjusted, calibrated, and sealed with paint or wire seals. It must be clearly understood by the owners and by Onan servicemen that tampering or inept repair attempts can cause irrepairable damage to pumps that will not be covered by the manufacturer's warranties or exchange agreements. Authorized distributors and dealers have the tool and seals to reseal injection pump after making the necessary repairs.

**⚠CAUTION** ***Pump or engine failures due to tampering with seals or any other unauthorized attempt to adjust or repair maximum fuel adjustment setting, or high idle throttle stop screw will void engine warranty.***

**⚠CAUTION** ***Onan does not recommend washing the diesel engine. However, if you must wash the engine, do so only when the engine is cold. Never wash a warm, hot, or running engine. Spraying water or cleaning solutions on a warm engine or injection pump can cause serious damage to the engine fuel system.***

### Fuel Shut Off Solenoid

If there is fuel to the injection pump, but no fuel at injection nozzle, the fuel solenoid may be defective.

To check energized-to-run fuel solenoid operation, listen for a click in injection pump when start switch is placed in the run position. If no click is heard and there is power to solenoid with the start switch in the run position, the fuel solenoid must be replaced. To check energized-to-stop fuel solenoid operation, listen for a click in injection pump when start switch is placed in the stop position. If no click is heard and there is no power to solenoid with the start switch in the stop positon, the fuel solenoid must be replaced.

**⚠CAUTION** ***A diesel engine cannot tolerate dirt or water in the fuel system. It is the major cause of diesel engine failure. A tiny piece of dirt or a few drops of water in the injection system may stop your unit.***

***Stanadyne DB2 Fuel Solenoid Replacement:***

1. Remove fuel return lines and wire lead from fuel shutoff solenoid.
2. Note location of ground strap on governor control cover.
3. Remove capscrews, washers, and governor control cover from injection pump (Figure 19).
4. Remove nuts, washers, and gaskets from fuel solenoid terminals.
5. Push solenoid out of cover.
6. Place a new fuel shut off solenoid in governor control cover.
7. Place new gaskets over terminal posts and install washers and nuts.
8. Remove rubber gasket by pulling it out of groove in cover.
9. Carefully place a new gasket in groove of governor control cover.
10. Install cover and torque capscrews to 4 Nm (3 Ft.-Lb.). Connect fuel return lines and make electrical connections.
11. Install new wire seal through the guide stud, the torque screw, and the cover screw.

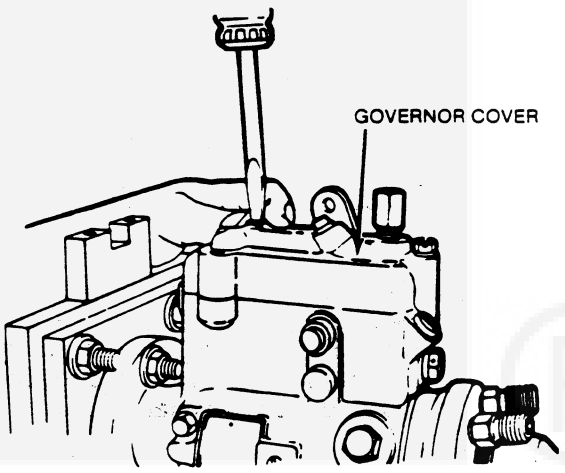



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**FIGURE 19. REMOVING GOVERNOR CONTROL COVER**

### Bosch VE Fuel Solenoid Replacement:

1. Remove wire lead from fuel shut off solenoid.
2. Remove fuel solenoid and O-ring from distributor head.
3. Place new O-ring on new fuel solenoid.
4. Install new fuel solenoid with O-ring into the distributor head.
5. Torque fuel solenoid to 42.5 Nm (31.5 Ft.-Lb.).

## INJECTION PUMP REMOVAL

Clean all external surfaces of injection pump, including all line connections and fittings that are to be disconnected. Clean area around injection pump mounting flange and injection pump gear cover to prevent dirt from entering crankcase.

**⚠CAUTION** ***Never clean the injection pump when it is hot, or even warm. To do so may cause it to seize.***

1. Rotate engine until Number 1 piston is near the top of its compression stroke and pointer in flywheel housing is aligned with proper number of timing degrees for the engine. On engines with front timing indicator, notch in pulley must line up with center of timing indicator.
2. Turn off ignition switch. Disconnect throttle control cable from speed control lever on injection pump.
3. Disconnect electrical lead from terminal on fuel solenoid and shut off fuel supply.
4. Remove fuel return lines from top of injection pump and plug.
5. Disconnect filter to injection pump inlet line and plug.
6. Remove all high pressure lines from injection pump. Be sure to hold discharge fitting on injection pump when removing high pressure line nuts. Remove high pressure lines. Cover all openings with fuel line plugs to prevent entrance of dirt.

**⚠CAUTION** ***A diesel engine cannot tolerate dirt or water in the fuel system. It is one of the major causes of diesel engine failure. A tiny piece of dirt or a few drops of water in the injection system may stop your unit. When opening any part of the fuel system beyond the fuel filter, place all parts in a pan of clean diesel fuel as they are removed. Before installing new or used parts, flush them thoroughly with diesel fuel, and install while still wet. Always wet fingers with diesel fuel before working with diesel injection system parts.***

7. The injection pump drive gear may be removed through the cover plate opening in gearcase cover or may be removed after gearcase cover has been removed from engine. Determine if radiator must be removed prior to removing injection pump cover plate, if radiator has to be removed begin with Step A. When cover plate can be removed without removing radiator begin with Step B.

   A. Drain cooling system. Remove all components from front of engine, in order to facilitate the removal of injection pump drive gear cover.

   B. Loosen capscrew that secures alternator to adjusting bracket. Push alternator in so that fan belt can be removed from alternator pulley.

   C. Remove capscrews and flat washers that secure pump drive gear cover to gearcase. Remove cover and O-ring.

   D. Remove hex nut from injection pump drive shaft.

   E. Thread three (M8 x 30mm) capscrews into injection pump drive gear. Install a slotted three jaw puller onto injection pump drive gear (Figure 20) and remove gear.

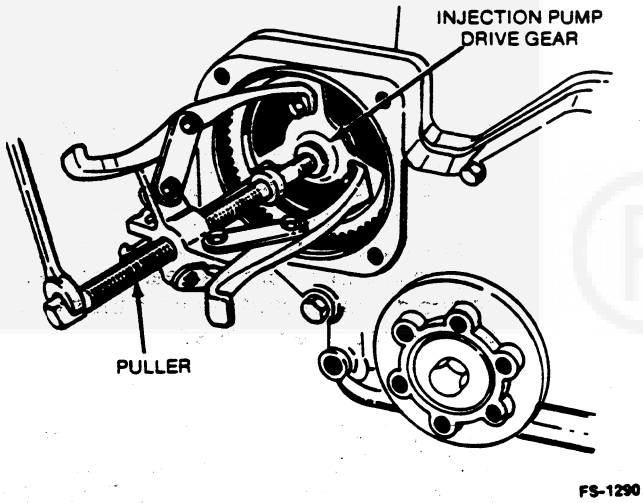



**FIGURE 20. INJECTION PUMP DRIVE GEAR REMOVAL**

8. Remove the three hex nuts and washers that secure injection pump to backplate.

9. Remove injection pump.

## INJECTION PUMP INSTALLATION AND TIMING

Accurate injection pump timing is essential for maximum engine performance and operation. The injection pump on each engine must be timed to that engine by using the timing marks on engine (Figure 21). All engine timing is performed with engine not running. When a new pump is installed on the engine, or after injection pump has been serviced and is ready to be reinstalled, use the following procedure.

1. Place a new injection pump O-ring on pump mounting collar.

2. Position injection pump on mounting studs with studs centered in mounting slots. Secure injection pump to backplate with three flat washers and hex nuts.

3. Stanadyne DB2 injection pump timing procedure.

   A. Rotate crankshaft in a counterclockwise direction, when viewed from flywheel, until Number 1 piston approaches TDC on its compression stroke. With the piston at TDC the crankshaft can be turned 90° in either direction without the valves on number one cylinder opening. If the valves open during this test the crankshaft must be turned one complete revolution (360°) in the direction of normal rotation. With number 1 cylinder at TDC continue to rotate crankshaft until pointer in flywheel housing is aligned with the proper number of timing degrees (Figure 22) stamped on the flywheel. On engines with front timing indicator, line up notch in crankshaft pulley with timing indicator. Refer to *Engine Nameplate* for proper number of timing degrees for the engine rpm stamped on injection pump.

**⚠CAUTION** ***A diesel engine cannot tolerate dirt or water in the fuel system. It is one of the major causes of diesel engine failure. A tiny piece of dirt or a few drops of water in the injection system may stop your unit. When opening any part of the fuel system beyond the fuel filter, place all parts in a pan of clean diesel fuel as they are removed.***

   B. Clean dirt and foreign material from around timing window cover on injection pump. Remove timing window cover from fuel injection pump. Two injection pump timing marks are used for timing injection of fuel into Number 1 cylinder. One mark is located on governor weight retainer hub; the other is located on cam ring. Turn injection pump shaft until timing marks are aligned as viewed through the timing window (Figure 22). Governor weight retainer must be manually positioned in the counterclockwise direction. Use a clean scribe or awl when aligning cam ring and governor weight retainer.

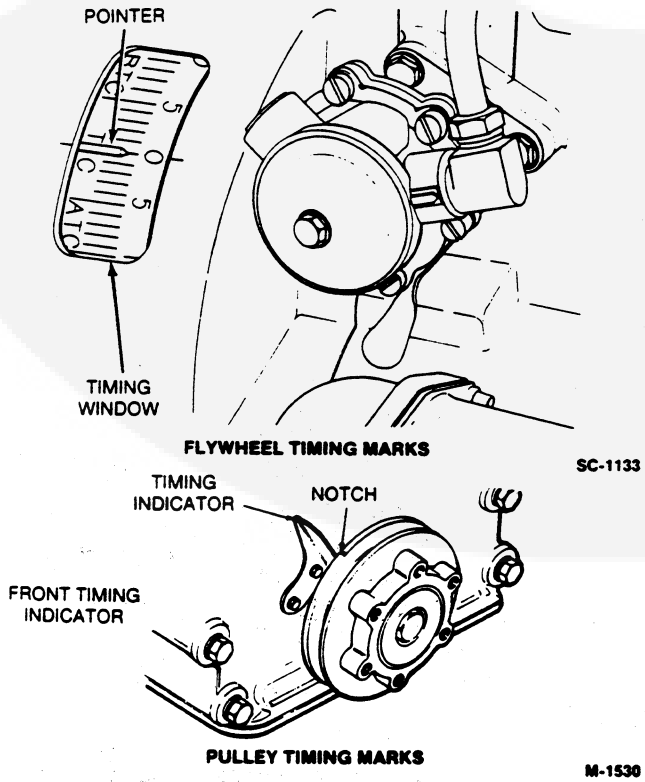



**FIGURE 21. ENGINE TIMING MARKS**

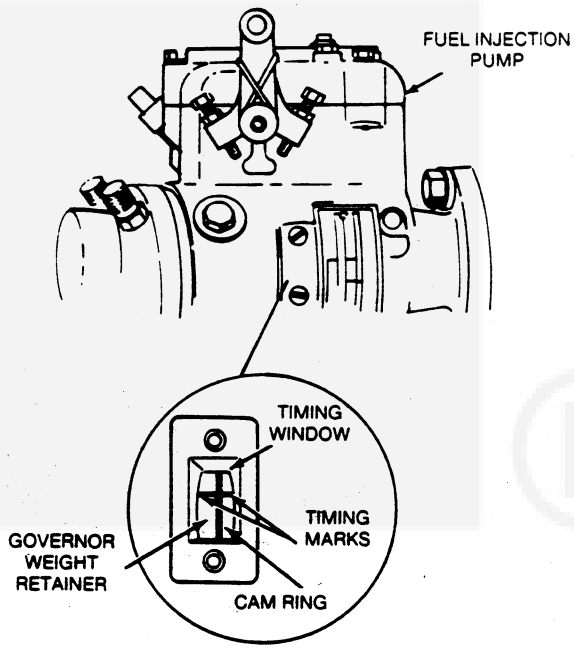



**FIGURE 22. INJECTION PUMP TIMING MARKS**

C. Place injection pump drive gear on pump shaft. Install hex nut and tighten to torque of 52 Nm (38 Ft.-Lb.). Be careful when installing gear so injection pump drive shaft does not rotate.

D. Rotate crankshaft back (clockwise when viewed from the flywheel) one-half of a revolution. Turn crankshaft in a counterclockwise direction until pointer or timing indicator is aligned with proper number of timing degrees or notch in pulley. Refer to *SECTION 1, SPECIFICATIONS* for proper timing setting.

E. Recheck alignment of injection pump timing marks. If pump timing marks do not line up, loosen the three pump mounting nuts and rotate injection pump until timing marks are in alignment. Tighten injection pump mounting hex nuts.

F. Install timing window cover and gasket.

G. Apply a pipe sealant (with Teflon) to fuel supply pipe threads. Install fuel return lines and filter to injection pump inlet line.

4. Bosch VE injection pump timing procedure.

A. Rotate crankshaft in direction of normal rotation until cylinder number 1 begins its compression stroke. Both valves of cylinder number 1 will be seated during the compression stroke. Continue to rotate crankshaft until 15 degree mark on crankshaft pulley is properly aligned with the pointer attached to the gearcase cover. Degree marks are stamped with the value on front face of crankshaft pulley.

B. Position injection pump driveshaft so the key slot points to discharge fitting for number one cylinder (Figure 24). Use a Bosch coupling wrench to turn injection pump shaft.

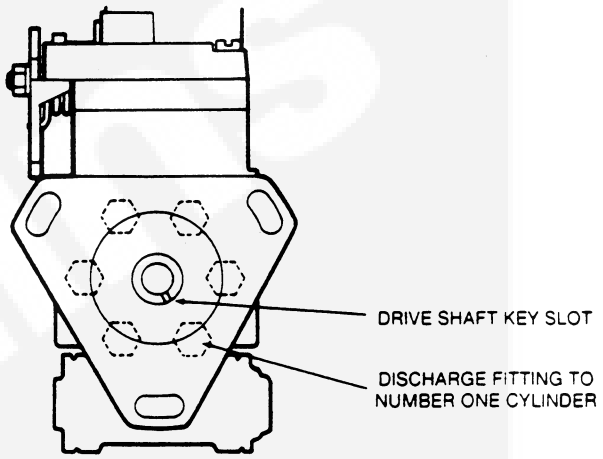



**FIGURE 24. POSITIONING INJECTION PUMP**

**⚠WARNING** ***Fuel discharged from discharge fittings can penetrate skin and cause severe personal injury. Be certain that discharge fittings are not aimed at anyone when rotating injection pump driveshaft.***

C. Remove bleed screw (Figure 25) and install proper timing holder and dial indicator. Adjust dial indicator for 1 to 2 mm of travel and secure.

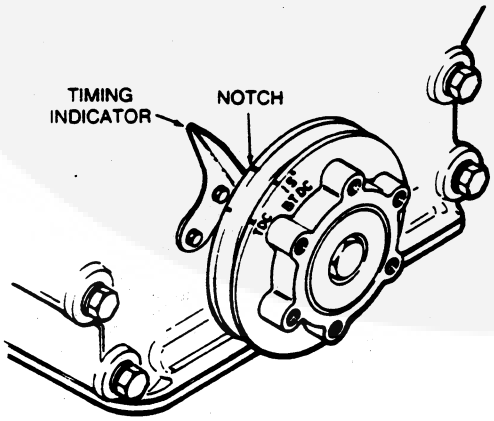



**FIGURE 23. ENGINE TIMING MARKS**

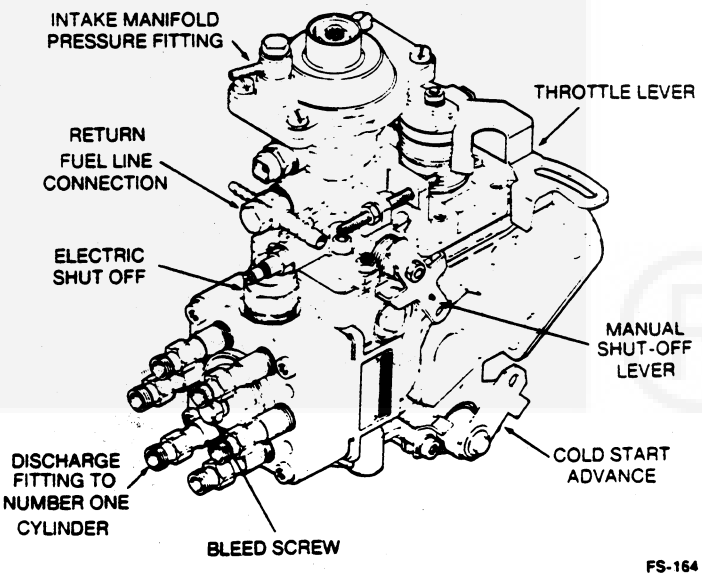



**FIGURE 25. BOSCH VE INJECTION PUMP TIMING**

**⚠WARNING** ***Fuel penetration of the skin can cause severe personal injury. Do not let the discharge fitting high-pressure fuel spray against skin surfaces. Cover discharge fittings or install high pressure lines.***

D. Use coupling wrench to turn injection pump drive shaft clockwise as viewed from front of engine until dial indicator shows the start of plunger lift.

E. Place injection pump drive gear on pump drive shaft. Install hex nut and tighten to a torque of 80 Nm (58 Lb.-Ft.). Be careful when installing gear so injection pump drive shaft does not rotate.

F. Rotate crankshaft counterclockwise (as viewed from front), then clockwise to determine minimum dial indicator reading. Zero dial indicator at this crankshaft position.

G. Rotate crankshaft clockwise to TDC. Loosen three hex nuts that secure injection pump. Rotate injection pump on mounting studs as required to obtain plunger lift of 1.050 ±0.050 mm at TDC.

H. Recheck dial indicator zero and plunger lift at TDC by rotating the crankshaft counterclockwise, then clockwise. Repeat preceding steps as necessary to obtain proper timing of 1.050 ±0.050 mm at TDC.

**⚠CAUTION** ***Do not strike end of injection pump driveshaft to drive shaft out of the gear. Internal injection pump damage will result.***

I. Torque injection pump mounting hex nuts. Remove dial indicator and install bleed screw with sealing washer. Torque bleed screw to 9 Nm (6.6 Ft.-Lb.).

J. Install fuel return line fitting (double-barbed) and special hollow screw with overflow restriction orifice, marked "OUT" (Figure 25). Use a copper sealing washer on each side of the barbed fitting. Large barb points away from engine. Torque hollow screw to 20 to 25 Nm (15 to 18.5 Lb.-Ft.). Install nozzle overflow line to small barb and tank return line to large barb. Install hollow screw through the banjo fitting on the filtered fuel supply line. Use a copper sealing washer on each side of the banjo fittting. Torque hollow screw to 20 to 25 Nm (15 to 18.5 Lb.-Ft.)

5. When used connect flexible line from intake manifold to intake manifold pressure fitting on injection pump.

6. Install high pressure lines. When securing high pressure line nuts be sure to hold discharge fitting to prevent over tightening of the fitting.

7. Connect electrical lead to nongrounded terminal on injection pump cover. Connect throttle control to speed control lever.

8. Install O-ring in groove in gearcase cover. Position gear cover on gearcase and secure capscrews and flatwashers.

9. Install and adjust fan belts. Refer to *SECTION 9, COOLING SYSTEM* for correct procedures.

10. Install all components that were removed from front of engine.

11. Fill cooling system to the proper level. Refer to *SECTION 9, COOLING SYSTEM.*

12. Prime fuel system. Refer to the procedure outlined earlier in this section.

## FUEL LINES

Inspect the fuel lines daily for loose connections, breaks, or flaws. Any leak will indicate a failure or loose connection.

Keep the high pressure line connectors torqued. Tighten until snug, but do not strip the threads. To avoid bending the lines or stripping the injection pump fittings, use a flare crows foot with torque wrench for final tightening.

When replacing an injection line, be sure to use a line that is identical in size, shape, length, and inside diameter. After removing an injection line it must be protected with the appropriate fuel line plugs to prevent dirt or moisture from entering the fuel line.

## FUEL TRANSFER PUMP

The fuel transfer pump (Figure 26) is a diaphragm and relief valve type. The pump is operated by a plunger driven off a cam lobe on the engine camshaft. The fuel transfer pump maintains a positive pressure to the fuel injection pump. Transfer pump output pressure should be 27 to 48 kPa (4 to 7 psi) at engine idle speed. Transfer pump pressure may be checked by connecting pressure gauge and tee at the fuel outlet.

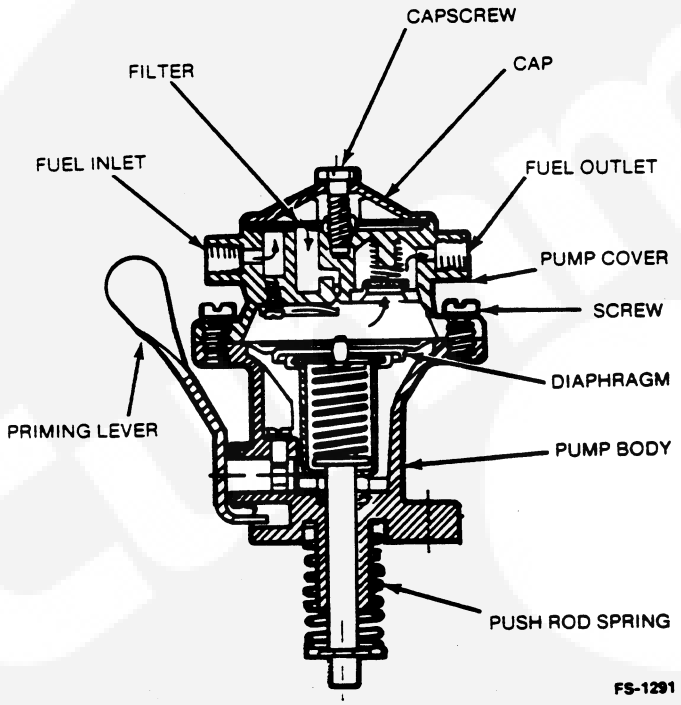



**FIGURE 26. MECHANICAL FUEL TRANSFER PUMP**

### Maintenance

If the diaphragm is leaking or broken, replace it and check for diluted crankcase oil. Change oil if necessary. Remove and clean transfer pump filter after every 2000 hours of operation. A damaged filter must be replaced.

### Fuel Pump Removal and Disassembly

1. Shut off valve at fuel tank. Disconnect pump inlet and outlet lines.
2. Remove three capscrews that secure pump to cylinder block and pull pump off. A special wrench is available to aid in transfer pump removal.
3. Notch pump cover and body with a file for location purposes when pump is being reassembled.
4. Remove hex head capscrew and cap. Loosen a sticking cap by carefully inserting a punch into capscrew bore and prying. Remove filter.
5. Remove the six cover screws. Tap pump cover with a soft plastic hammer to separate the two parts. Do not pry them apart, this may damage the diaphragm.
6. Compress push rod spring against pump body and remove retaining ring and spring washer.
7. Remove diaphragm assembly from pump body.

### Inspection

Clean all pump components and rinse with clean diesel fuel. Use low pressure compressed air to dry parts. Visually inspect pump components for damage.

A kit is available for the replacement of gaskets, diaphragm, and filter. If any other components are damaged or worn, replace the pump assembly.

### Assembly and Installation

1. Lubricate diaphragm shaft and insert carefully through oil seal into pump body.
2. Place spring and spring plate onto diaphragm shaft. Compress spring and secure with retaining ring.
3. Push diaphragm shaft upward against spring force. Assemble cover to body with notch marks lined up. Install screws, but do not tighten.
4. Release tension on diaphragm shaft and uniformly tighten screws to 2 to 3 Nm (17 to 26 in.-lbs.).
5. Position filter in pump cover with spacer legs facing upwards.
6. Place gasket and cap on pump cover. Torque capscrew with gasket to 2 to 3 Nm (17 to 26 in.-lbs.).
7. Install pump on engine. Open fuel shut off valve and prime low pressure fuel system.
8. Pressure test transfer pump output for correct pressure.

## INJECTION NOZZLES

The injection nozzle must inject an equal amount of fuel into each cylinder, atomize the fuel, and spread the fuel spray to mix it fully with the air for smooth operation.

### Type of Nozzle

The L diesel engine uses a hydraulically operated, throttling pintle type of nozzle assembly.

The injection nozzle and nozzle holder is a simple device. A spring is used to oppose injection pump pressure until the right moment for injecting fuel, at which time the nozzle opens.

Each nozzle holder assembly is adjusted to open at a specific pressure. See Table 1.

### TABLE 1. NOZZLE OPENING PRESSURE

| | |
|---|---|
| Naturally Aspirated | 13,000 to 13,800 kPa (1890 to 2000 psi) |
| Turbocharged | 17,000 to 17,800 kPa (2470 to 2580 psi) |

Opening pressure can be adjusted by changing the shim thickness in the nozzle holder.

### Operating Principle

High pressure fuel from injection pump enters nozzle holder fuel inlet and flows through drilled passages in the nozzle body to the pressure chamber.

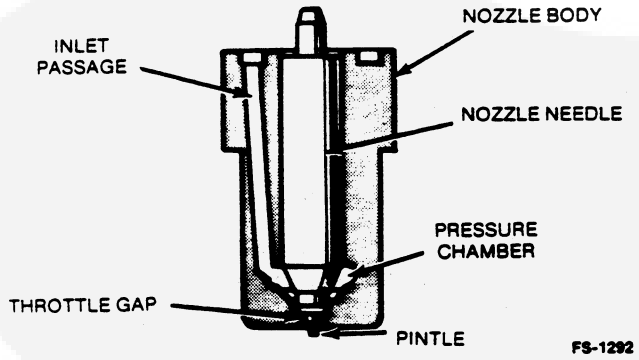



**FIGURE 27. NOZZLE ASSEMBLY**

At the instant pressurized fuel in the pressure chamber (Figure 27) exceeds spring pressure on the nozzle needle, injection begins as pressure lifts the nozzle needle off its seat. Early in the injection sequence the nozzle opens up only a narrow amount (throttle gap) (Figure 27), allowing a small amount of fuel to be injected into pre-combustion chamber. This is called pre-spray. Due to the continuing delivery of fuel by the injection pump, there is a further rise in injection pressure, which lifts the nozzle needle further, opening a larger throttle gap and allowing a greater amount of fuel to be injected into combustion chamber. This forms the main spray. By first injecting a small amount of fuel, and subsequently a larger amount, combustion is more uniform. Combustion pressures rise slower with this type of fuel metering.

As soon as fuel injection pump stops delivering fuel to nozzle holder assembly, nozzle needle returns to its seat, cutting off fuel injection into combustion chamber.

A certain amount of fuel seeps between the lapped surfaces of nozzle needle and nozzle body; this is necessary for lubrication. Excess fuel accumulates around spring seat and in spring compartment of nozzle. Excess fuel is returned to tank after each injection cycle by a return line that connects nozzle holder assemblies together. A fuel return fitting combines the return fuel from nozzles with the flow-through fuel from injection pump ball check valve. A return line connected at this point returns excess fuel to fuel supply tank.

### Injection Nozzle Tester

**⚠CAUTION** ***Testing and adjustment can be performed only with a nozzle tester, Figure 28. Do not attempt to disassemble nozzles or adjust nozzle pressure without the proper test equipment.***

Nozzle assembly is tested with nozzle holder as a complete assembly.

Absolute cleanliness is required when testing nozzle holder assemblies.

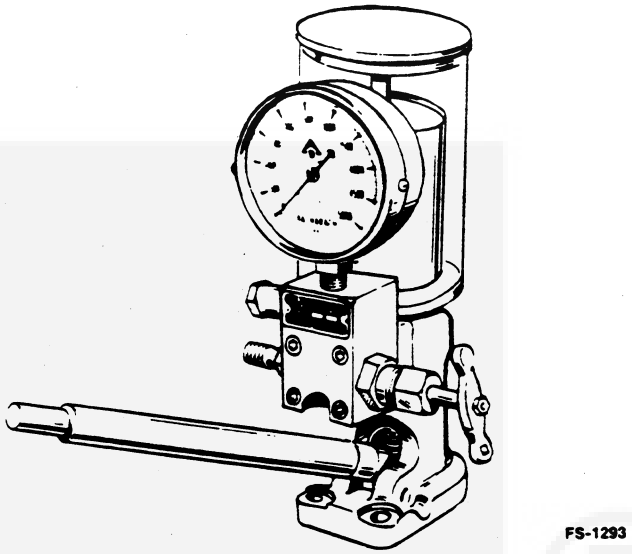



**FIGURE 28. INJECTION NOZZLE TESTER**

Check opening pressure, leakage, and spray pattern using a nozzle tester. If any leakage or abnormal spray pattern is detected, inspect with a magnifying glass for erosion, scoring, etc. If cleaning with solvent does not correct the malfunctions, a new nozzle assembly will be required. Opening pressure can then be set and the spray pattern checked.

Use test oil (Viscor 1487) in the injection nozzle tester.

## Nozzle Removal

1. Thoroughly clean injection nozzles, lines, and surrounding area.

2. Remove high pressure lines and fuel return lines from injection nozzles. Do not bend high pressure lines when disconnecting. Cap all fuel line openings to prevent the entrance of dust, dirt, and moisture.

3. Remove dust shields from injection nozzles.

4. Remove injection nozzles from cylinder head using a deep 27 mm socket.

5. Remove injection nozzle seals from injection nozzle bore. Do not reuse injection nozzle seals. They must be replaced whenever nozzles are removed.

## Testing Nozzle

**⚠WARNING** ***Keep hands away from a spraying nozzle! The nozzle discharge pressure can cause oil to penetrate the skin and can cause blood poisoning or a serious skin infection.***

Connect injection nozzle assembly to the tester. Make sure line fittings used to connect injection nozzle assembly to tester are of the same type as on injection nozzle assembly and tester.

When testing injection nozzle assemblies a systematic approach is recommended. There is a sequence of tests to perform to insure a good injection nozzle assembly; failure to pass any of the tests is reason to reject an assembly. Do not combine test procedures or results, and do not skip any tests.

***Check for Nozzle Jamming:*** With the pressure gauge by-passed, test nozzle for jamming by pressing nozzle tester hand lever down quickly (about four to six times a second). When nozzle valve moves properly, nozzle will operate with a shrill whistle.

The spray pattern must be compact and well atomized at full lift to be correct. The pressure difference between start of nozzle opening and full lift causes the fuel to emerge in a stream, change to flag-like formations, and finally reach atomized spray pattern at full lift with lever movements producing 4-6 nozzle opening cycles per second. See Figure 29.

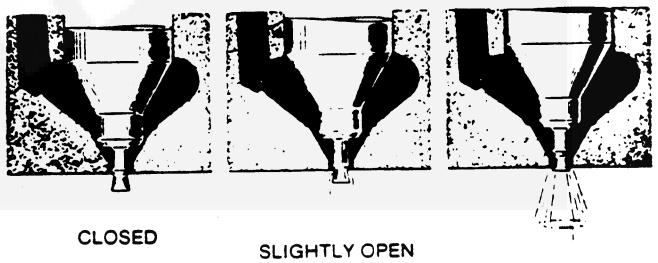



**FIGURE 29. NOZZLE SPRAY ACTION**

***Opening Pressure:*** Open tester pressure gauge valve. Slowly (1 stroke per second) depress pump lever until nozzle ejects. Note nozzle opening pressure on pressure gauge. See Table 1 for correct nozzle opening pressure.

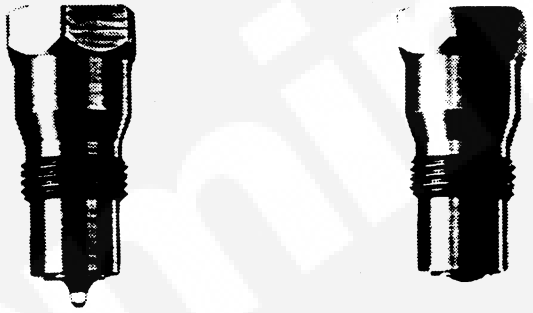
Nozzles with incorrect opening pressure should be readjusted by changing shims.

An abnormal nozzle spray pattern or fuel stream is normal when checking nozzle opening pressures.

***Leakage Test:*** With the pressure gauge valve still open, depress pump lever until the pressure is 1,034 kPa (150 psi) below the specified opening pressure.

If no drops fall from nozzle tip within 10 seconds, as shown in Figure 30, the nozzle is good.

If a drop falls from the nozzle within 10 seconds, see Figure 30, the nozzle leaks and must be cleaned and retested. Nozzles that still drip within 10 seconds must be replaced. Lapping is not recommended.



**ACCEPTABLE** **UNACCEPTABLE**

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**FIGURE 30. NOZZLE LEAK TEST**

***Chatter Test and Spray Pattern:*** The chatter (noise) test will indicate the ability of the nozzle needle to move freely and properly atomize fuel.

Compare the chatter test and spray pattern for new nozzle holder assemblies with the Chatter Test Descriptions. See Table 2.

Used nozzles should not be evaluated for chatter at lower testing speeds. An old nozzle can generally be used if it passes the leakage test, chatters audibly at high testing speeds, and if it uniformly atomizes the fuel.

## TABLE 2. CHATTER TEST DESCRIPTIONS

| Chatter Test Description | Spray Pattern |
|---|---|
| Soft chatter at lever speeds of 1—2 strokes per second. | Spray pattern cannot be evaluated under 4—6 strokes per second.<br>Stringy, split streams that are not well atomized are normal at 1—2 strokes per second. |
| Hissing noise from 2—4 strokes per second. | |
| High pitched sound only at 4—6 strokes per second. | Uniform and well atomized spray pattern at 4—6 strokes per second. |

## Nozzle Removal

1. Thoroughly clean i
surrounding area

2. Remove high
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**TABLE 3. INJECTION NOZZLE SHIMS**

| PART NUMBER | THICKNESS (mm) |
|---|---|
| 147-0617 | 0.80 |
| 147-0618 | 0.84 |
| 147-0619 | 0.88 |
| 147-0620 | 0.92 |
| 147-0621 | 0.96 |
| 147-0622 | 1.00 |
| 147-0623 | 1.04 |
| 147-0624 | 1.08 |
| 147-0625 | 1.12 |
| 147-0626 | 1.16 |
| 147-0627 | 1.20 |
| 147-0628 | 1.24 |
| 147-0629 | 1.28 |
| 147-0630 | 1.32 |
| 147-0631 | 1.36 |
| 147-0632 | 1.40 |
| 147-0633 | 1.44 |
| 147-0634 | 1.48 |
| 147-0635 | 1.52 |
| 147-0636 | 1.56 |
| 147-0637 | 1.60 |
| 147-0638 | 1.64 |
| 147-0639 | 1.68 |
| 147-0640 | 1.72 |
| 147-0641 | 1.76 |
| 147-0642 | 1.80 |
| 147-0643 | 1.84 |
| 147-0644 | 1.88 |
| 147-0645 | 1.92 |
| 147-0646 | 1.96 |

## Disassembly

In most cases, disassembly and cleaning of the injection nozzle is all that is required to place it in good operational condition. The nozzle valve and nozzle valve body are mated parts and must be kept together. If replacement of either part is necessary, both parts must be replaced as matched sets. Never interchange components between nozzle assemblies.

**⚠CAUTION** ***Before starting the disassembly of a fuel injection nozzle holder, it is very important to have a clean work bench, clean washing fluid containers, clean tools, and clean hands. Cleanliness is emphasized because injection nozzle service troubles are in most cases, due to dirt entering the nozzles. Use clean lint-free paper on work bench. As nozzle holder is disassembled, place components in a container of clean diesel fuel as a protection against dirt and corrosion.***

**⚠CAUTION** ***Do not attempt to disassemble the nozzles or adjust nozzle pressure without the proper test equipment. A nozzle pressure tester is essential to do a satisfactory job.***

Clean the outside of the nozzle holder and nozzle before disassembling the nozzle holder assembly. Remove carbon residue from nozzle needle tip, nozzle valve body, and lower nozzle holder body with the brass wire brush and a piece of hardwood (dipped in test oil) found in the nozzle cleaning kit.

1. Clamp the upper nozzle holder body in a vise (use jaw covers). Loosen the lower nozzle holder body with the appropriate wrench (Figure 31).

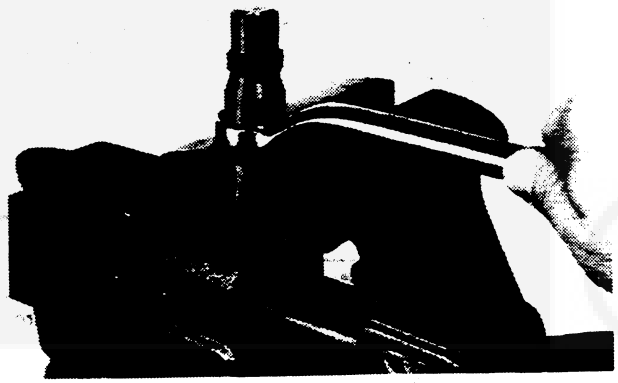

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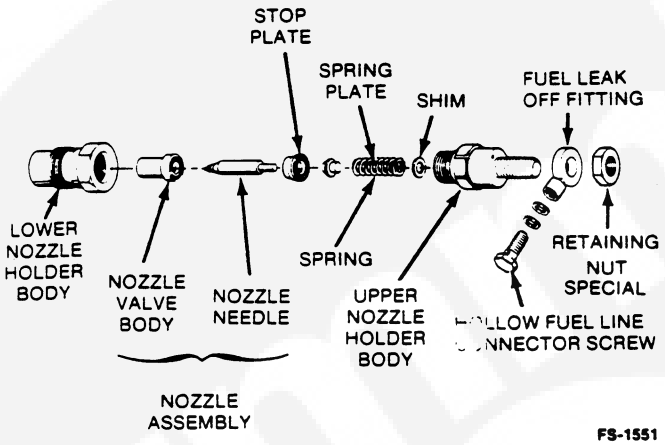
**FIGURE 31. NOZZLE HOLDER DISASSEMBLY**

2. Remove nozzle holder from vise and disassemble nozzle (Figure 32). Normally the nozzle can be easily removed from nozzle holder. However, in some cases it may be necessary to soak the holder in fuel before nozzle assembly can be withdrawn. Hold the nozzle needle by the stem only. Perspiration and oils from the skin can corrode the finely lapped surfaces of the needle.



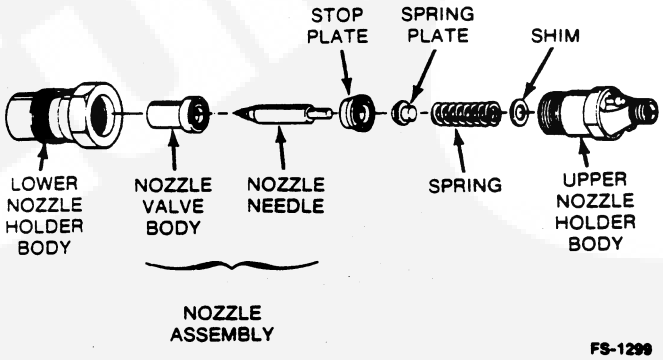




**FIGURE 32. NOZZLE AND HOLDER ASSEMBLIES**

## Inspection and Cleaning

The nozzle needle and seat in nozzle valve body are ground to provide a fine contact seat between the two parts. Most wear occurs on the nozzle valve body seat. The nozzle needle should never be lapped to the nozzle valve body seat. A nozzle cleaning tool kit is required to clean a nozzle assembly properly.

Clean the interior ring groove of the nozzle valve body with the scraper (Figure 33). Rinse in solvent to remove all dirt and carbon residue, and dip in clean test oil or diesel fuel.

Remove burnt-on combustion deposits from all nozzle assemblies with a commercially available cleaner. Rinse all parts in clean test oil.

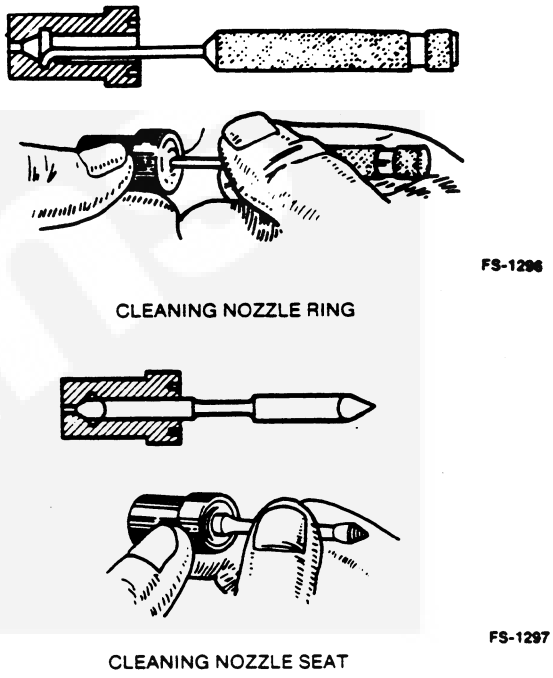



**FIGURE 33. CLEANING NOZZLE ASSEMBLY**

After cleaning, nozzle assembly should be dipped in clean test oil and inspected.

***Inspect the nozzle needle for:*** pounded or rough valve seat area, worn or damaged pintle, score marks, pressure marks, cavitation erosion, and damage from fuel contamination. The pressure shoulder (Figure 34) will normally have an acceptable, rough machined appearance.

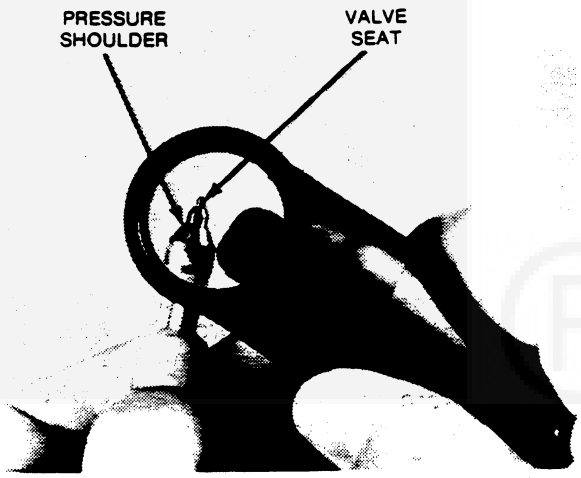



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**FIGURE 34. NOZZLE NEEDLE INSPECTION**

***Inspect the nozzle valve body for:*** pounded or carboned seat, out of round injection hole, erosion, excessive operating temperature, and corrosion.

All nozzles should be given the following slide test after cleaning and inspection. Thoroughly rinse nozzle assembly in clean diesel fuel or test oil. Needle must fit freely in nozzle body. To check this fit, lift needle about one third of its length out of nozzle body. Needle should slide down to its seat by its own weight when assembly is held at a 45 degree angle (Figure 35).

If the nozzle fails the slide test, clean the nozzle again and retest it.

Any nozzle needle and nozzle body assembly which cannot pass this test must be replaced. The needle valve and nozzle body are a matched set and must be replaced as an assembly.

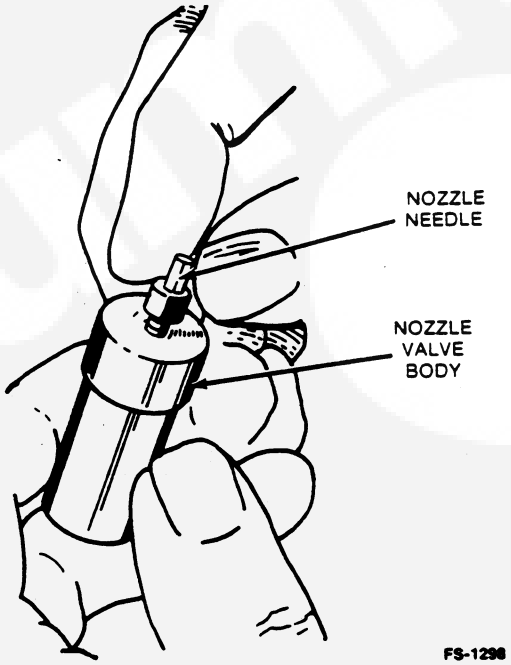


**FIGURE 35. NOZZLE ASSEMBLY SLIDE TEST**

Rinse new nozzle bodies and nozzle needles in solvent to flush thoroughly and completely remove all protective coating material.

Worn or damaged parts must be replaced. Nozzle needle and valve body are replaced together as an assembly.

The premature failure of nozzle assemblies is in most cases caused by improperly filtered air and fuel, fuel contamination, excessive operating temperatures, incorrect combustion pressures, improper nozzle handling, and poor nozzle assembly and installation procedures.

## Assembly

Thoroughly rinse all injection nozzle components in clean diesel fuel and assemble while wet. Always wet fingers with diesel fuel before assembling injection nozzle.

1. Set nozzle assembly into lower body.
2. Place stop plate in lower body with smooth, flat side against nozzle assembly.
3. Place spring seat over nozzle needle in stop plate.
4. Insert shim into upper nozzle holder body.
5. Insert spring into upper body. Thread upper body into lower body just enough to hold the parts in place (several turns of the lower body).
6. Mount the upper nozzle holder body in a vise (Figure 36) use jaw covers, and tighten lower nozzle holder body to the specified torque.

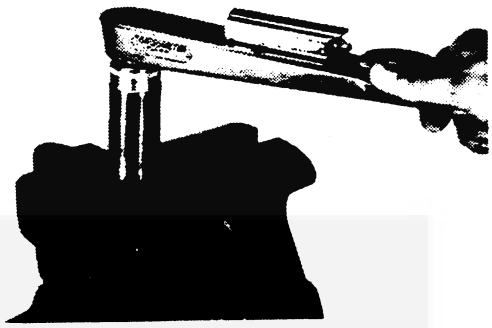

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**FIGURE 36. NOZZLE HOLDER ASSEMBLY**

7. After nozzle assemblies have been cleaned, inspected and given the slide test, the nozzle and holder assembly should be tested for opening pressure, leakage, chatter, and spray pattern.

**⚠WARNING** ***Keep hands away from a spraying nozzle! The nozzle discharge pressure can cause oil to penetrate the skin and can cause blood poisoning or a serious skin infection.***

### Installation

1. Place new injection nozzle seals in nozzle bore with concave side down (Figure 37). Do not reuse injection nozzle seals. They must be replaced whenever nozzles are removed. Install injection nozzles into cylinder head and tighten to the specified torque.


**FIGURE 37. INJECTION NOZZLE SEALS**

**⚠CAUTION** ***Incorrect installation of the injection nozzle seals will cause the injection nozzle to overheat and stick. Sticky nozzles cause excessive noise and smoke.***

2. Place dust shields over injection nozzles if used.

3. Install and connect injection lines and return lines. Make certain lines are clean and dry before installing them.

   On marine engines torque 8 mm hollow fuel line connector screw to 8 Nm (6 Ft.-Lb.). Torque Banjo fitting retaining nut to 40 Nm (30 Ft.-Lb.). Torque high pressure injection line nuts to 24 Nm (18 Ft.-Lb.) on all engines.

## INTAKE MANIFOLD

The air intake system consists of those parts which transport filtered air to the engine cylinders.

The air intake system has two basic components, air cleaner and intake manifold. If engine has a turbocharger, the compressor side of turbocharger is part of intake system.

It is important to provide an adequate supply of fresh clean air to the combustion chambers. Insufficient air supply will limit the amount of fuel engine can burn and lead to loss of power, excessive smoke, and high fuel consumption. Dirty contaminated air results in worn engine parts, high oil consumption, and early engine failure.

### Removal

1. Remove air inlet hose and air cleaner if necessary, from intake manifold flange.
2. Remove high pressure fuel lines from injection nozzles. Loosen high pressure lines at injection pump. Be sure to hold discharge fittings when loosening lines.
3. Remove injection line clamps from intake manifold. Carefully pull injection lines away from manifold.
4. Remove capscrews and washers that secure intake manifold to cylinder head.
5. Remove intake manifold and manifold gasket.

### Inspection

1. Wash and clean intake manifold in a good solvent.
2. Check manifold for deposits, clean and remove any obstructions found in manifold.
3. If manifold is cracked or mounting surface is warped enough so that it will not seal, the manifold must be replaced.
4. Clean and inspect for warpage mounting surface on cylinder head to make sure that it is smooth and free of gasket material.

### Installation

1. Place a new manifold gasket on manifold.
2. Mount intake manifold and torque capscrews to 23 Nm (17 Ft.-Lb.) in a pattern, from inside to outside.
3. Install high pressure fuel lines. Refer to *Injection Pump Installation* procedure.
4. Connect or install air inlet hose and air cleaner.

## AIR CLEANER

The purpose of air cleaner is to remove dust, dirt, and other foreign material from air used by the engine. Engine life depends to a great extent on air cleaner efficiency. Rapid wear on cylinder bores, pistons, and rings will result if air cleaner is not kept in good condition and properly serviced.

A variety of air cleaners are available and used on this series of engines. The required service interval, regardless of air cleaner type, depends on the amount of foreign material in air surrounding engine.

Some dry type air cleaners are equipped with a filter service indicator. Service or replace filter when so indicated. However, if a service indicator is not used, refer to equipment manufacturer's operators manual for specific air cleaner service instructions.

Inspect air cleaner body periodically for dents and cracks. Check for damaged gaskets and hoses, loose hose clamps, and for leaks that would allow unfiltered air to enter the engine. Correct any such condition by the immediate repair or replacement of the faulty parts.

# 11. Exhaust System

## EXHAUST SYSTEM OPERATION

The exhaust system collects exhaust gases from each engine cylinder and carries these gases to the atmosphere. The exhaust system consists of exhaust manifold, gaskets, muffler, and exhaust piping. If engine is equipped with a turbocharger, the turbine portion of turbocharger is part of exhaust system.

The exhaust system must efficiently expel all combustion products and muffle exhaust noises with a minimum amount of back pressure. If back pressure is too high, the engine volumetric efficiency is reduced, fuel economy drops, exhaust temperature increases, and valve life is shortened. Any combustion products left in combustion chamber following the exhaust stroke, dilutes the amount of air that can be drawn in on the next intake stroke. This reduces engine power and increases fuel consumption.

### Exhaust Smoke

A light gray or light blue smoke may be a result of low ambient temperature and light load. This smoke is unburned fuel (not harmful to the engine) and disappears when more load is applied.

**⚠WARNING** ***On service calls, always inspect exhaust systems for possible leaks. Report any exhaust hazards to the owner/operator and warn them of the potential dangers to life if not repaired.***

## INSTALLATION TIPS

Points to remember when installing an exhaust system are:

- Exhaust pipes should be as short as possible with a minimum of fittings.
- The muffler must be as close to engine as possible. Mufflers which are too far from the manifold remain cool and collect carbon residue.
- Avoid sharp bends by using large radius elbows.
- Check back pressure with a mercury or water column type manometer at the exhaust manifold outlet.
- Vent exhaust gases outside. Use flexible tubing only between the engine exhaust outlet and rigid piping.
- Position exhaust outlet away from engine air intake, windows, doors, air conditioners, and other air inlets.

Exhaust noise can be suppressed or reduced by:

- Using a heavy duty exhaust system with a more efficient muffler.
- Avoid long runs of flexible line.
- Installing a deflector at the exhaust outlet to direct exhaust toward the ground, but away from operator.
- Using a resonator in addition to a muffler.

The importance of exhaust systems (normally supplied by the customer) cannot be over-emphasized. A poor or clogged system causes low power, overheating and engine damage. A poor exhaust system increases back pressure which reduces efficiency, causing low power and may result in overheating thereby causing engine damage.

**⚠WARNING** ***If an OEM manufacturer tailors its own exhaust system, Onan Applied Engineering must approve the installation for warranty purposes. A leaking exhaust system can result in personal injury or death.***

**⚠WARNING** ***Inhalation of exhaust gases can result in serious personal injury or death. Pipe exhaust outside the hull and do NOT terminate exhaust pipe near any window or bulkhead door openings.***

**⚠WARNING**

***EXHAUST GAS IS DEADLY!***

***Exhaust gases contain carbon monoxide, a poisonous gas that can cause unconsciousness and death. It is an odorless and colorless gas formed during combustion of hydrocarbon fuels. Symptoms of carbon monoxide poisoning are:***

- ***Dizziness***
- ***Headache***
- ***Weakness and Sleepiness***
- ***Vomiting***
- ***Muscular Twitching***
- ***Throbbing in Temples***

***If you experience any of these symptoms, get out into fresh air immediately, shut down the unit and do not use until it has been inspected.***

***The best protection against carbon monoxide inhalation is proper installation and regular, frequent inspections of the complete exhaust system. If you notice a change in the sound or appearance of exhaust system, shut the unit down immediately and have it inspected and repaired at once by a competent mechanic.***

## EXHAUST MANIFOLD

Two types of exhaust manifolds are used. A dry exhaust manifold is used on non-marine cooled naturally aspirated and turbocharged engines. A water cooled exhaust manifold with integral heat exchanger and expansion tank is used on marine engines. Exhaust manifolds are of a one piece construction manufactured from alloy cast iron.

The exhaust manifold is sealed to the exhaust ports with embossed stainless steel gaskets.

### Dry Exhaust Manifold Removal

1. If engine is installed in an application, remove all components necessary to gain access to exhaust manifold.
2. Remove exhaust pipe or muffler from exhaust manifold.
3. If engine is equipped with a turbocharger, unbolt turbocharger from exhaust manifold.
4. Remove capscrews from exhaust manifold and remove manifold.

### Dry Exhaust Manifold Installation

1. Install capscrews with flatwashers and lock tabs when used onto exhaust manifold.
2. Place new gaskets on capscrews.
3. Mount exhaust manifold and torque capscrews twice to the proper torque using the torque sequence in Figure 1. Exhaust manifold capscrews without locktabs should be retorqued after two hours of operation. Edge of lock tab (Figure 2) must contact unmachined ridge that remains after spotfacing operation. This will prevent capscrew rotation in a counterclockwise direction (loosening) when lock-tab is crimped, with a plier, to fully contact a flat or corner of the hex (Figure 2).

**Exhaust Manifold Capscrew Torques**

| | |
|---|---|
| Capscrew with flatwasher | 28 Nm (21 Ft.-Lb.) |
| Flangehead capscrew | 35 Nm (26 Ft.-Lb.) |

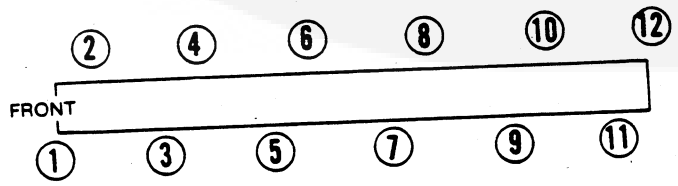


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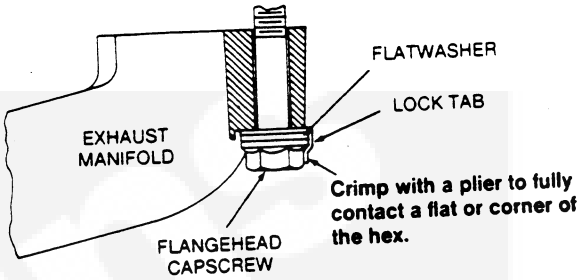
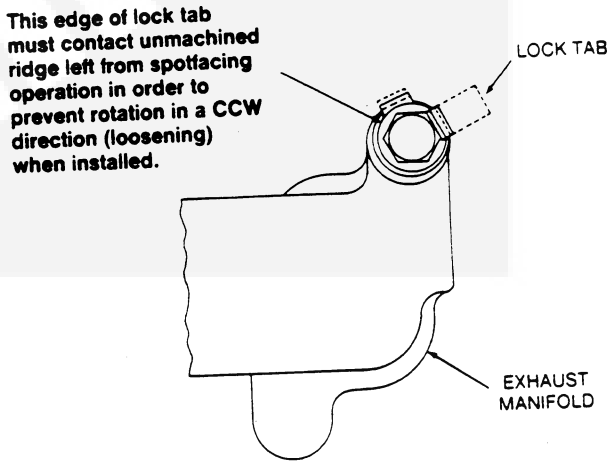
**FIGURE 1. EXHAUST MANIFOLD BOLT TORQUE SEQUENCE**




EXS-

**FIGURE 2. LOCK TAB INSTALLATION**

**⚠CAUTION** ***Exhaust pipe or muffler mus place any strain or pressu turbocharger flange. Make certain exhaust pi muffler is adequately supported.***

4. Connect exhaust pipe or muffler to exhaust mar
5. Install all components removed in order to access to manifold.

### Exhaust Manifold Inspection

1. After removal wash and clean exhaust manifo good solvent.
2. Check manifold for carbon deposits, clea remove any obstructions found in the manifc
3. If manifold is cracked, replace it.
4. If mounting surface of manifold is warped sc will not seal, the manifold must be machinec replaced.
5. Inspect and clean mounting surface on c head and exhaust manifold to make sure it is gasket material and other deposits.

## Water Cooled Exhaust Manifold Removal and Installation

1. Remove all components necessary to gain access to exhaust manifold. Drain captive water system by removing block drain plugs and drain plugs in front and rear manifold end caps. Drain sea water system by removing drain plug from 90° elbow at rear of heat exchanger cover and by removing hose from sea water pump. On generator set engines remove the drain plug from the sea water tube assembly located at the lower front of the generator set model.
2. Remove exhaust muffler from exhaust elbow.
3. Disconnect coolant hoses at exhaust manifold assembly and heat exchanger.
4. Use an overhead hoist or suitable lift to support exhaust manifold assembly.
5. Remove capscrews from exhaust manifold and remove manifold assembly.
6. By reversing the removal procedure, install manifold assembly to engine. Refer to Figure 1 for torque sequence and proper torque value.

## Water Cooled Exhaust Manifold and Heat Exchanger Disassembly, Inspection

1. Remove exhaust elbow and heat exchanger covers.

   Heat exchanger core can be removed from assembly without removing manifold end caps. Loosen manifold end cap retaining screws. This will free heat exchanger core. Push heat exchanger core out one end.
2. Remove manifold end caps from exhaust manifold and heat exchanger shell.
3. Inspect manifold for carbon deposits, clean and remove any obstructions found in the manifold.
4. If manifold or end caps are cracked, replace them.
5. If mounting surface of manifold is warped so that it will not seal, the manifold must be machined flat or replaced.
6. Inspect and clean mounting surface on cylinder head and exhaust manifold to make sure it is free of gasket material and other deposits.
7. Inspect heat exchanger core tubes for deposits. Flush out any deposits that have accumulated in the tubes.

## Water Cooled Exhaust Manifold and Heat Exchanger Assembly (Figure 3)

Always use new gaskets and O-rings when assembling heat exchanger and exhaust manifold.

1. Place one coolant flow tube O-ring in each manifold end cap.
2. Set manifold front cap gasket on front manifold end cap. Gasket must line up with passages in exhaust manifold.
3. Lubricate each end of coolant flow tube with clean vegetable based oil. Install coolant flow tube in O-ring in front manifold end cap.
4. Slide exhaust manifold over coolant flow tube onto front manifold end cap.
5. Secure front manifold end cap to exhaust manifold with capscrews and flat washers. Torque capscrews to 35 Nm (26 Ft.-Lb.).
6. Install heat exchanger shell gasket in front manifold end cap. Stand assembly on front manifold end cap.
7. Position heat exchanger shell in front manifold end cap.
8. Place manifold rear cap gasket on exhaust manifold over coolant flow tube.
9. Place heat exchanger shell gasket on heat exchanger shell.
10. Install rear manifold end cap on exhaust manifold and heat exchanger shell. Hold end cap in place with three capscrews and flatwashers.
11. Insert heat exchanger core into heat exchanger shell. Heat exchanger core is centered and held in place by heat exchanger covers.
12. Place an O-ring and gasket on each heat exchanger cover.
13. Install heat exchanger covers on manifold end caps. Torque capscrews to 11 Nm (8 Ft.-Lb.).
14. Place exhaust elbow manifold gasket and exhaust elbow on rear manifold end cap. Torque capscrews to 35 Nm (26 Ft.-Lb.).
15. If a remote oil filter is used make certain mounting bracket is installed before installing manifold assembly. Apply Loctite 271 to M12 hex head capscrew that secures oil filter mounting bracket to engine.

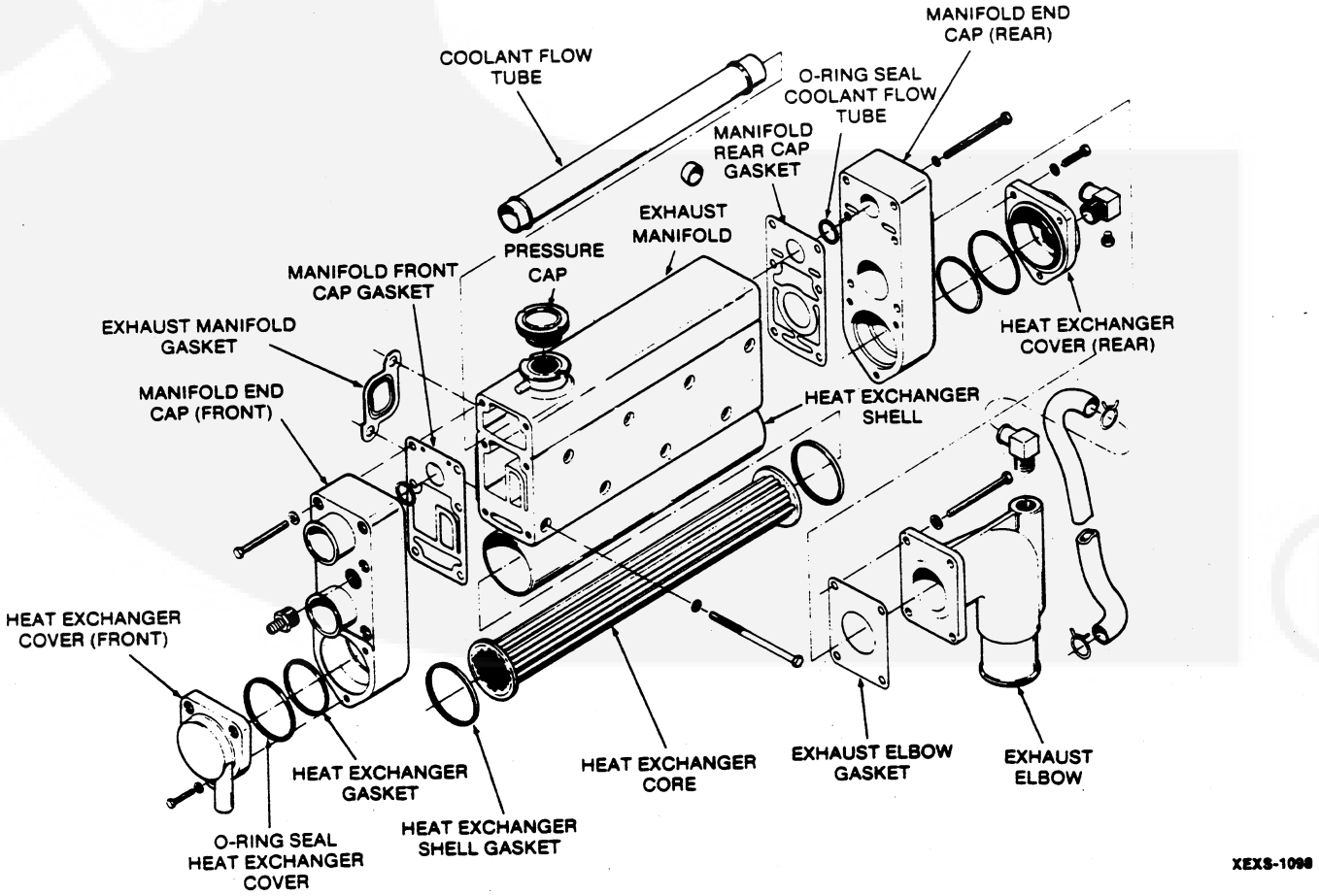



**FIGURE 3. HEAT EXCHANGER ASSEMBLY**

# 12. Electrical System

## ELECTRICAL SYSTEM OPERATION

The electrical system includes starter motor, alternator with voltage regulator, fuel injection pump solenoid, storage battery, and glow plugs.

The charging circuit includes battery, alternator, and voltage regulator. The wet cell battery is the storage cell for electrical energy required to start engine. It must be kept fully charged at all times. Electrical energy drained from the battery is replaced by the alternator. A voltage regulator in the circuit prevents excessive current flow from burning out alternator and damaging battery.

The starting circuit consists of the electric starting motor, and solenoid, a storage battery, and start switch. When start switch is placed in the start position, current flows through the starter solenoid, shifting the drive pinion into mesh with the flywheel ring gear, closing main contacts in solenoid connecting battery directly to starter motor. When engine starts and start switch is released, the solenoid contacts open, automatically disengaging drive pinion.

## BATTERIES

If electrolyte level is low, add distilled water to bring level of each cell to the bottom of filler neck. Be sure filler plugs are tight and vents are open.

**⚠CAUTION** ***Do not add water in freezing weather unless the engine is to be run long enough (two or three hours) to assure a thorough mixing of water and electrolyte.***

Keep batteries clean by wiping them with a damp cloth whenever dirt appears excessive.

If corrosion is present around terminal connections, remove battery cables and wash terminals with an ammonia solution or a solution consisting of 115 grams of baking soda added to 1 litre of water. Be sure vent plugs are tight to prevent cleaning solution from entering cells. After cleaning, flush outside of the battery, battery compartment, and surrounding areas with clear water.

Keep battery terminals clean and tight. After making connections, coat terminals with a light application of petroleum jelly or non-conductive grease to retard corrosion.

**Maintain battery in a fully charged condition. Check charge condition or specific gravity with a hydrometer when electrolyte temperature is at 27° C (80° F).**

| Hydrometer Indication | Charge Condition |
|---|---|
| 1.110 to 1.135 | Completely discharged |
| 1.170 to 1.200 | One-fourth charged |
| 1.205 to 1.230 | One-half charged |
| 1.235 to 1.260 | Three-fourths charged |
| 1.265 to 1.290 | Fully charged |

When batteries are being charged, an explosive gas forms under each cell cover. Some of this gas escapes through vent holes in the plugs. This gas may form an explosive atmosphere around the battery if ventilation is poor.

**⚠WARNING** ***Explosive gas may remain in and around the battery for several hours after it has been charged. Sparks, flames, or smoking can ignite this gas causing an explosion which could shatter the battery. Flying pieces of the battery structure and splash of electrolyte can cause personal injury.***

## PREHEAT CIRCUIT COMPONENTS

The preheat system consists of glow plugs, glow plug control, and a switch to energize preheat circuit. The glow plugs supply heat to the cylinders so compression temperatures are high enough to ignite the fuel during start-up.

Before testing, remove wires from all glow plug terminals. Then, test each glow plug individually for continuity (a high resistance). A plug that tests "open" must be replaced.

## STARTER (Mitsubishi)

The standard starter motor is a 12 volt, overrunning clutch type, with an integral solenoid. The solenoid is connected by a lever assembly to a clutch in the front bracket (nose) assembly. The solenoid shifts the pinion gear into mesh with flywheel ring gear and holds it in place during engine cranking.

**⚠CAUTION** ***Do not engage starter for periods longer than 30 seconds without allowing 2 minutes for starter to cool. Failure to observe this caution can result in overheating and failure of the motor.***

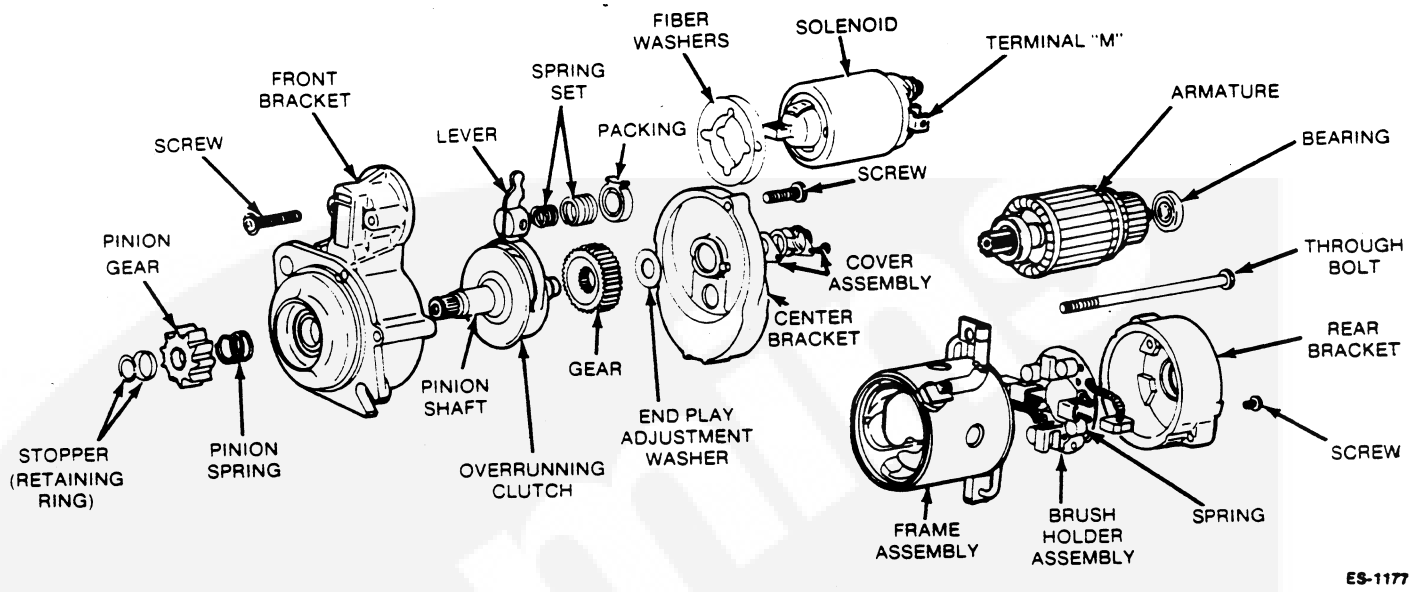



**FIGURE 1. STARTER MOTOR**

## Service

When starting engine, note starter motor action. The pinion gear should mesh quickly with flywheel ring gear and spin engine. Once engine starts and solenoid opens, the starter should disengage and stop. If starter cranks engine slow or not at all, check start circuit components. Failure to crank is normally caused by low battery charge, defective battery cables, corroded or poor connections, or low temperatures. If after checking these variables, starter continues to crank slow it must be removed and repaired.

## Removal and Installation

1. Remove both battery cables from battery. Disconnect ground cable first.
2. Disconnect battery cable and electrical lead wires from starter.
3. Remove capscrews and flat washers that attach starter to flywheel housing.
4. Remove starter. Some rotation of starter may be necessary in order to clear flywheel housing.
5. Mount starter motor to engine by a direct reversal of the removal procedure. Connect battery cable and wires to starter.
6. Connect battery cables to battery. Connect ground cable last.

## Disassembly

1. Remove "M" terminal nut and wire lead from solenoid (Figure 1).
2. Remove the two solenoid mounting screws and remove solenoid.
3. Remove the two through bolts and brush holder retaining screws. Remove rear bracket (Figure 2).

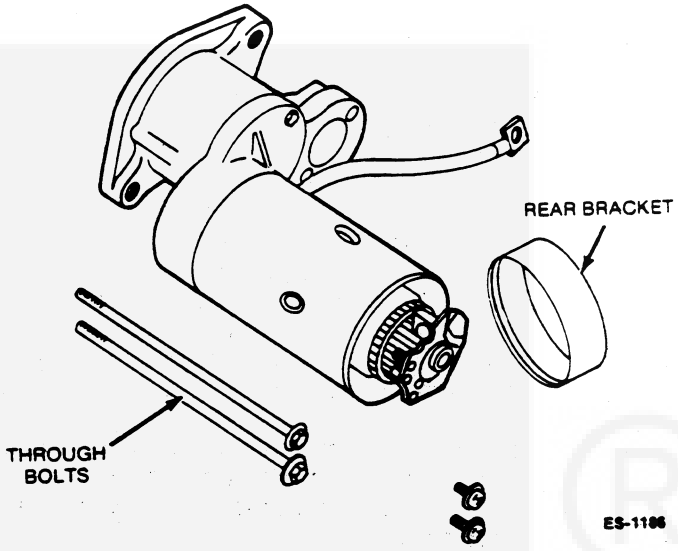



**FIGURE 2. REMOVING REAR BRACKET**

4. Remove frame assembly and brush holder assembly, while pulling the brushes upward. Then remove armature assembly.
5. Remove cover assembly, (snap ring and washer) from the pinion shaft (Figure 3).

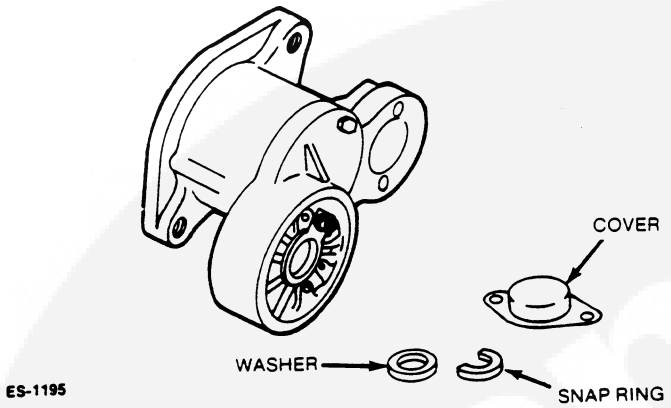



**FIGURE 3. REMOVING SNAP RING AND WASHER**

6. Remove capscrew that secures center bracket to front bracket. Remove the center bracket; several washers used to adjust pinion shaft end play can now be removed (Figure 4).

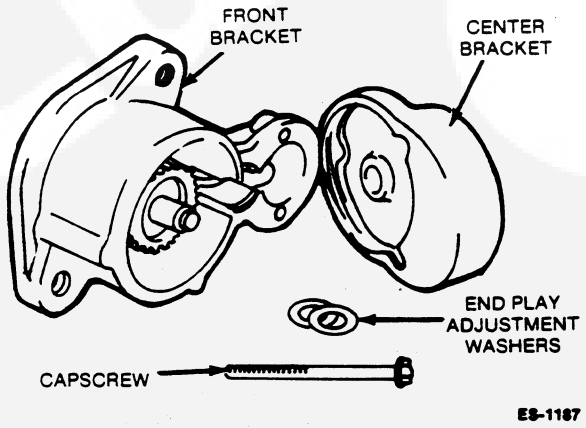



**FIGURE 4. REMOVING CENTER BRACKET**

7. Remove gear, spring set, and lever assembly from front bracket. Note direction in which the lever assembly is installed.
8. Push pinion gear and stopper down and remove retaining ring. Remove stopper, pinion gear, spring, and pinion shaft assembly.
9. Inspect ball bearings. If they are rough or noisy when rotated replace them. The front bearing is not replaceable and must be replaced with the bracket.

## Inspection and Testing

Inspect the starter components for mechanical defects before testing for grounds or shorts.

***Testing Armature for Grounds:*** Touch armature shaft or core and each commutator bar with a pair of ohmmeter leads. If ohmmeter or continuity tester shows continuity, it indicates a grounded armature. Replace the armature assembly. See Figure 5.

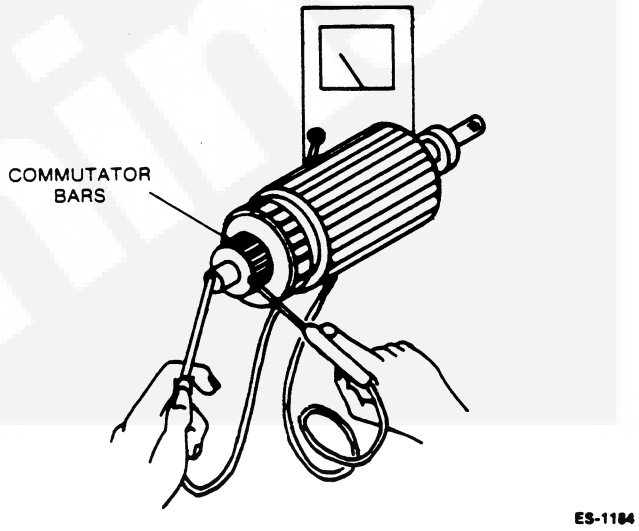



**FIGURE 5. TESTING ARMATURE FOR GROUNDS**

***Testing Armature for a Short Circuit:*** Use a growler for locating shorts in armature. Place armature in growler and hold a thin steel blade (e.g. hacksaw blade) parallel to the core and just above it while slowly rotating armature in growler. A shorted armature will cause the blade to vibrate and be attracted to the core. If armature is shorted, replace with a new one (Figure 6).

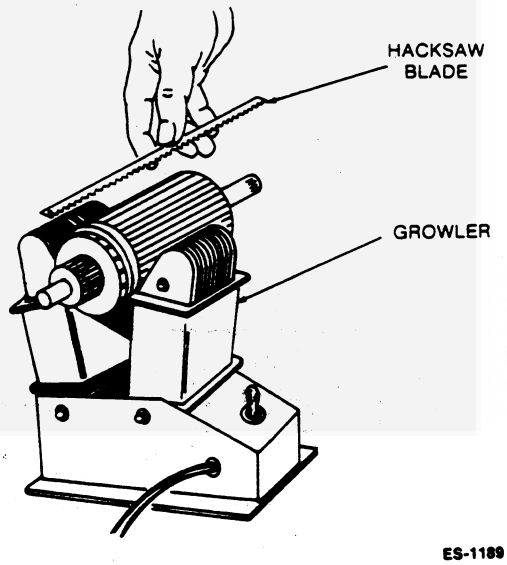



**FIGURE 6. TESTING ARMATURE FOR SHORT CIRCUITS**

***Inspecting for an Open Circuit In Armature:*** Using an ohmmeter, check for continuity between the commutator segments. If there is no continuity (high resistance), the segments are open and armature must be replaced (Figure 7).

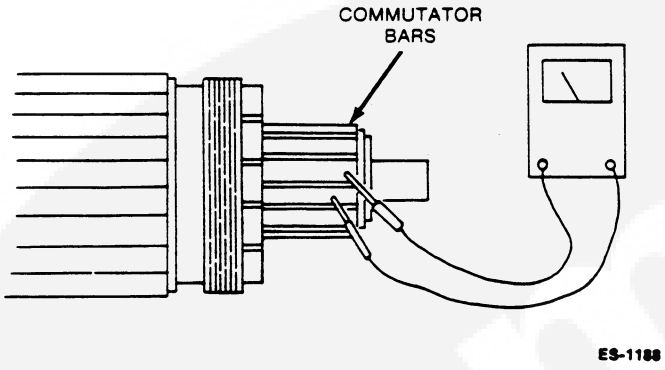



**FIGURE 7. TESTING ARMATURE FOR OPEN CIRCUITS**

***Commutator Inspection:*** If commutator is dirty or discolored, clean with number 00 to 000 commutator paper. Blow grit out of armature after cleaning.

If commutator is scored, rough or worn, turn it down in a lathe.

***Field Coil:*** Use an ohmmeter to check for continuity between brushes. If there is no continuity, the field coil is open and must be replaced. With field coil mounted in the frame, check for continuity between the field coil and frame. Replace frame assembly if there is continuity.

***Brushes:*** Clean around brushes and holders wiping off all brush dust and dirt. If brushes are worn shorter than 11.5 mm (.4528 inch) replace them (Figure 8).

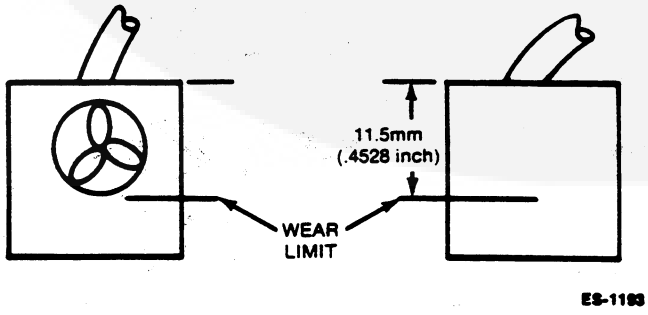



**FIGURE 8. BRUSH WEAR LIMIT**

Check for shorts between positive side of brush holder and brush holder base. If there is continuity, replace holder assembly. Check for free movement of brushes. All brushes should move freely in the brush holders.

***Solenoid:*** Push solenoid plunger in and release it. The plunger should return to its original position. While holding plunger all the way in, check for continuity between terminals "M" and "B". If there is no continuity, replace the solenoid (Figure 9).

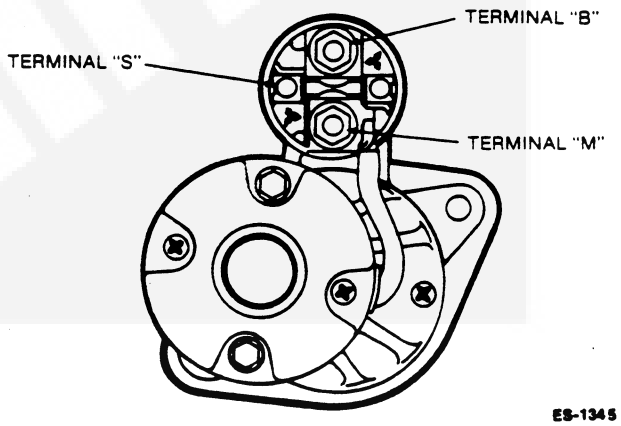



**FIGURE 9. SOLENOID TERMINALS**

***Reduction Gears:*** Inspect armature shaft gear, reduction gear, and pinion shaft gear for wear and damage. Replace any part that is worn or damaged.

***Overruning Clutch:*** Inspect pinion and spline teeth for wear or damage.

If pinion gear is worn or damaged inspect flywheel ring gear also. Rotate pinion. It should turn free when turned in one direction, and lock when turned in the opposite direction.

**⚠CAUTION** ***Do not clean overrunning clutch in solvent or liquid cleaning solution. Washing the clutch will cause the grease to leak out.***

## Starter Assembly

For assembly reverse the disassembly procedure, but note the following items.

***Lubrication:*** Whenever starter motor is disassembled apply grease to each of the following points. (Recommended grade; Multemp PS No. 2.)

- Armature shaft gear
- Reduction gear
- Ball bearing (Both ends of armature)
- Stopper on pinion shaft
- Sleeve bearing
- Pinion gear
- Sliding portion of lever

***Pinion Shaft End Play Adjustment:*** Adjust end play so that it is 0.1 to 0.8 mm (.0039 to .0315 inch) with the adjusting washers placed between center bracket and reduction gear (Figure 10).

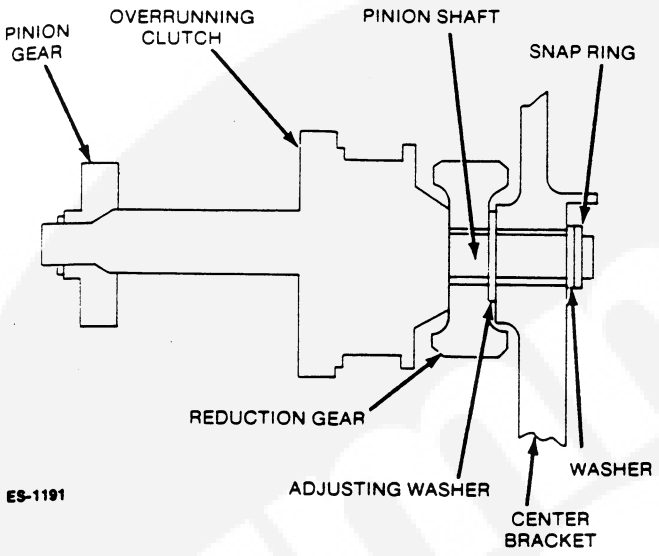



**FIGURE 10. ADJUSTING PINION SHAFT END PLAY**

With pinion gear removed, install reduction gear onto pinion shaft. Place pinion shaft into center bracket and secure with washer and snap ring. Measure the end play with a feeler gauge between center bracket and gear. If necessary, adjust end play by adding or removing adjusting washers.

If pinion gear has not been removed, place pinion shaft and reduction gear between front bracket and center bracket. With lever spring removed and bolt tightened, push pinion shaft out and measure end play. Adjust end play if necessary by adding or removing shims.

***Pinion Gear Installation:*** Place spring and pinion gear onto pinion shaft. Slide stop ring onto pinion shaft and install retaining ring in groove. Pull stop ring over retaining ring (Figure 11).

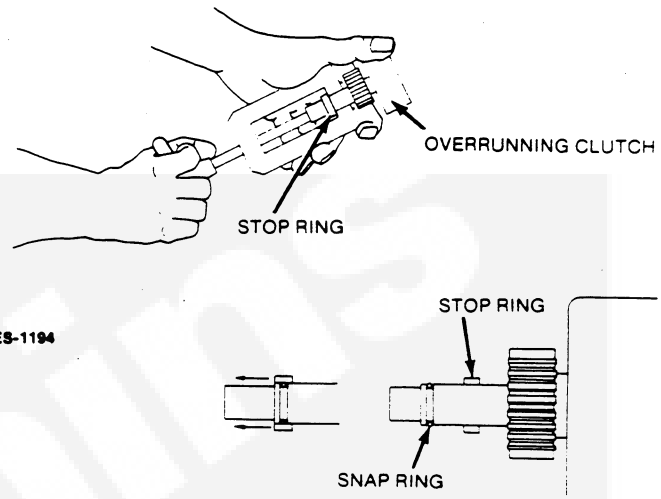



**FIGURE 11. PINION GEAR INSTALLATION**

***Lever Assembly Installation:*** Figure 12 shows the correct method of installing the lever assembly, spring, and packing. Pay close attention to direction of lever.

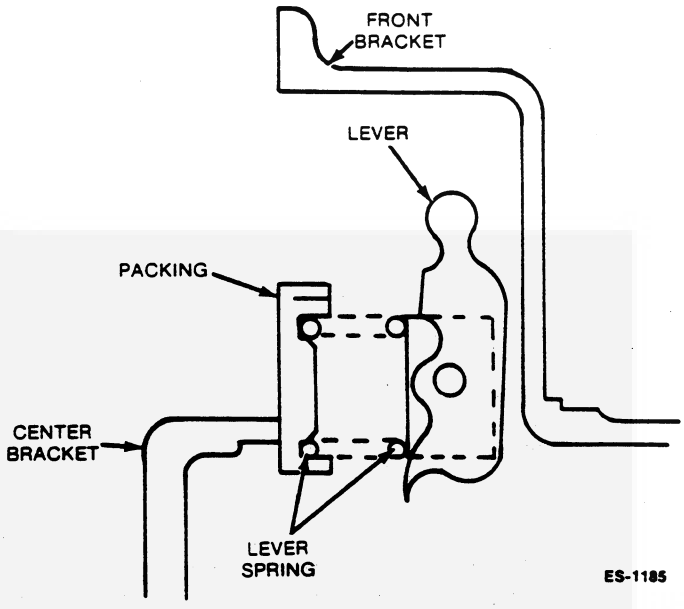



**FIGURE 12. LEVER INSTALLATION**

***Pinion Gap Adjustment:*** After assembling starter motor, adjust pinion gap.

1. Remove "M" terminal nut and wire from solenoid.
2. Connect positive terminal of battery to "S" terminal on solenoid and negative terminal to starter body. With battery connected pinion gear will shift into the cranking position.
3. Gently push pinion shaft back towards front bracket and measure the amount of travel (Figure 13).

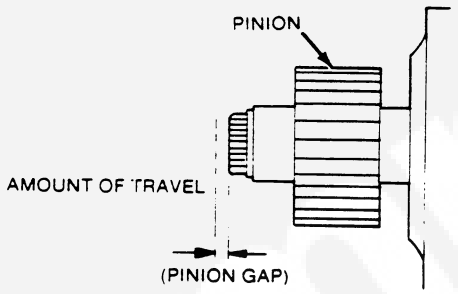



**FIGURE 13. PINION GAP ADJUSTMENT**

4. The pinion gap should be 0.3 to 2.0 mm (.0118 to .0787 inch). Adjust by changing the number of fiber washers used on solenoid mounting surface. Increasing the number of fiber washers decreases clearance. Decreasing the number of washers increases clearance.

## ALTERNATOR

The alternator is a continuous output, diode rectified unit, designed and constructed to provide long periods of dependable service with minimum maintenance. The alternator assembly consists of an alternator and voltage regulator combined as a single unit. Two brushes carry current through two slip rings to the rotor field coil. The rotor is mounted on sealed ball bearings eliminating the need for periodic lubrication.

The stator windings are a part of the laminated core that forms a portion of the alternator housing. Mounted in the rear housing are six rectifier diodes that are connected to the stator windings. The six rectifying diodes change alternating current and voltage to direct current and voltage, by a three-phase, full wave rectifier system.

It is not necessary to remove alternator to replace the brushes or voltage regulator. These operations are usually done with alternator on engine.

The following information is for field use only. For a major repair, remove alternator and take it to a reputable alternator repair shop.

### Removal and Installation

1. Remove capscrew attaching alternator to adjusting bracket and loosen capscrew that secures alternator to bracket.
2. Remove drive belts from alternator pulley.
3. Mark alternator lead wires for subsequent installation. Disconnect lead wires.
4. Remove capscrew attaching alternator to mounting bracket. Note location of spacer and remove alternator.
5. Install alternator by reversing removal procedure.
6. Adjust belt tension. Refer to *SECTION 9, COOLING SYSTEM* Drive Belt Adjustment procedure.

### Service

If alternator output is weak check the following items before removing alternator for servicing.

1. Check drive belts for alignment, tension, and wear.
2. Check for loose alternator drive pulley and loose alternator mounting.
3. Check terminals for corrosion and loose connections. Check wiring for frayed insulation and breaks.
4. Remove and inspect brush assembly.
5. Alternator Output Test

   Use a DC voltmeter (0-30 volts) to measure alternator output. Connect the negative lead from the voltmeter to a good ground on the alternator. Connect the positive lead from the voltmeter to the positive output terminal on the alternator (Figure 14).

   With voltmeter connected, start and run engine at a fast idle of approximately 1000 rpm. A charging system operating properly has a normal system output voltage between 13.8-14.8 volts.

   If the alternator output voltage does not fall within the proper range, remove the alternator for further inspection and testing.

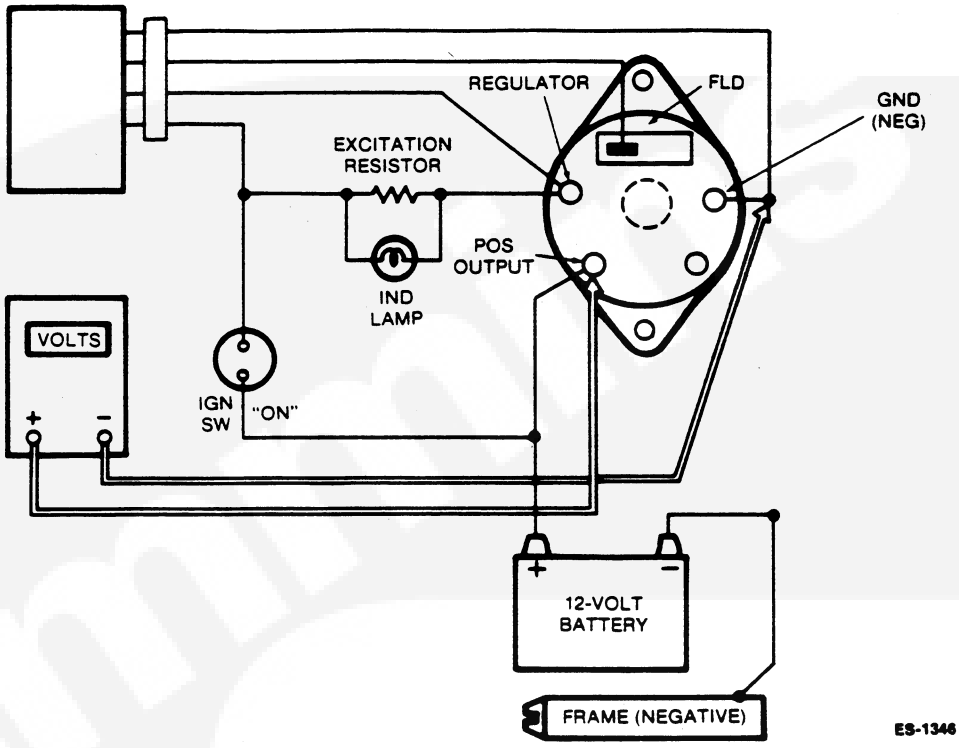



**FIGURE 14. ALTERNATOR OUTPUT TEST CIRCUIT**

***Brush Assembly Removal:***

1. Remove voltage regulator. Make certain regulator leads are disconnected from studs on rectifier diode plate. Remove three screws which fasten regulator and hold regulator away from rear housing. Detach regulator brush connecting lead.
2. Remove two brush mounting screws from cover, and lift cover and dust shield from brush.
3. Remove brush assembly by pulling up and outward to clear index pins.
4. Assemble brush assembly by reversing disassembly procedure (Figure 15).

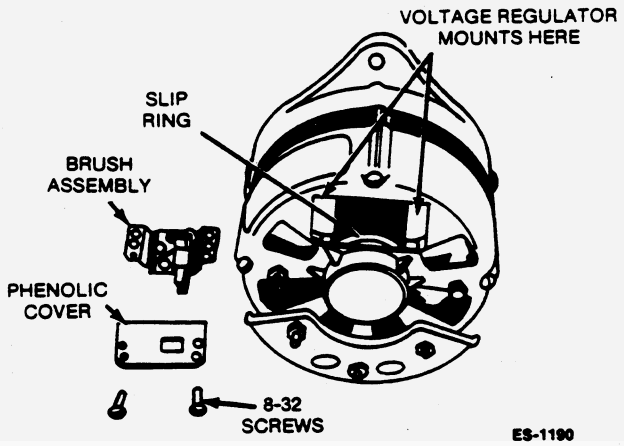



**FIGURE 15. MOTOROLA ALTERNATOR**

***Brush Assembly Inspection:***

1. Measure brush length. Replace, if less than 4.2 mm (0.1654 inch) extends below bottom of holder.
2. Clean entire holder assembly in cleaning solvent and dry. Check movement of brush in holder, as a binding condition will result in poor slip ring contact.
3. Check brush spring tension. A brush spring tension of 113 to 170 grams (4 to 6 ounces) is required to move brush against spring.
4. Check surface of slip rings. If surface is smooth but covered with a carbon-oil-dirt mixture clean with fine crocus cloth and wipe dust and residue away. If slip rings are rough or out-of-round, replace the rotor assembly.

***Brush Assembly Tests:***

1. Connect an ohmmeter or test lamp (12 volts) to the field terminal and to the bracket. The test lamp should not light or resistance reading should be high (infinite). If not, there is a short and the assembly must be replaced.
2. Move one ohmmeter lead from the bracket to insulated brush. Use an alligator clip directly on the brush. Be careful not to chip it. Resistance reading should be zero (continuity).
3. Connect ohmmeter leads to the grounded brush and the bracket. Resistance should be zero (continuity).

## OPTIONAL SPEED SENSOR ADJUSTMENT (Tachometer)

Adjust magnetic pick-up sensor, located on the flywheel housing (Figure 16) as follows:

**⚠WARNING** ***Disconnect engine batteries. Disconnect engine from load. Accidental starting of unit can result in serious personal injury.***

1. Remove sensor.
2. Manually rotate ring gear so one gear tooth is centered directly under sensor mounting hole.
3. Install sensor by turning inward until pole face just touches the gear tooth.
4. Back sensor out 3/4 turn and tighten "jam nut" (Figure 16). [The gap between the sensor and the gear tooth should be 0.9 to 1.3 mm (0.035 to 0.050 inch).]

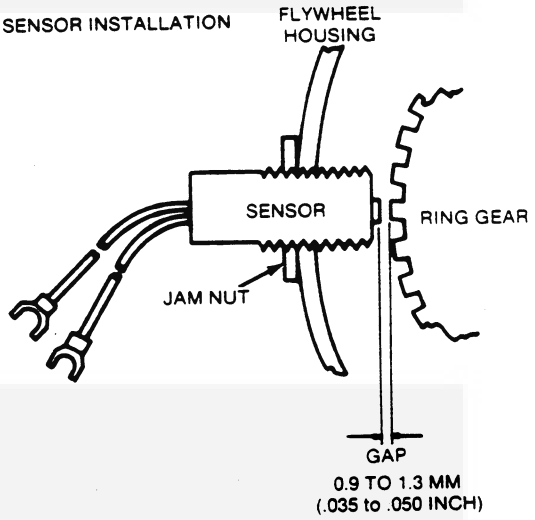



**FIGURE 16. SPEED SENSOR ADJUSTMENT**

## ENGINE CONTROL

Due to the wide variety of uses to which these engines are adapted, operating controls are not supplied with the engines. In most cases, the engines are used for prime power to operate other manufacturers' equipment. Installation nearly always differs, and the manufacturer or fabricator generally provides a control for the complete unit.

Purpose of the control is to tie the starting and charging circuits together at a convenient location. The control may also contain gauges to monitor engine operation and emergency shut-down funtions.

### Maintenance

Periodically check all connections and contacts in the control system to be sure that they are tight and clean.

### Standard Control

Only the standard control used on the closed L Series Power Units is covered in this section. The control is located on the rear housing. This control has a coolant temperature gauge, oil pressure gauge, ammeter, preheat switch, preheat light, start-stop switch, and a fuse to protect the circuit on the control panel (Figure 17).

***Coolant Temperature Gauge:*** Indicates temperature of coolant in engine water jacket.

***Oil Pressure Gauge:*** Indicates pressure of lubricating oil in main oil gallery when engine is running.

***Start-Stop Switch:*** When in the start position, this switch connects battery power to the start solenoid for engine cranking. The switch also controls the power to the fuel injection pump solenoid and returns to the run position when it is released.

***Ammeter:*** Indicates battery charge condition.

***Preheat Switch:*** The preheat switch is a momentary ON switch that cotnrols power to the glow plugs for cold engine starting.

***Preheat Lamp:*** The preheat lamp is lit during preheating. The lamp will go out when the engine is ready for starting.

***Fuse:*** The fuse protects the starting and charging circuits from burning out if a short should occur in the circuit.

### Preheat Circuit

The preheat circuit consists of glow plugs, ballast resistor, and a switch to energize preheat circuit. The glow plugs supply heat to the cylinders permitting compression temperatures to ignite the fuel during start-up.

Using an ohmmeter, check glow plugs and ballast resistor for continuity. If there is no continuity (high resistance), the components are open and must be replaced.

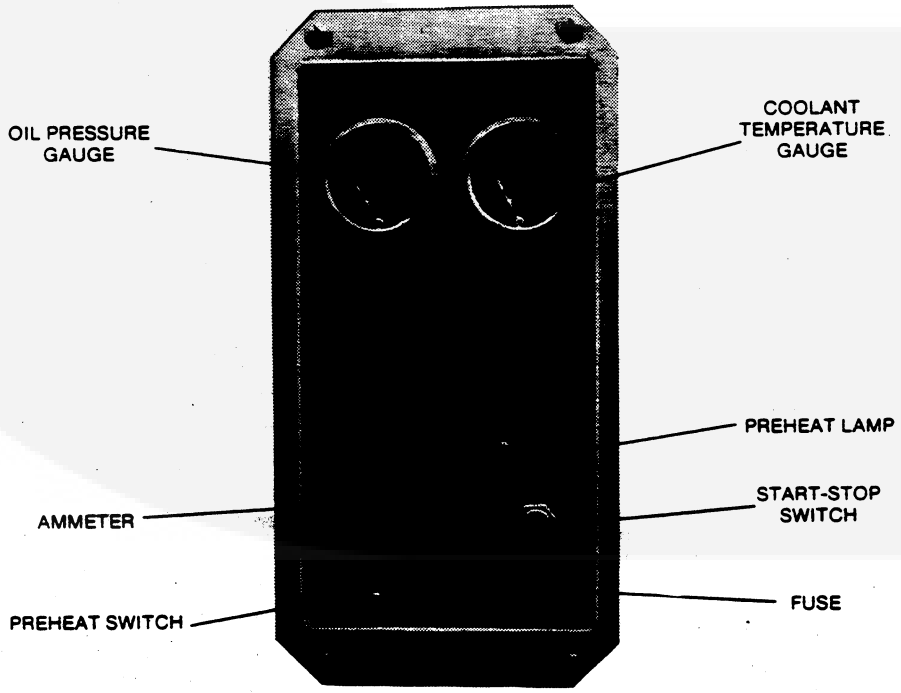
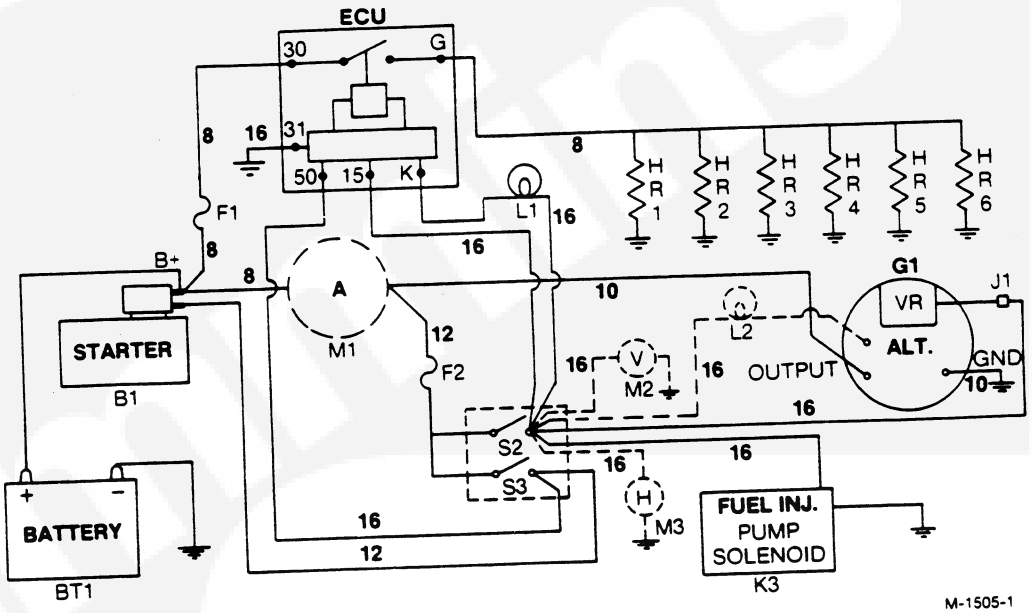



**FIGURE 17. CLOSED POWER UNIT CONTROL (SPEC A)**

# WIRING DIAGRAMS

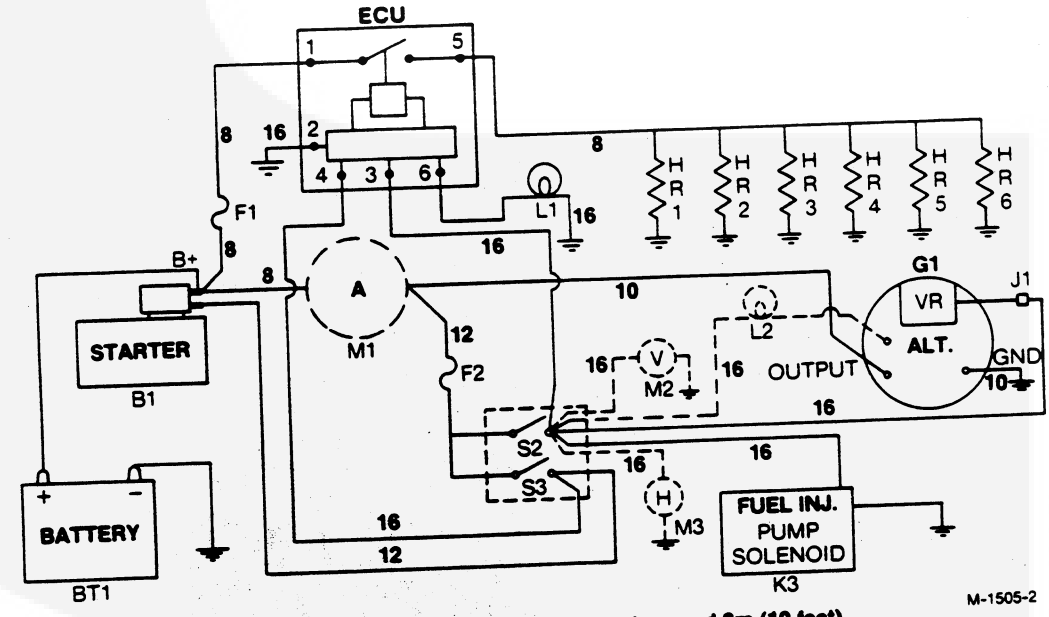
## Wiring Diagram for Electronic Control Unit (ECU)

**ECU Part No. 333-0237**




**Large numbers indicate AWG size. If wire length must exceed 3m (10 feet), use next larger wire size.**

**ECU Part No. 333-0231**



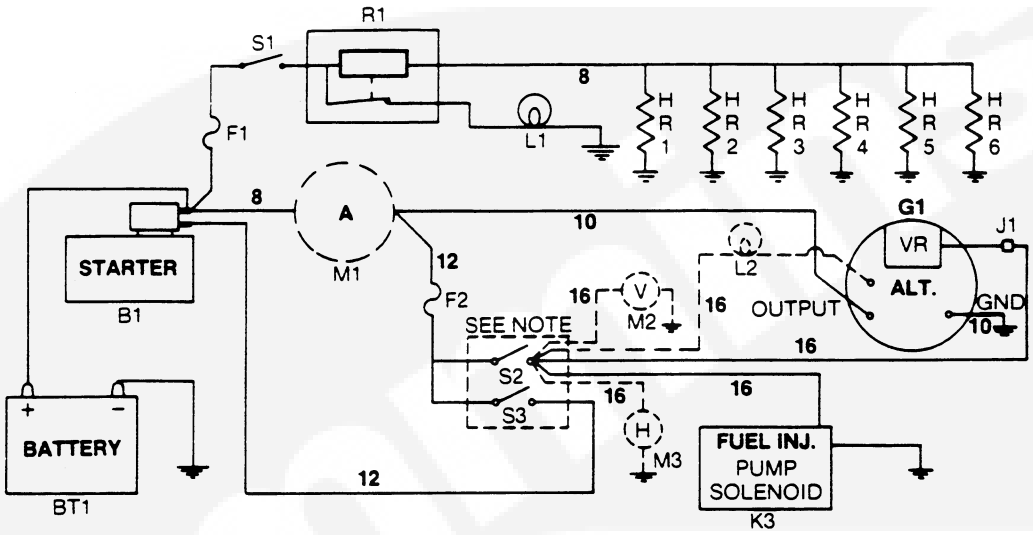

**Large numbers indicate AWG size. If wire length must exceed 3m (10 feet), use next larger wire size.**

| REF. | DESCRIPTION |
|---|---|
| BT1 | Battery, 12V |
| B1 | Starter, Solenoid |
| ECU | Electronic Control Unit |
| F1 | Fuse (50 amp, 3 & 4 cyl.; 80 amp, 6 cyl.) |
| F2 | Fuse (20 amp) |
| G1 | Alternator & Regulator |
| HR1-6 | Glow Plug |
| K3 | Fuel Injection Pump Solenoid (Note: Ground is internal) |

| REF. | DESCRIPTION |
|---|---|
| L1 | Lamp, Glow Plug |
| L2 | Lamp, Charge Indicator (Optional) |
| M1 | Ammeter (Optional) |
| M2 | Voltmeter (Optional) |
| M3 | Hourmeter (Optional) |
| S2 | Switch, Fuel Solenoid (normally open, snap action)* |
| S3 | Switch, Start (normally open, momentary contact)* |

* - S2 and S3 are often combined in an automotive type key switch.

## Wiring Diagram for Ballast Resistor Control Unit




**Large numbers indicate AWG size. If wire length must exceed 3m (10 feet), use next larger wire size.**

| REF. | DESCRIPTION |
|---|---|
| BT1 | Battery, 12V |
| B1 | Starter, Solenoid |
| F1 | Fuse (50 amp, 3 & 4 cyl.; 80 amp, 6 cyl.) |
| F2 | Fuse (20 amp) |
| G1 | Alternator & Regulator |
| HR1-6 | Glow Plug |
| J1 | Connector |
| K3 | Fuel Injection Pump Solenoid |
| L1 | Lamp, Glow Plug |
| L2 | Lamp, Charge Indicator (Optional) |

| REF. | DESCRIPTION |
|---|---|
| M1 | Ammeter (Optional) |
| M2 | Voltmeter (Optional) |
| M3 | Hourmeter (Optional) |
| R1 | Resistor, Ballast |
| S1 | Switch, Glow Plug (normally open, momentary contact) |
| S2 | Switch, Fuel Solenoid (normally open, snap action)* |
| S3 | Switch, Start (normally open, momentary contact)* |

* - S2 and S3 are often combined in an automotive type key switch.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# 13. Engine Disassembly

# ENGINE REBUILDING RECOMMENDATIONS

Removal and installation of engine components such as cylinder head, pistons, crankshaft, camshaft, etc., are covered in this section. The extent of the work to be done on engine determines which accessories such as starter, alternator, water pump, fuel pump, etc., must be removed. When completely overhauling an engine, all accessories should be removed, disassembled, inspected, and repaired or replaced as required before they are reinstalled on engine.

Have an adequate supply of pans or boxes available for storage of small parts and hardware as they are removed. Machined parts that have surfaces which could be damaged should be stored on wooden racks or supported on wooden blocks. Mark all parts that are identical, such as valves, rocker arms, push rods, tappets, etc., and store in racks so they can be reinstalled in their original position.

**The disassembly procedures outlined in this section were done with the engine mounted on an engine stand unless otherwise noted. Right side and left side is determined by facing flywheel end (rear) of engine.**

Use an engine stand whenever extensive repair or a complete engine overhaul is required. Before engine can be attached to the stand, remove exhaust manifold, oil cooler, and any optional equipment that is attached to left side of engine. There are four 12mm x 1.75 threaded holes located on left side of engine. Mount engine to stand using these four threaded holes. An adapter plate may be necessary depending on the type of engine stand being used.

Use of the special Onan service tools illustrated in this manual is recommended. Most jobs can be accomplished faster and more accurately when the proper tools are used. Many items require a special tool for correct removal and installation. Some of the recommended tools are:

- Front and rear oil seal tools.
- Valve spring compressor, valve guide driver, and valve seat remover.
- Gear puller and gear puller rings.
- Piston ring spreader and compressor.
- Cam bearing puller.
- Torque wrench, plastigauge (for correct bearing clearance).
- Front and rear (seal) wear sleeve installation tool.

See *Onan Tool Catalog* (900-0019) and *SECTION 4, SPECIAL TOOLS* of this manual for specific tool numbers.

## Disassembly

The order in which engine components are removed is left to the discretion of the mechanic. As disassembly progresses, the order may have to be changed to suit the application. A suggested disassembly procedure would be as follows:

1. Tag and identify all wires removed.
2. Drain coolant.
3. Drain oil - discard oil removed.
4. Fan, water pump, alternator.
5. Fuel lines, transfer pump, injection pump.
6. Fuel filter, oil filter.
7. Oil pan, oil pick up tube.
8. Flywheel, flywheel housing with starter.
9. Rear seal plate assembly.
10. Rocker cover, cylinder head, tappets.
11. Gearcase cover, camshaft, gear train.
12. Gearcase backplate with oil pump, oil pressure regulating valve.
13. Piston and connecting rod assemblies.
14. Crankshaft and main bearings.
15. Cam bearings.

**Analyze the reasons for any component's failure and extent of the repair required. Determine if cylinder bores require reboring, crankshaft journals need grinding, or if other machine shop work is necessary. All machining work must be performed by a qualified machine shop. Replace all worn or damaged parts with new parts.**

## Assembly (Use Genuine Onan Parts)

**NEAT, CLEAN, AND ORDERLY WORK AREAS MAKE THE JOB EASIER.**

1. Engine assembly procedure is normally the reverse of disassembly. Observe proper clearances of bearings, connecting rod, proper fitting and sizing of piston, rings, etc. A list of dimensions and clearances is furnished in *SECTION 2, DIMENSIONS AND CLEARANCES* of this manual.
2. Follow the recommended procedure for the fitting of valves, pistons, bearings, and adjusting clearances.
3. A torque wrench is a must when assembling engine. All torques specified are wet. Use clean engine oil to lubricate threads prior to installation. A table of torques is furnished in *SECTION 3, ASSEMBLY TORQUES* of this manual and should be used whenever capscrews or nuts are tightened.

4. Use new gaskets whenever required. A new cylinder head gasket must be used each time cylinder head is removed.
5. Use capscrews of the correct size, type, grade, and length. Size and length of various capscrews are listed in the Parts Catalog available from your dealer. Hardened flat washers must be used wherever indicated. Lockwashers are not recommended and should not be used anywhere on the engine. Always tighten each fastener to its recommended torque.
6. As each internal engine part is assembled, manually rotate crankshaft, making certain it turns freely. If tightness is noted after any operation you then know your last step is the cause.
7. As each internal engine part is assembled, coat it heavily with oil (same grade used in crankcase). During the first few critical moments of operation, the engine will depend on this oil for lubrication.
8. After you have the internal engine parts reassembled, the engine should turn freely. If care and attention have been given, engine will operate efficiently.
9. Refer to *Cylinder Head* and *Valve Lash Adjustment* for cylinder head capscrew torque sequence and for valve lash adjustment.
10. For correct injection pump timing see *SECTION 10, FUEL SYSTEM.*
11. At this point, it is a matter of mechanically adding outside accessory items to the block assembly. Order of assembly is reverse of disassembly.
12. When engine is complete, install controls. Reinstall the tagged wires. Use wiring diagram to connect leads to control, and from control to engine. All wires should have been marked for correct identification. If unit is to work properly, wires must be connected correctly.
13. Follow set-up and starting procedures outlined in *SECTION 6, START-UP* of this manual.
14. Start engine and check for oil pressure buildup.
15. Check for oil, fuel, and exhaust leaks. Correct any leaks found.
16. Run engine about 15 minutes under light load to reach operating temperature.

**Break-in Procedure**

The only time an engine will require a break-in period, is when the pistons are removed or after cylinder boring. The unit should be run in the following sequence.

1. One half hour at 1/2 rated speed with one quarter load applied.
2. One half hour at rated speed with one half load applied.
3. Full rated speed under normal operating conditions.

Drain and replace crankcase oil and filter after the first 50 hours of operation: drain while engine oil is still warm.

When overhauling a turbocharged engine head bolts must be retorqued, after running for two hours with load.

## CYLINDER HEAD

The cylinder head is made from high strength cast iron alloy. It is secured to cylinder block by hardened capscrews. Intake and exhaust ports are cast in the cylinder head for the intake of air and the expulsion of exhaust gases. Cored passages are provided for the circulation of coolant in the head. A gasket is used to seal combustion chamber and all water and oil passages between the block and head. The flow and distribution of coolant through head is controlled by various size coolant flow holes in head gasket. Located in cylinder head above each cylinder is an intake and exhaust valve, valve springs, guides, spring retainers and locks, a fuel injection nozzle, glow plug, and two rocker arms. The valve train is enclosed within a rocker arm cover and sealed with a gasket.

Service on some parts of cylinder head can be done with the head installed on engine. For other service the head must be removed from cylinder block.

### Service Operations That Do Not Require Removal of Cylinder Head Are:

1. Valve lash adjustment.
2. Servicing or replacement of fuel injection nozzles.
3. Replacement of rocker arms, rocker arm studs, or push rods.

### Service Operations That Do Require Removal of Cylinder Head Are:

1. Replacement or grinding of the valves.
2. Replacement of valve guides.
3. Grinding or replacement of valve seats or inserts.

### Cylinder Head Removal

1. Drain cooling system. Refer to *SECTION 9, COOLING SYSTEM.*
2. Remove or disconnect all components and assemblies necessary to gain access to cylinder head, such as exhaust pipe, engine shroud, air cleaner, etc.
3. If engine is equipped with a turbocharger, disconnect turbo oil lines and remove turbocharger assembly.
4. Remove fan belt, fan, and water pump assembly.
5. Disconnect fuel lines from injection nozzles and injection pump. Remove fuel return lines from injection nozzles and injection pump. Cap all fuel line openings to prevent the entrance of dirt or dust.

**⚠CAUTION** ***Due to the precise tolerances of diesel injection systems, it is extremely important the fuel be kept clean. Dirt in system can cause severe damage to both injection pump and injection nozzles.***

6. Remove injection lines.
7. Remove capscrews and washers that secure intake and exhaust manifolds to head.
8. Remove manifolds, gently tap with a soft hammer, if necessary.
9. Remove lead from glow plugs.
10. Remove rocker arm cover.
11. Disconnect rocker arm oiling tube from the pipe fitting at front of engine and remove oiling tube.
12. Remove rocker arms, push rods, and valve stem caps.

**Keep rocker arms, rocker arm balls, washers, rocker arm nuts, and push rods in order, so they go back in the same valve train position.**

13. Remove capscrews securing cylinder head to block.
14. Remove head by lifting it straight up until the dowel pins in block are cleared.
15. Remove head gasket.

## Cylinder Head Inspection

Visually check for damage to the sealing surfaces of cylinder head and block. Clean all carbon deposits from head by scraping or brushing with a wire brush. If engine has overheated or has compression leaks, check head for warpage and cracks. Use a heavy, accurate straight edge and feeler gauge to check for warpage (Figure 1) at each end and between all cylinders. Check cylinder head for end-to-end warpage in at least five places.

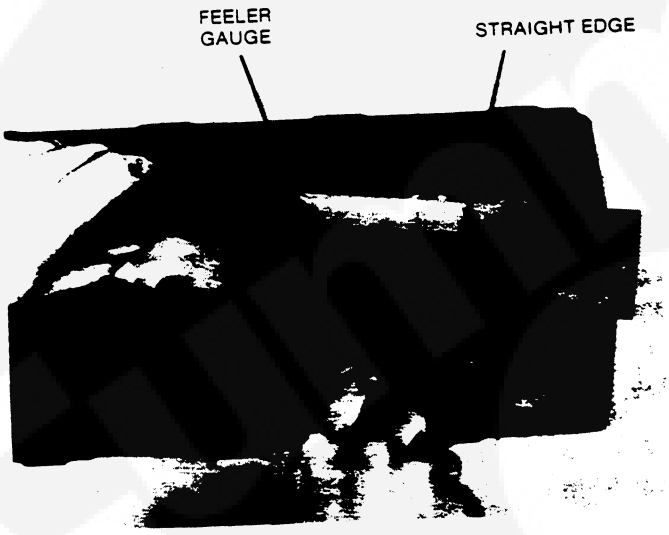


**FIGURE 1. CHECKING THE HEAD FOR WARPAGE**

## Cylinder Head Refacing

If cylinder head face is scratched, nicked, or warped it may be refaced. A maximum of .25mm (.0098 inch) can be removed from face of head before it must be replaced.

The cylinder head surface may be refaced by either one of the following methods:

1. Milling:

   A. Remove hot plugs and inspect. Remove hot plugs by placing a brass drift into injection nozzle bore and driving out the hot plug (Figure 2). Reface cylinder head on a milling machine.

   B. Grind hot plugs individually making certain the hot plug face does not protrude more than .065 mm (.0026 inch) or recess more than .025 mm (.001 inch) from cylinder head gasket surface.

   C. Install hot plugs. See *Hot Plugs* for correct installation procedure.

2. Grinding

   A. Inspect the hot plugs and replace any that are worn or damaged.

   B. Make certain that all hot plugs are tight in the counterbores. Use Locktite 325 to secure any loose hot plugs.

   C. Reface the cylinder head by grinding.

After refacing the cylinder head the valves and seats must be ground. Refer to *Valve Face and Seat Grinding* procedures.


**FIGURE 2. HOT PLUG REMOVAL**

## Hot Plug

Hot plug throat size varies depending on engine operating speed and application.

If hot plugs are damaged or show signs of erosion, replace them. After a short period of running, hot plugs will develop hairline cracks. This is normal and acceptable.

Clean hot plugs to remove any carbon deposits and inspect. Replace hot plug if any hairline cracks intersect, or a piece of the hot plug has broken out. Clean carbon deposits from hot plug counterbore with a wire brush after removing injection nozzles.

When installing hot plugs, note the keyway in head and the raised guide on hot plug (Figure 3). Align guide on hot plug with keyway in head and drive hot plug in with a soft hammer.

The hot plug face must not protrude more than 0.065 mm (0.0026 inch) from cylinder head gasket surface. If protrusion of hot plug is greater than specified, remove hot plug and grind face of plug. The hot plug face must not be recessed more than 0.025 mm (0.001 inch). If recess is greater than specified, replace hot plug.

If hot plug is loose in counterbore after installation, remove hot plug and coat it with Locktite 325 before reinstalling. This will keep hot plugs in place while assembling head to block.

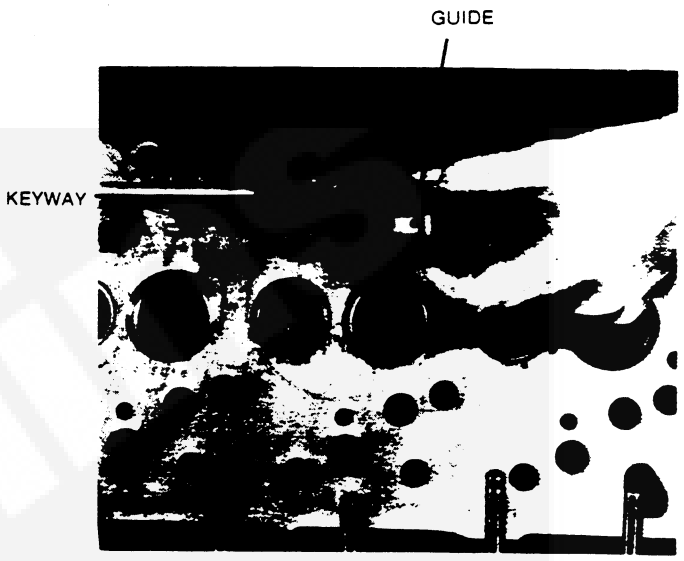


**FIGURE 3. HOT PLUG INSTALLATION**

## Cylinder Head Installation

Make certain machined surfaces of cylinder head and block are thoroughly clean. A new head gasket must be installed before installing cylinder head.

**⚠CAUTION** ***Before cylinder head is installed, make certain that there is not an excessive amount of oil, or any other liquid, in the capscrew holes in cylinder block. Too much oil in any of these holes may cause a hydrostatic lock when the capscrew is tightened.***

1. Check for warpage, scratches or nicks on sealing surfaces of head and block. Repair or replace the head if necessary.
2. Clean cylinder block and head contact surfaces. Thoroughly clean cylinder bores of any foreign material or liquid. Install valve tappets.
3. Install a new cylinder head gasket over dowel pins and on to cylinder block with the indicated side up as marked on gasket. Do not use any sealer or gasket cement. The gasket is precoated with a sealer and anti-stick compound.
4. Position cylinder head assembly gently over dowel pins and onto cylinder block.
5. Lubricate cylinder head capscrew threads with a light coat of clean engine lubricating oil.
6. Install head bolts, washers, and push rods with push rod guides. There are no flat washers on the bolts for the push rod guides. Draw cylinder head down in gradual and even steps to assure a good seal between cylinder head and block. Tightening the head bolts in one step may distort head and cause head gasket leakage. Tighten each bolt about 1/4 turn at a time until the specified torque of 129 Nm (95 Ft.-Lb.) is reached. Figure 4 shows the torque sequence for tightening cylinder heads.

   When overhauling a turbocharged engine head bolts must be retorqued, after running for two hours with load.
7. Make certain push rods are seated properly in tappets.
8. Position rocker arms, rocker arm balls, and flat washers on the same rocker arm studs that they were removed from.
9. Lubricate threads on rocker arm studs and install rocker arm locknuts. Lubricate rocker arm assemblies with clean SAE 10 engine oil.

   Replace any rocker arm locknut that cannot hold a minimum wet torque of 3.4 Nm (30 In.-Lb.). New, well oiled rocker arm locknuts should have a minimum initial torque of 6.2 Nm (55 In.-Lb.).

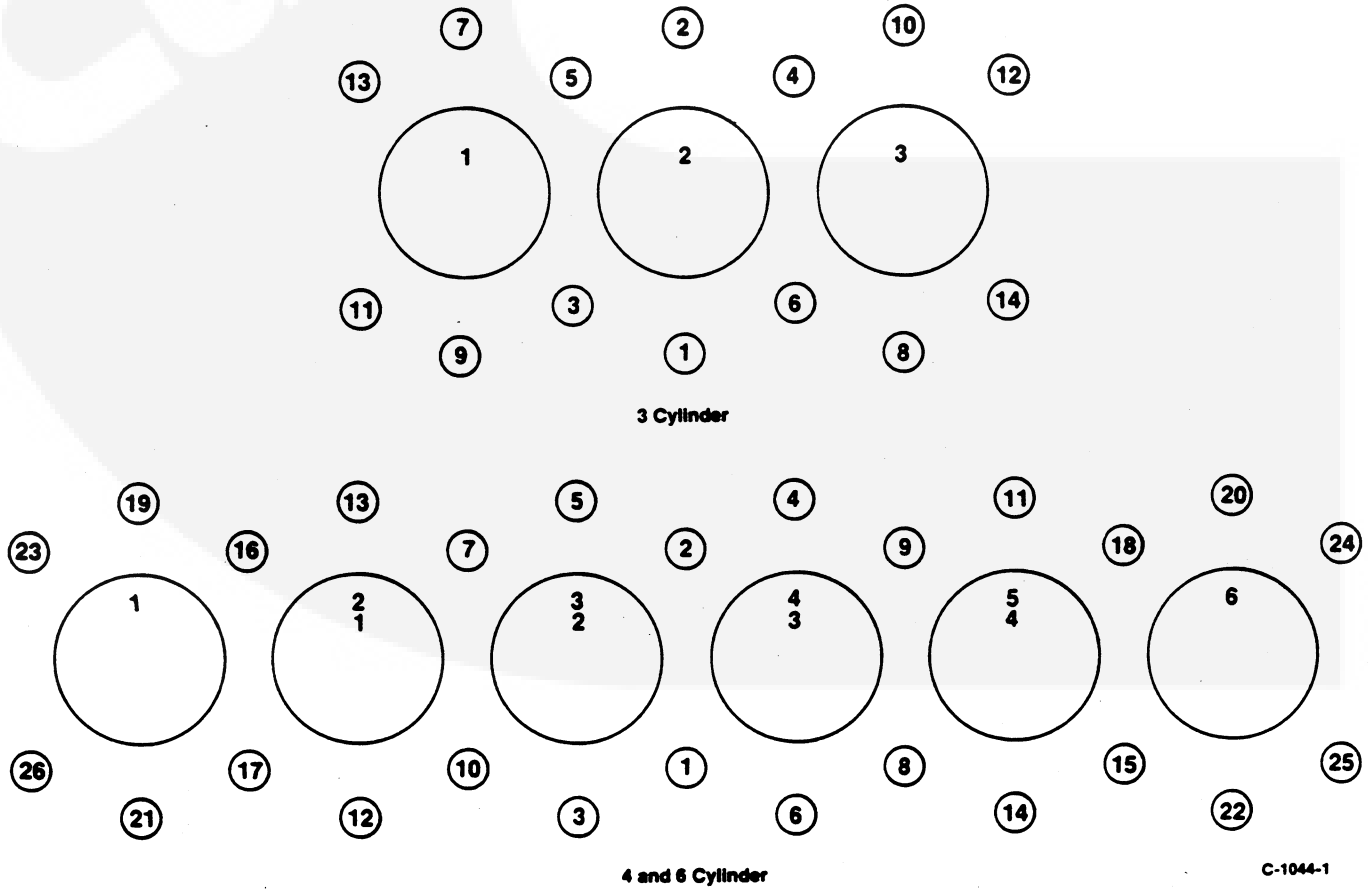


**FIGURE 4. CYLINDER HEAD BOLT TORQUE SEQUENCE**

**⚠CAUTION** ***Do not tighten rocker arm locknuts. Pulling locknuts down tight will cause valves to hit pistons when making valve clearance adjustment. Do not run the rocker arm nuts down with an air wrench. Using an air wrench to remove or install locknuts will destroy the self-locking feature.***

10. Set valve clearance. Refer to *Valve Lash Adjustment* procedure.


**FIGURE 5. INJECTION NOZZLE SEALS**

11. Install rocker arm oiling tube on Spec A to C engines. Make certain rocker arms clear oiling tube, as engine crankshaft is rotated one complete revolution.

12. Install rocker arm cover with a new cover gasket and capnut gaskets.

13. Place new injection nozzle seals in nozzle bore with the concave side down (Figure 5). Do not reuse injection nozzle seals. They must be replaced whenever nozzles are removed. Install injection nozzles into cylinder head and tighten to the specified torque.

**⚠CAUTION** ***Incorrect installation of injection nozzle seals will cause injection nozzle to overheat and stick. Sticky nozzles cause excessive noise and smoke.***

14. Install and connect glow plugs and leads.
15. Mount intake and exhaust manifolds.
16. Install and connect fuel lines. Make certain the lines are clean and dry before installing them.
17. Grease "O" ring on cylinder head water outlet with a light duty grease. Replace "O" ring if any nicks or cracks are evident.
18. Install water pump, water pump pulley, and fan belt. Refer to *SECTION 9, COOLING SYSTEM.*
19. Complete remainder of installation by a direct reversal of disassembly procedure.
20. Refill cooling system with clean coolant. Refer to *SECTION 7, MAINTENANCE.*
21. Inspect engine for fuel, coolant, or oil leaks and correct any leaks found.

## VALVE LASH ADJUSTMENTS

Valve adjustment is achieved by turning rocker arm nut up or down until correct valve lash is obtained between valve stem and rocker arm. Allow engine to cool before adjusting. The cylinders are numbered from front to rear.

To adjust valve lash, proceed as follows:

1. Place start-stop switch in stop position to prevent accidental starting.

2. Remove all parts necessary to gain access to rocker arm cover.

3. Remove rocker arm cover.

4. Replace any rocker arm locknut that cannot hold a minimum wet torque of 3.4 Nm (30 In.-Lb.). New, well oiled rocker arm locknuts should have a minimum initial torque of 6.2 Nm (55 In.-Lb.).

**⚠CAUTION** ***Pulling locknuts down tight will cause valves to hit pistons when making valve clearance adjustment. Do not run the rocker arm nuts down with an air wrench. Using an air wrench to remove or install locknuts will destroy the self-locking feature.***

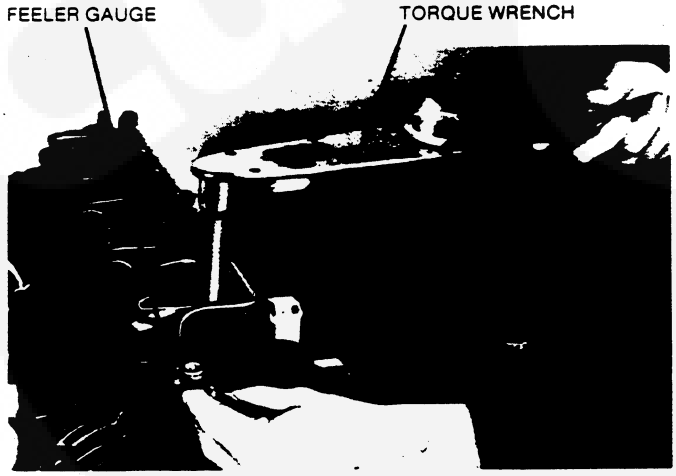


**FIGURE 6. VALVE ADJUSTMENT**

5. Turn engine in direction of rotation (clockwise when viewed from the front of engine) until number one cylinder is on a compression stroke and the 0° TDC mark on flywheel or front crankshaft pulley lines up with the timing indicator.

With the piston at TDC the crankshaft can be turned 90° in either direction without the valves on number one cylinder opening. If the valves open during this test the crankshaft must be turned one complete revolution (360°) in the direction of normal rotation.

### Solid Tappet Valve Lash Adjustment (Spec A to C)

See *SECTION 1, SPECIFICATIONS* for correct valve lash.

1. To check valve lash, insert the correct size feeler gauge between rocker arm and valve stem (Figure 6). Press down lightly on push rod end of rocker arm. Make certain rocker arm is properly seated on push rod. If feeler gauge cannot be inserted, loosen rocker arm locknut on top of rocker arm. Tighten rocker arm nut until feeler gauge can be inserted and withdrawn with a slight drag.

   A. After positioning number one cylinder adjust intake and exhaust valves listed in Table 1.

   B. Turn engine in a clockwise direction 360° (1 revolution) from position used in Step A. Adjust intake and exhaust valves listed in Table 2.

### Hydraulic Tappet Valve Lash Adjustment (Begin Spec D)

With hydraulic tappets the valve lash is zero, however an initial adjustment is required. Adjust valves by inserting a 0.05 mm (0.002 inch) feeler gauge between valve stem and rocker arm. If feeler gauge cannot be inserted, loosen rocker arm locknut on top of rocker arm. Make certain rocker arm is properly seated on push rod. Tighten rocker arm locknut until feeler gauge can be inserted and withdrawn with a slight drag.

A. After positioning number one cylinder adjust intake and exhaust valves listed in Table 1.

B. Turn engine in a clockwise direction 360° (1 revolution) from position used in Step A. Adjust intake and exhaust valves listed in Table 2.

C. Turn engine in a clockwise direction 45° (1/8 revolution) from position used in Step B.

D. Turn each rocker arm locknut, clockwise, two full revolutions. This will preset the hydraulic tappets into their proper operating position.

E. If used tappets are installed, that have not been cleaned, the tappets will be full of cold used engine oil. With cold engine oil the tappets will leak down at a very slow rate during the adjustment procedure. This may cause the valves to open when Step D is performed.

Because of this the best procedure is to always disassemble, clean and lubricate used tappets before valves are adjusted.

**⚠CAUTION** ***Starting engine before tappets have completely leaked down will cause valves to stay open, causing valves to strike pistons. Before cranking engine turn crankshaft a minimum of two revolutions by hand to ensure that the valves do not strike the pistons.***

F. After initial start-up allow engine to idle a minimum of five minutes. This allows the tappets to return to their normal operating position.

6. Replace rocker arm cover using new capnut gaskets and rocker cover gasket.

7. Replace all parts removed in Step 2. Torque all bolts.

**TABLE 1**
**VALVE TAPPET ADJUSTMENT**

| Valve | Cylinder Number* | Three Cylinder | Four Cylinder | Six Cylinder |
|---|---|---|---|---|
| Intake | 1 | X | X | X |
| Exhaust | 1 | X | X | X |
| Intake | 2 | X | | X |
| Exhaust | 2 | | X | |
| Intake | 3 | | X | |
| Exhaust | 3 | X | | X |
| Intake | 4 | | | X |
| Exhaust | 5 | | | X |

* - The cylinders are numbered from front to rear.

**TABLE 2**
**VALVE TAPPET ADJUSTMENT**

| Valve | Cylinder Number* | Three Cylinder | Four Cylinder | Six Cylinder |
|---|---|---|---|---|
| Intake | 2 | | X | |
| Exhaust | 2 | X | | X |
| Intake | 3 | X | | X |
| Exhaust | 3 | | X | |
| Intake | 4 | | X | |
| Exhaust | 4 | | X | X |
| Intake | 5 | | | X |
| Intake | 6 | | | X |
| Exhaust | 6 | | | X |

* - The cylinders are numbered from front to rear.

## VALVES

Intake and exhaust valves are made of alloy steel. The exhaust valves are chrome-cobalt faced with hardened exhaust valve seats pressed into the cylinder head. Valve guides are pressed into cylinder head to hold the valves in alignment with the valve seats. Valve springs are held in place on the upper end of each valve stem by spring retainers and locks. The lower end of each valve spring is centered with a thin washer.

The rocker arms are mounted on studs that thread into the cylinder head. The rocker arms pivot on rocker arm balls that are retained with a hardened washer and a self-locking hex nut. The push rods extend down through cylinder head and block, into the tappets. The upper end of each push rod sets in a recess in one end of the rocker arm.

Adjustment is achieved by turning rocker arm nut up or down until correct valve lash is obtained between valve stem and rocker arm.

Valve stem caps are used on most Spec A to C engines to decrease contact stress between rocker arm and valve tip.

### Valve Removal

1. Remove cylinder head. Refer to *Cylinder Head Removal* procedure.

2. Place cylinder head on a solid bench with exhaust side down.

   **Place valves, springs, retainers and wear plates in a rack as they are removed from cylinder head so they can be identified and reinstalled in their original locations. Discard old valve stem seals and replace with new ones during assembly.**

3. Using a valve spring compressor, compress valve springs and remove valve spring retainer locks.

4. Release valve spring compressor tool and remove valve spring retainers, valve springs, and valves.

5. Remove valve spring wear plates or spacers and valve stem seals. Remove valve rotators when used.

### Inspection and Repair

Clean carbon from the valves, valve seats, valve guides, and cylinder head ports. Remove all oil and crankcase deposits from rocker arm assemblies and push rods by washing in solvent.

***Valve Stem Seals:*** Do not reuse valve stem seals. Each time the valves are removed from cylinder head, a new seal must be used when valve is reinstalled.

***Valve Stem Cap:*** Inspect valve stem caps for cracks and wear. Replace valve stem cap if it is cracked or worn.

Valve stem caps may be installed on Spec A to C engines not originally equipped with valve stem caps. A minimum clearance of 0.05 mm (0.002 inch) must be maintained between valve stem cap and valve lock collet (Figure 7).

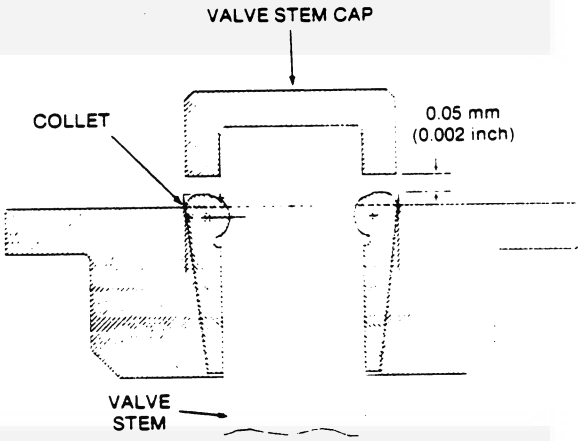


**FIGURE 7. VALVE STEM CAP CLEARANCE**

***Tappets:*** Refer to *Tappets* found later in this section for removal, inspection and installation of tappets.

***Valves:*** Replace valves if they are cracked, bent, burned, warped, or stems are worn. Use a micrometer to measure diameter of valve stem. Measure inside diameter of valve guide with a telescopic gauge and micrometer. Check valve stem to guide clearance by subtracting the valve stem diameter from the valve guide inside diameter. Refer to *SECTION 2, DIMENSIONS AND CLEARANCES* for valve stem diameter, valve guide diameter, and clearances. If valve stem is worn, replace the valve. Replace valve guide, if excessive clearance is still present using a new valve.

Refinish valves that are slightly pitted or burned on an accurate valve grinder. If they are badly pitted or have a thin margin when refacing, replace them.

***Guides:*** Worn valve guides may be removed by pressing them out through the bottom of cylinder head using a valve guide removal tool (Figure 8) and hydraulic press.

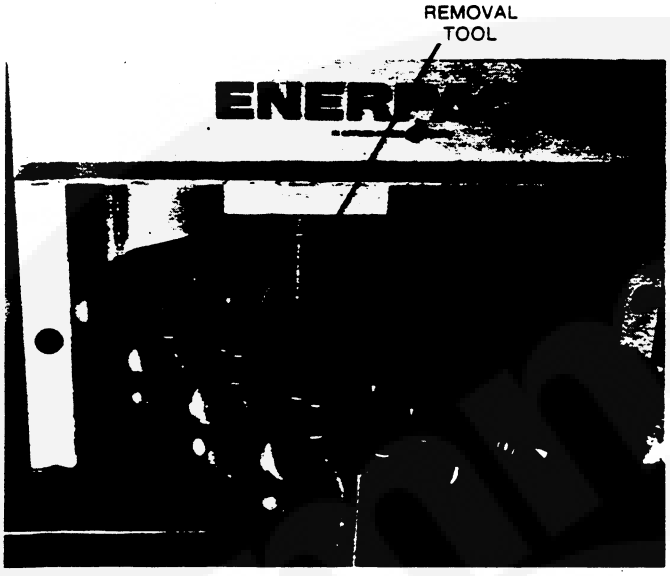


**FIGURE 8. REMOVING VALVE GUIDE**

The exhaust valve guide is 6mm longer (.2362 inch) than the intake valve guide. Guides must be installed in the correct guide bore.

Press new valve guides into position from the top of cylinder head with an Onan valve guide installation tool and hydraulic press. Install replacement valve guides with grooved end up. To use tool, place cylinder head in a hydraulic press with head gasket surface down. Place valve guide driver pilot into valve guide. Insert installing tool and guide into guide bore in cylinder head and press downward until driver rests on machine surface of cylinder head (Figure 9). Valve guide must protrude a specific distance above cylinder head. Measure from machined surface around valve guide to the top of guide.

The bore of a replacement valve guide is 7.63 to 7.74 mm (0.3004 to 0.3047 inch). The interference fit of a guide in cylinder head is 0.025 to 0.065 mm (0.0009 to 0.0026 inch). The valve guide bore will close some when installed. Use a valve guide reamer to resize valve guides after installation to the correct inside diameter. Do not ream or hone guides already installed in service replacement cylinder heads. Valve seats must be refinished after installing new valve guides.

***Rocker Arm and Stud:*** Check rocker arms for cracks, galling, scoring, or wear. Replace the rocker arm and ball if excessively worn.

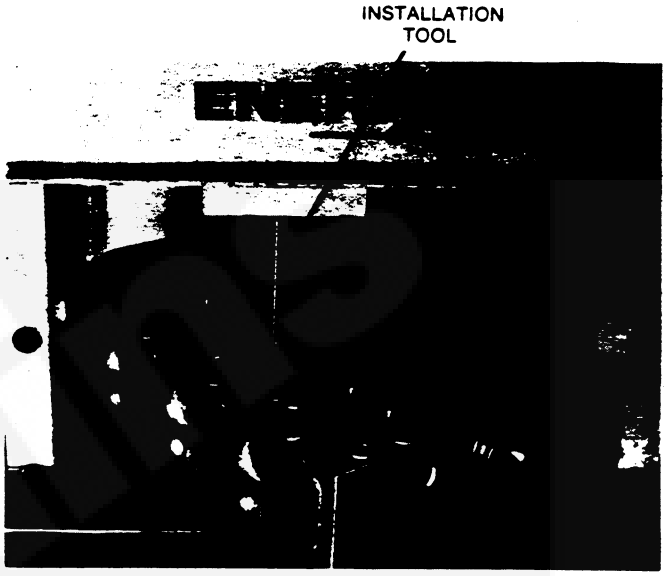


**FIGURE 9. INSTALLING VALVE GUIDES**

Each time the rocker arm locknuts are removed the rocker arm stud threads must be inspected for wear. Test for stud thread wear as follows:

1. Use a torque wrench to measure the rocker arm locknut breakaway torque from operating position.

2. Use the torque wrench to remove rocker arm locknut, and observe any increase in torque.

3. If the removal torque increases more than 2.3 Nm (20 In.-Lb.) above the breakaway torque measured in Step 1, replace the rocker arm stud.

   To replace a worn or damaged rocker arm stud, unscrew the stud using the lower nut. Coat lower threads of new stud with oil and install. Rocker arm studs are installed starting with a long stud on each end then a short, long, short, etc. ending with two short studs in center of head (Figure 9a).

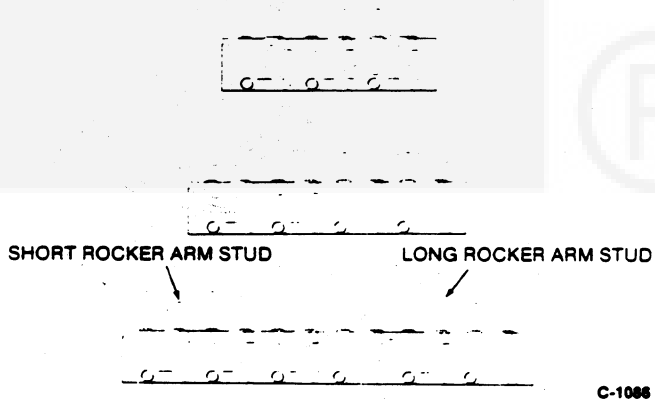


**FIGURE 9a. ROCKER ARM STUD LOCATION**

***Rocker Arm Ball and Locknut:*** Inspect rocker arm balls for cracks and wear. Replace rocker arm ball and arm if it is cracked, worn, or damaged.

Rocker arm locknuts should be replaced each time they are removed. Replace rocker arm studs, if after installing new locknuts a minimum wet torque of 3.4 Nm (30 In.-Lb.) cannot be held. New, well oiled rocker arm locknuts should have a minumum initial torque of 6.2 Nm (55 In.-Lb.), when installed on new rocker arm studs.

***Spring:*** Check valve springs for cracks, worn ends, distortion and tension. If spring ends are worn, check lower valve spring wear plate and valve spring retainer for wear. Check for spring distortion by placing spring on a flat surface next to a square. Measure height of spring and rotate it against square edge to measure distortion. If distortion exceeds 2 mm (.0787 inch) replace spring. Check spring tension at the installed height for both the valve open and closed position using an accurate valve spring tester. Replace any valve spring that is weak, cracked, worn or distorted.

***Valve Seats:*** Most naturally aspirated engines do not have intake valve seat inserts. If intake seat area is extremely worn and cannot be reground to specifications, machine cylinder head to receive a valve seat insert. See Table 3.

***Inspection and Removal:*** Inspect valve seat inserts. If they are loose, cracked or severely pitted, new ones must be installed. Remove valve seat inserts using a valve seat removal tool (Figure 10).

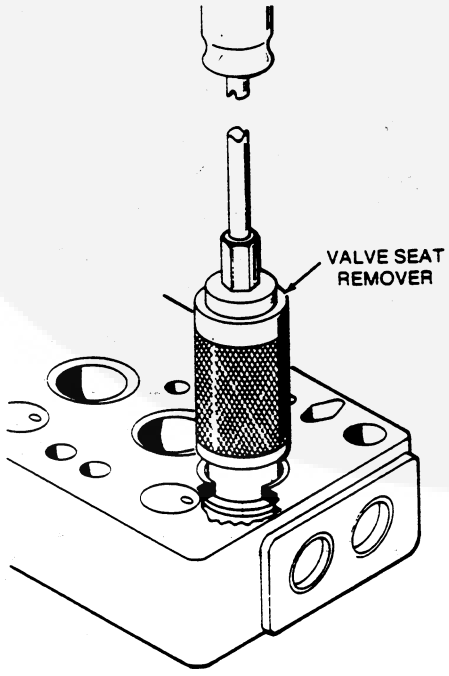


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**FIGURE 10. REMOVING VALVE SEATS**

***Installation:*** If it becomes necessary to replace valve seat inserts, or install intake valve seat inserts, a press fit must be maintained (see Table 3) between the new inserts and insert bores in cylinder head. If insert bores in cylinder head are damaged or worn so that a press fit cannot be obtained when installing new standard size valve seat inserts, the bores must be machined for an oversize seat. Oversize intake and exnaust seats are available in 0.25 mm (0.009 inch) and 0.50 mm (0.019 inch).

Refer to Table 3 for the O.D. of valve seat inserts, corresponding I.D. of bores in cylinder head, and depth of counterbore.

The depth of counterbore in cylinder head for valve seat inserts is measured from gasket surface of cylinder head.

Install valve seat inserts as follows:

1. Thoroughly clean valve seat counterbore and remove any burrs.
2. Using wooden blocks to support cylinder head, place head on a bench bottom side up.
3. Ensure that counterbores are clean and start an insert into bore (valve seat side up).
4. Use the appropriate valve seat insert installation tool (intake or exhaust) and drive insert down tightly into counterbore.
5. It will be necessary to refinish valve seat inserts with a grinder before installing valves.

**TABLE 3**
**VALVE SEAT INSERT**
**MACHINING SPECIFICATIONS**

| VALVE SEAT INSERT | O.D. OF NEW INSERT | INSERT BORE IN CYL. HEAD | DEPTH |
|---|---|---|---|
| **Std. Size Exhaust** | 37.00 to 37.03 mm | 36.93 to 36.95 mm | 8.49 to 8.59 mm |
| **Oversize Exhaust** | | | |
| 0.25 mm | 37.25 to 37.28 mm | 37.18 to 37.20 mm | 8.49 to 8.59 mm |
| 0.50 mm | 37.50 to 37.53 mm | 37.43 to 37.45 mm | 8.49 to 8.59 mm |
| **Std. Size Intake** | 40.37 to 40.40 mm | 40.30 to 40.32 mm | 8.40 to 8.50 mm |
| **Oversize Intake** | | | |
| 0.25 mm | 40.62 to 40.65 mm | 40.55 to 40.57 mm | 8.40 to 8.50 mm |
| 0.50 mm | 40.87 to 40.90 mm | 40.80 to 40.82 mm | 8.40 to 8.50 mm |

***Push Rod:*** Clean all push rods in a suitable solvent. On push rods with an oil passage, blow out the passage with compressed air. Check push rod ends for wear or damage. Check push rod for bends by rolling it on a flat surface. If push rods are bent, twisted, or damaged, they must be replaced.

***Valve Rotators:*** Positive Valve rotators are used on some engines. The valve rotator is located below the valve spring in the cylinder head. There is no easy way to determine if a valve rotator is good or bad. Onan recommends that valve rotators be replaced at each major overhaul or if a build-up of carbon is noted on valve face and valve seat.

***Push Rod Guide Plates:*** Inspect push rod guide plates. If holes in guide plate are worn or burred replace guide plate and push rod.


**FIGURE 11. VALVE SEAL PROTECTOR**

**⚠CAUTION** ***Do not remove valve after seal is installed. Valve can be withdrawn only as far as the groove in valve stem. Do not allow valve stem seal to come in contact with groove or seal damage will result.***

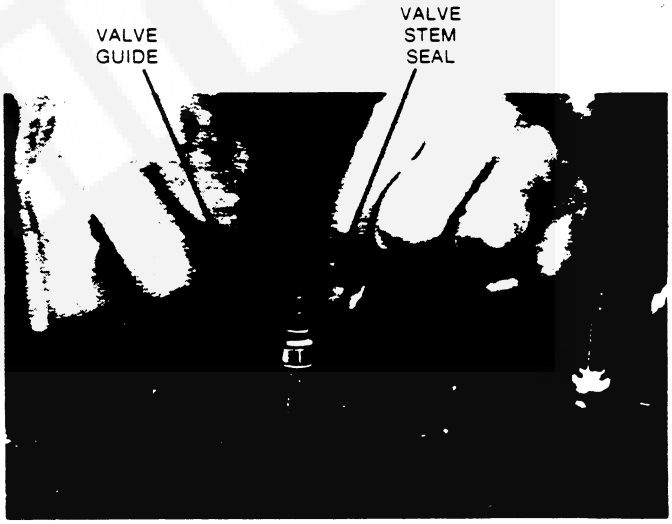


**FIGURE 12. VALVE STEM SEAL INSTALLATION**

## Valve Assembly

1. Lubricate the stem of each valve and insert into the guide from which it was removed.
2. Install valve spring wear plate, spacer, or rotators over valve guides into recess of the head.
3. Place a clear plastic seal protector over valve stem (Figure 11).

   **Do not reuse valve stem seals. Each time the valves are removed from cylinder head, a new seal must be used when the valve is reinstalled.**

4. Coat inside of valve stem seal with oil. Push valve stem seal over seal protector and all the way onto valve guide flange (Figure 12). Remove seal protector from valve stem. Save for reuse on other valves.
5. Using a valve spring compressor, compress each valve spring and retainer.
6. Insert valve spring retainer locks and remove valve spring compressor tool.
7. Install cylinder head with new gasket. Refer to *Cylinder Head Installation* procedure.


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## VALVE FACE AND SEAT GRINDING

Before installing new valves or previously used valves, inspect valve seats for proper valve seating. If used valves are reinstalled, the valve stems should be cleaned and valve faces ground to their specified angles of 44° for exhaust valves and 29° for intake valves. Refinish intake valve seats to a 30° angle and exhaust valve seats to a 45° angle. When refacing valves and seats, remove all evidence of pitting and grooving. If end of valve stem is pitted or worn, true it and clean it up on the refacer wheel. A very light grind is usually enough to square stem and remove any pits or burrs. A minimum clearance of 0.05 mm (0.002 inch) must be maintained between valve stem cap and valve lock collet. If clearance is less than 0.05 mm (0.002 inch) replace valve. The valve guide should be thoroughly cleaned. If valve guide is worn, or valve is warped, the necessary parts must be replaced.

By grinding the valve face and seat at slightly different angles, a fine line of contact on face and seat is obtained, eliminating the need to lap the seating surfaces. The one degree difference in angles is defined as the interference angle. The seat angle is greater than that of the valve face. This assures contact at the maximum diameter on valve seat seating surface.

Refinish intake valve faces to a 29° angle and exhaust valve faces to a 44° angle on a valve refacing machine. The first cut from valve face must be a light grinding. Check if there is an unevenness of metal being removed. If only part of valve's face has been touched, check to see if valve is properly seated in machine or if valve is warped, worn, or distorted. When cut is even around the whole valve face, keep grinding until complete face is ground clean. Be sure the correct valve face angle is maintained. When valve head is warped, a knife edge will be ground (Figure 13) on part or all of the head due to the large amount of metal that must be removed to completely reface valve. Heavy valve heads are required for strength and good heat dissipation. Knife edges lead to breakage, burning, and pre-ignition due to heat localizing on the edge.

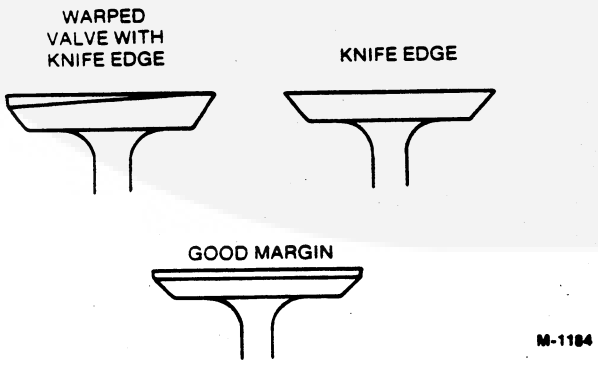


**FIGURE 13. VALVE HEAD MARGIN**

Replace any valve that cannot be entirely refaced while keeping a good valve margin (Figure 13) or is warped, worn, or damaged in any way. The amount of grinding necessary to true a valve indicates whether valve head is worn or warped.

When refinishing intake valve seats that do not have inserts, use a fine stone only. Using a coarse stone may remove too much material too rapidly, resulting with a head that must be machined for intake valve seat inserts. If intake valve grinding specifications cannot be maintained on a cylinder head that does not have intake valve seat inserts, machine the head to receive inserts.

When new valve seats are installed, or previously used seats reground, refinishing must be done with a valve seat grinder used according to the manufacturer's directions.

The following tools are required to assure accurate valve seating:

1. Valve seat grinder.
2. Dial indicator (valve seat runout).
3. Pilot tool.
4. Four fine grinding stones: 15°, 30°, 45°, and 60°.
5. Valve refacer.

To assure correct valve seating, the following tolerances must be verified before and after valves and seats are replaced or refinished:

1. Depth: Distance from cylinder head gasket surface to top of valve head. This depth must be 0.48 mm to 1.13 mm (0.0189 to 0.0445 inch) for intake valves and 0.67 to 1.33 mm (0.0264 to 0.0524 inch) for exhaust valves.
2. Runout: This is the concentricity of seat relative to the valve guide. The total runout of a good seat must not exceed 0.050 mm (0.0019 inch).
3. Width: Width of seat should be 0.88 to 2.30 mm (0.0346 to 0.0901 inch).

**Grind intake seats to a 30° angle as follows:**

1. Remove carbon from valve seat area.
2. Grind seat with a 30° stone until a uniform seat appears on the surface.

   Dress stones frequently during seat grinding to assure proper cutting angles.

3. Refinish intake valve face to a 29° angle and place valve in the appropriate valve guide.

4. Measure valve head depth (Figure 14). If this depth is less than 0.48 mm (0.0189 inch), grind seat until a depth of 0.48 mm (0.0189 inch) is obtained. If valve head depth is greater than 2.13 mm (0.0839 inch) with a new valve, replace seat insert or have the cylinder head machined to receive a valve seat insert.

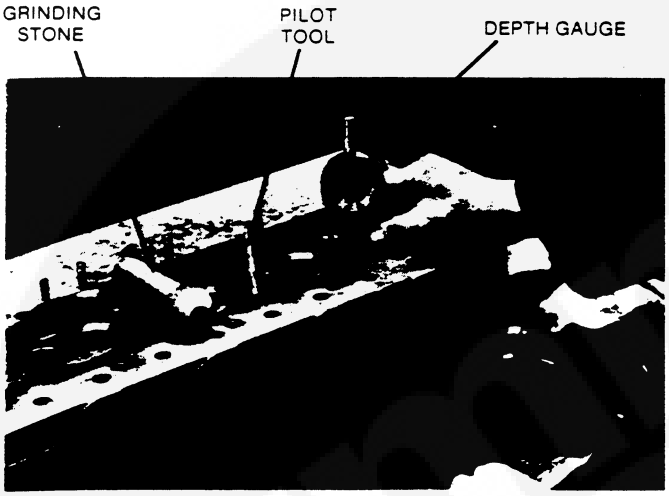


**FIGURE 14. VALVE HEAD DEPTH**

5. Use a dial indicator (Figure 15) to measure valve seat runout. Set dial indicator at zero and rotate indicator to check runout of valve seat. If runout exceeds 0.050 mm (0.0019 inch), grind seat until the runout is less than 0.050 mm (0.0019 inch).

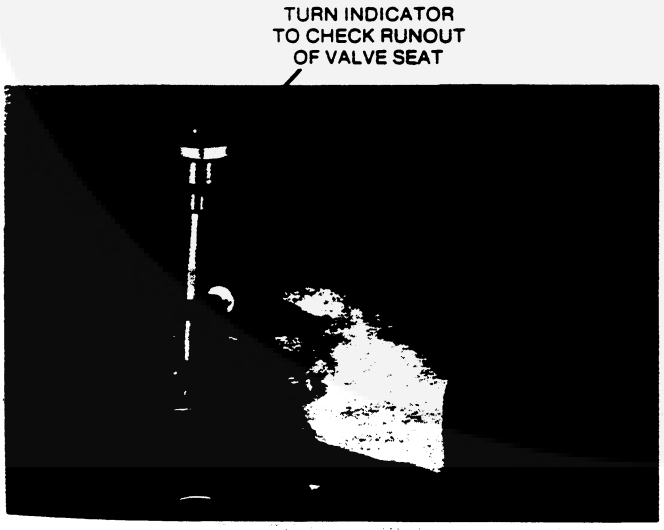


**FIGURE 15. CHECKING RUNOUT OF VALVE SEAT**

6. Remeasure valve head depth. If depth is less than 0.48 mm (0.0189 inch) repeat Steps 4 and 5. If depth exceeds 2.13 mm (0.0839 inch) replace or install new valve seat inserts.
7. Mark seat with a black felt marker or machinist blueing.
8. Use the 45° stone and lightly grind seat.
9. Use the 15° stone and lightly grind seat until seat width is 0.88 to 2.3 mm (0.0346 to 0.0906 inch).
10. Clean seat and remark with black marker.
11. Hand turn a 30° stone on the seat.
12. Recheck seat width (Figure 16).

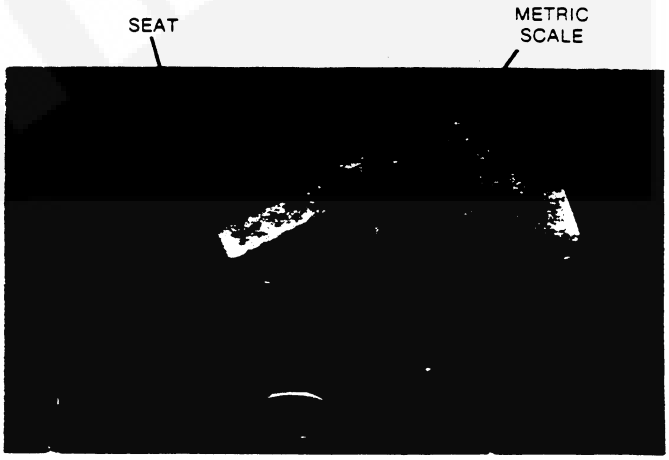


**FIGURE 16. MEASURING SEAT WIDTH**

**ats to a 45° angle as follows:**

n from valve seat area.

with a 45° stone until a uniform seat pears on the surface.

Dress stone frequently during seat grinding to assure proper cutting angles.

3. Refinish exhaust valve face to a 44° angle and place valve in the appropriate valve guide.
4. Measure valve head depth (Figure 14). If this depth is less than 0.67 mm (0.0264 inch), grind seat until a depth of 0.67 mm (0.0264 inch) is obtained. If valve head depth is greater than 2.33 mm (0.0917 inch), replace the valve seat insert.
5. Use a dial indicator (Figure 15) to measure valve seat runout. Set dial indicator at zero and rotate indicator to check runout of valve seat if runout exceeds 0.050 mm (0.0019 inch), grind seat until runout is less than 0.050 mm (0.0019 inch).
6. Remeasure valve head depth. If depth is less than 0.67 mm (0.0264 inch) repeat Steps 4 and 5. If depth exceeds 2.33 mm (0.0917 inch) replace or install new valve seat inserts.
7. Mark seat with a black felt marker or machinist blueing.
8. Use the 60° stone and lightly grind seat.
9. Use the 30° stone and lightly grind seat until seat width is 0.88 to 2.3 mm (0.0346 to 0.0906 inch).
10. Clean seat and remark with black marker.
11. Hand turn a 45° stone on the seat.
12. Recheck seat width (Figure 16).

Check valves for a tight fit to the valve seat with an air-pressure-type testing tool. The seat width and contact pattern can also be checked using blueing. If there are any uneven spots, regrind the seat. Do not lap the seats with grinding compound since this may destroy a good grinding job.

## CRANKSHAFT PULLEY AND DAMPER

The type of crankshaft pulley used on this series of engines is designed to use a damper when required. Remove the six damper retaining capscrews and work damper and adapter off pulley before removing pulley on some six cylinder engines.

**⚠CAUTION** ***Do not use a hammer or jaw type puller to remove vibration damper. Dents, bends, or cracks in damper from using the incorrect removal procedure will damage it.***

### Pulley Removal

If engine is installed in a unit, determine if puller can be used without first removing radiator. If the radiator must be removed, drain cooling system, remove components necessary to remove radiator, and remove radiator.

1. Release tension on water pump and alternator drive belts and remove belts.
2. Loosen crankshaft pulley retaining capscrew and turn it out approximately 13mm (.50 inch).
3. Thread two M10 x 45 Lg capscrews through puller into tapped holes in pulley (Figure 17).


**FIGURE 17. CRANKSHAFT PULLEY REMOVAL**

4. Tighten puller screw. To assist in loosening pulley hub from crankshaft, strike puller screw with a soft faced hammer.
5. Remove puller tools, crankshaft pulley retaining capscrew, washer, and pulley.

### Pulley Installation

1. Remove any burrs, if necessary, from crankshaft. Place woodruff key on crankshaft.
2. Position crankshaft pulley on crankshaft and install washer and pulley retaining capscrew.
3. On engines equipped with a damper, slide adapter and damper on and secure with the six flat washers and capscrews.
4. Install water pump and alternator drive belts. Check for correct belt tension. Refer to *SECTION 9, COOLING SYSTEM.*
5. Install all parts removed during disassembly.

### Vibration Damper

Replace vibration damper if it is bent, cracked, has been dropped, or mishandled in any way. Onan also recommends that the vibration damper be replaced at each major overhaul. A failed vibration damper may cause fan belt(s) to flip over, excessive gear train wear, or crankshaft breakage.

## FLYWHEEL AND RING GEAR

The flywheel is mounted on the crankshaft with six flanged hex head capscrews. A hollow dowel pin driven into flywheel ensures proper crankshaft to flywheel alignment. The flywheel can be attached to crankshaft in only one position. The starter ring gear is shrunk onto flywheel rim.

### Flywheel Removal

Remove any accessory that may be mounted to flywheel and flywheel housing before removing flywheel. It is not necessary to remove starter.

1. Remove capscrews that secure flywheel to crankshaft flange.
2. Thread two capscrews in opposite holes of flywheel face to serve as handles.
3. Thread two M10 x 1.75 threaded rods into flywheel mounting bolt holes. This will support flywheel as it comes off the crankshaft flange.
4. Pull outward on capscrews threaded into flywheel (Figure 18) to remove flywheel.


**FIGURE 18. FLYWHEEL REMOVAL**

If the flywheel cannot be removed with a direct pull and shaking of handles, it may be necessary to remove starter and tap flywheel loose. Turn flywheel and tap exposed area at intervals until flywheel comes loose.

### Flywheel Inspection

Remove any burrs or nicks from flywheel surface where it fits against crankshaft flange. If this surface is not smooth and true, the flywheel may have a slight wobble which will result in engine vibration. If a clutch is mounted on engine, a scored or heat checked flywheel face surface must be machined smooth. Replace flywheel if more than 0.40 mm (0.0157 inch) of stock must be removed. Inspect engine clutch shaft pilot bearing located in flywheel bore. If bearing is worn, drive it out. When installing a new bearing, use a driver that will press against bearing outer race and press bearing into position in flywheel.

### Ring Gear Inspection, Removal, and Installation

1. Inspect flywheel ring gear for cracked, chipped, or broken teeth. Ring gear must be replaced if any of these conditions exist.
2. To remove a flywheel ring gear proceed as follows:
   A. Grind through ring gear at the base of one of the teeth until ring gear separates.
   B. Expand ring gear and drive ring off flywheel using a drift and hammer. Work around the circumference of ring gear to avoid binding ring on flywheel.
3. To install a new flywheel ring gear, proceed as follows:
   A. The ring gear is expanded and allowed to shrink onto flywheel by uniformly heating the gear to 185° to 195° C (365° to 383° F), then placing it on flywheel.

   **⚠CAUTION** ***Do not heat ring gear to a bright red as ring gear may warp and the heat treatment will be destroyed.***

   B. Drive ring gear down tight against shoulder on flywheel. Do it fast and do not damage gear teeth. The ring will contract rapidly and may shrink to flywheel before it is in place. If this occurs, a new ring gear will be required.

### Flywheel Installation

Make sure dowel pin is lined up and install flywheel by reversing the removal procedure. Secure flywheel in two steps by tightening capscrews to a torque of 68 Nm (50 Ft.-Lb.) using a star pattern torque sequence.

## FLYWHEEL HOUSING

The flywheel housing is a one piece casting that is positioned on rear of cylinder block with two dowel pins. The housing is secured to cylinder block with capscrews and flat washers.

### Removal, Inspection, and Installation

The only time the flywheel housing may require service or replacement is when it is cracked or damaged. To remove flywheel housing from engine, proceed as follows:

1. Remove any accessory attached to rear of engine.
2. Remove flywheel. Refer to *Flywheel Removal* procedure.
3. Remove capscrews and washers securing flywheel housing to engine. Tap housing with a soft hammer to break it loose from the positioning dowels then remove housing. Remove starter from flywheel housing.
4. Inspect housing for cracks and other damage. Replace housing if it is damaged.
5. Inspect dust seal located between flywheel housing and rear seal plate. Replace, if necessary.
6. By reversing the removal procedure, assemble flywheel housing to rear of block.
7. Check flywheel-to-flywheel housing runout as follows:

   A. Load crankshaft so that all endplay is taken up.

   B. Mount a dial indicator on face of flywheel.

   C. Adjust indicator point so that it rests on flywheel housing face perpendicular to flywheel face. Set dial indicator to zero.

   D. Keeping endplay removed, rotate crankshaft one complete revolution to determine runout.

   E. If runout exceeds .15 mm (.0059 inch) remove flywheel and flywheel housing. Use a straight edge and feeler gauge to check for warpage on flywheel housing face and mounting surface.

## CRANKSHAFT REAR OIL SEAL AND WEAR SLEEVE

The rear oil seal is a spring-loaded, single lip type pressed into an aluminum alloy rear seal plate. Rear seal plate assembly mounts on the back of cylinder lock under block flywheel housing. A steel wear sleeve is used to protect the crankshaft. The use of a wear sleeve increases seal life and reduces crankshaft wear. The sleeve is pressed onto the crankshaft flange and secured with Loctite number 271.

### Seal Removal

1. Remove flywheel and flywheel housing from the engine. Refer to *Flywheel Removal* and *Flywheel Housing Removal* procedures.
2. Remove capscrews from face of seal plate.
3. Remove four capscrews on back end of the oil pan and loosen capscrews along each side of oil pan.
4. Slide seal plate off crankshaft flange. Be careful not to damage oil pan gasket.
5. Support seal plate assembly and drive old seal out.

### Wear Sleeve Removal and Installation

1. Inspect wear sleeve for nicks, burrs, and wear grooves. Replace if necessary.
2. If replacement is required, use a hammer and a chisel that is only as wide as wear sleeve, to make one or two chisel marks across wear sleeve (Figure 19). This will expand wear sleeve allowing removal from crankshaft.

**⚠CAUTION** ***Do not nick or gouge the crankshaft with chisel. If crankshaft is damaged it must be removed and repaired or replaced.***

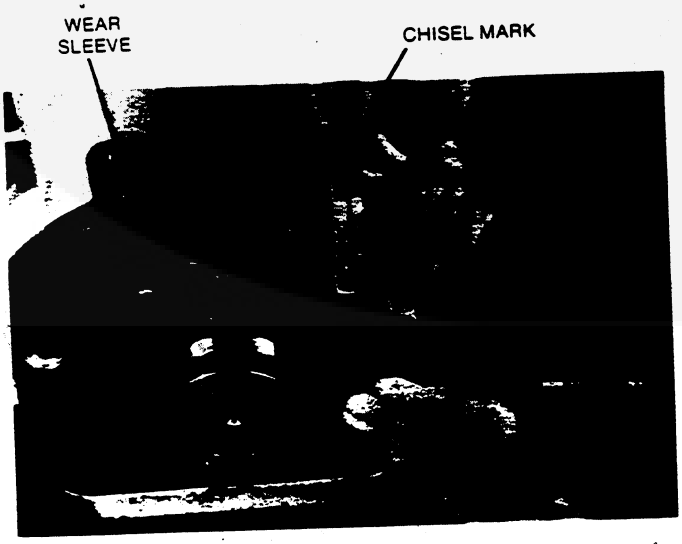


**FIGURE 19. WEAR SLEEVE REMOVAL**

3. Apply Loctite number 271 to crankshaft and inside of new wear sleeve before installing. Position wear sleeve on crankshaft flange with outside chamfer toward the back of engine.
4. Using the rear wear sleeve installing tool (Figure 20), press wear sleeve onto crankshaft flange. Alternately tighten the bolts until tool bottoms on crankshaft flange.


**FIGURE 20. WEAR SLEEVE INSTALLATION**

5. Clean any surplus Loctite off the wear sleeve and crankshaft flange.

### Seal Installation

1. Lubricate new oil seal with oil to ensure sufficient lubrication until crankcase oil enters seal.
2. Using oil seal driver, install a new seal with the rubber lip facing outward (open side of seal inward). See Figure 21. Drive new seal in flush with the machined surface of seal plate.

**⚠CAUTION** ***A new seal must be installed with a new wear sleeve. The seal should not be positioned in a wear groove on wear sleeve. Positioning a seal on a worn, dirty, rough, or grooved crankshaft surface will cause seal to leak.***

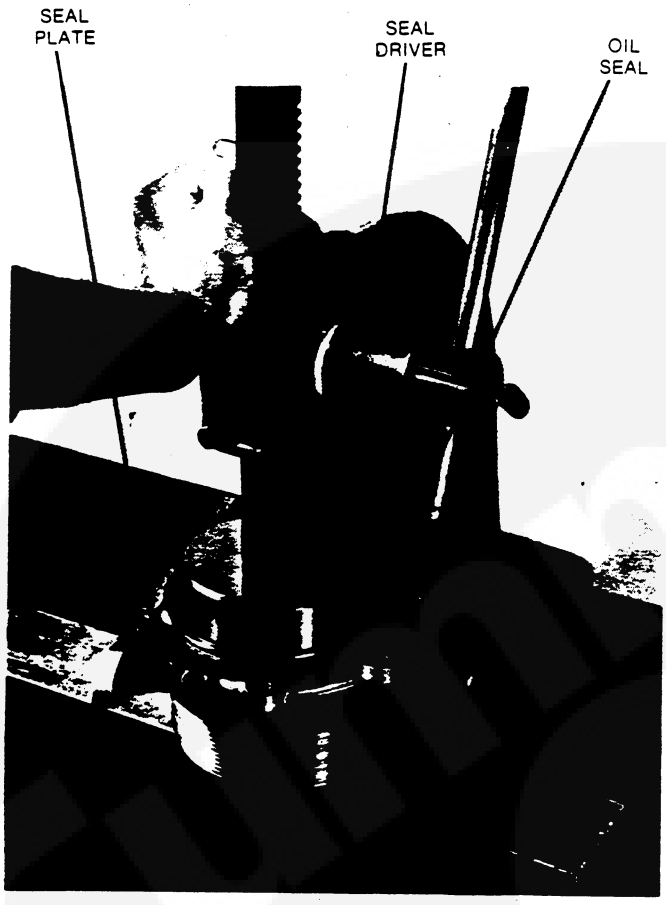


FIGURE 21. INSTALLING SEAL IN SEAL PLATE

3. Make certain wear sleeve on which seal rides is free of dirt, nicks, burrs, and wear grooves.
4. Lubricate crankshaft flange with clean engine oil. Apply a bead of "RTV" Sealant to the junction of cylinder block, seal plate, and oil pan.
5. Push seal plate assembly onto crankshaft (Figure 22). Use extreme care when installing seal plate so the oil pan gasket is not damaged. If oil pan gasket is damaged, remove oil pan and replace the gasket.


FIGURE 22. REAR SEAL PLATE INSTALLATION

6. Torque seal plate capscrews and oil pan.
7. Check crankshaft-to-seal runout as follows:
   A. Load crankshaft so that all end play is taken up.
   B. Mount a dial indicator on face of crankshaft flywheel mounting flange (Figure 23).
   C. Rotate crankshaft one complete revolution. Note maximum runout.
   D. If runout exceeds .25mm (.0098 inch) remove seal plate assembly and reposition seal in plate.
8. After the correct crankshaft-to-seal runout is obtained, install flywheel housing, flywheel, and any other components removed during disassembly.

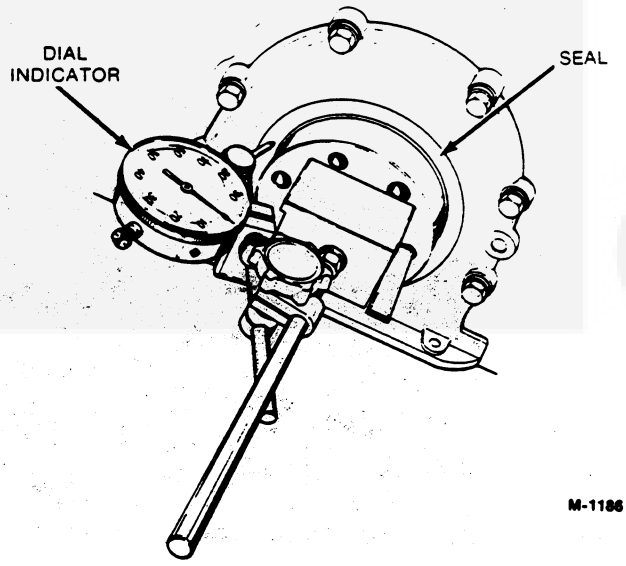


FIGURE 23. CHECKING CRANKSHAFT TO SEAL RUNOUT

## CONNECTING ROD AND PISTON ASSEMBLY

Onan L engines use high strength aluminum alloy pistons with top ring groove protection. Each piston is tapered and fitted with two compression rings and an oil control ring. Full floating piston pins connect the piston to its connecting rod. The pins are held in place with a snap ring at each end.

Keystone pistons are used in all turbocharged engines. A relief in the turbocharged piston skirt provides clearance for the oil spray nozzle. Pistons for use in naturally aspirated engines cannot be installed in engines equipped with piston cooling jets.

High speed turbocharged engines have hard anodized piston crowns.

The connecting rods are made of tapered, I-beam section, heat treated steel. A funnel shaped hole in upper end of each rod catches oil that is splashed or sprayed within the cylinder block and allows it to flow into connecting rod bushing for continuous piston pin lubrication.

The lower end of each connecting rod contains half-shell precision bearings and the upper end is fitted with a steel backed bronze bushing. The precision type connecting rod bearings are replaceable without machining.

### Removal and Disassembly

Replacement of connecting rod bearings can be done without removing piston and connecting rod assemblies. If replacing only the rod bearings, follow Steps 1 and 4.

1. Drain crankcase oil, remove oil pan, and oil pickup tube. See *SECTION 8, OIL SYSTEM.*
2. Remove cylinder head. Refer to *Cylinder Head Removal* procedure.
3. Remove carbon from top of cylinder bore and check for a ridge. Remove ridge (Figure 24) with a ridge reamer before attempting piston removal.

**⚠CAUTION** ***Using a ridge reamer to remove carbon can cause damage to cylinder bore.***

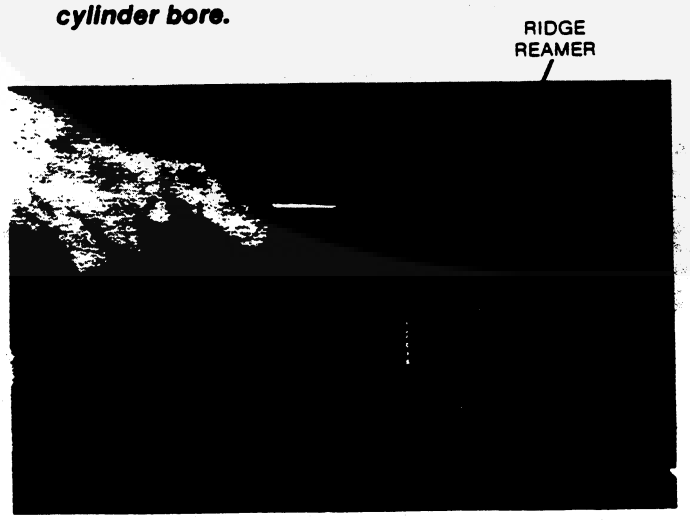


**FIGURE 24. REMOVING RIDGE FROM CYLINDER**

**⚠CAUTION** ***Forcing piston from cylinder before cleaning carbon or removing ridge may cause damage to piston lands and break rings.***

4. Turn crankshaft until piston is at the bottom of its stroke and remove connecting rod nuts. Remove bearing caps and free lower end of connecting rods from crankshaft. Remove bearing shells from bearing caps and connecting rods.

**Mark and number each piston and rod assembly so it can be returned to its respective cylinder after overhaul. Keep connecting rod bearing caps with their respective rods. The rod and cap are marked with the same identifying characters.**

5. Push rod and piston assembly out through top of cylinder using a hammer handle. Avoid scratching crankpin and cylinder wall when removing piston and rod (Figure 25). Protect crankshaft rod journals by placing a piece of rubber tubing over rod bolts during removal.

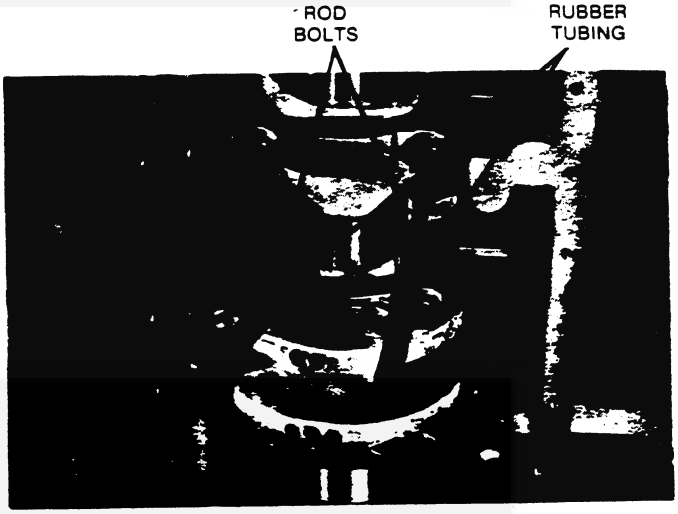


**FIGURE 25. REMOVING PISTON ASSEMBLY**

6. Remove piston rings with a piston ring spreader as shown in Figure 26.

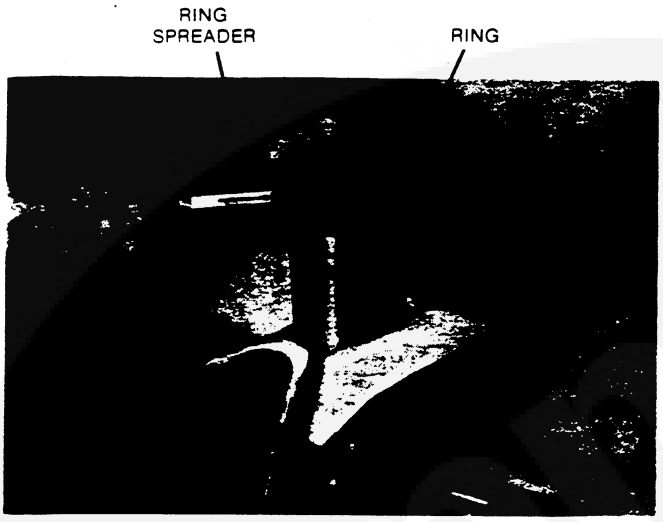


FIGURE 26. REMOVING PISTON RINGS

7. Using a pair of snap ring pliers, remove piston pin retainers and push piston pin out (Figure 27).

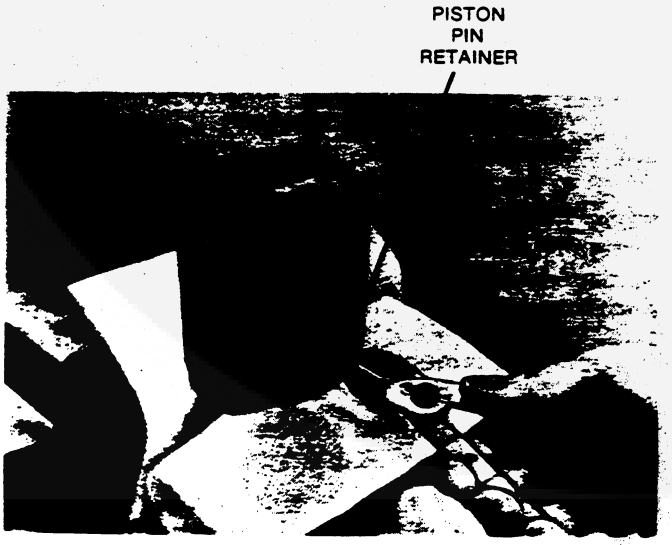


FIGURE 27. REMOVING PISTON PIN RETAINER

Remove dirt and deposits from piston surfaces with an approved cleaning solvent. Clean piston ring grooves with a groove cleaner or the end of a piston ring filed to a sharp point (Figure 28). Care must be taken not to remove metal from the ring groove sides.

**⚠CAUTION** ***Do not use a caustic cleaning solvent or wire brush for cleaning pistons. These materials will cause piston damage.***

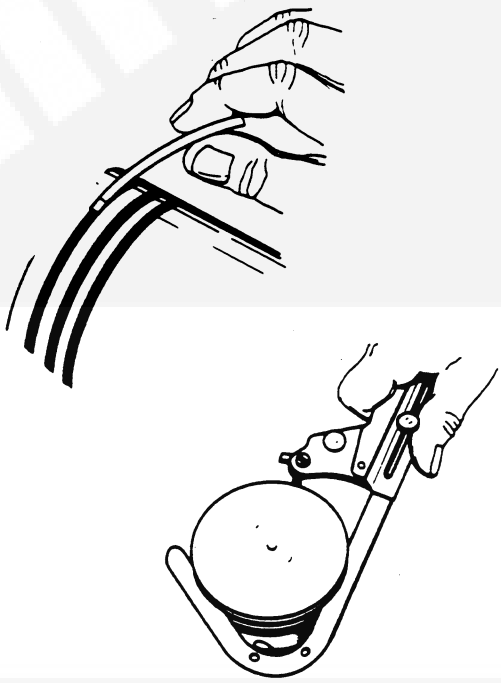

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FIGURE 28. PISTON GROOVE CLEANING

## Inspection (Piston, Rings, and Cylinder Bore)

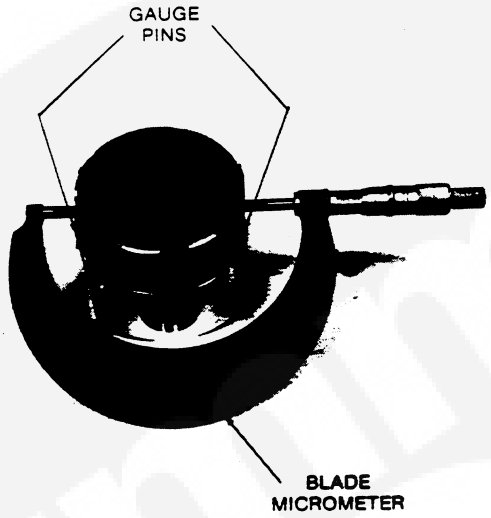
The following text contains inspection procedures concerning pistons, rings, and cylinder bores.

1. Piston Inspection

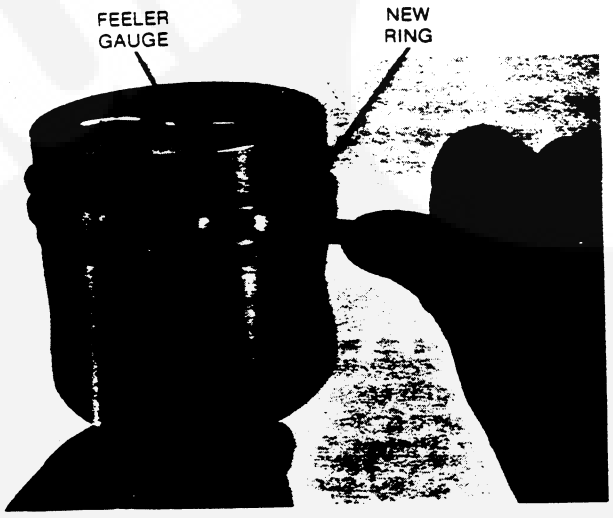
   After cleaning, examine the piston for score marks, damaged ring grooves, or signs of overheating. Inspect pistons for cracks in the head or skirt areas and for bent or broken ring lands. Fatigue failures will normally show up as cracks in the pin boss area.

   Some minor surface cracks may appear on the piston head of high speed turbocharged engine pistons, this is normal.

A. Check for ring groove wear by installing a new ring in top ring groove. Insert a feeler gauge between new ring and the land to check clearance (Figure 29). Keystone ring groove wear must be checked using special gauge pins (Figure 29).




KEYSTONE PISTON




STANDARD PISTON

**FIGURE 29. CHECKING RING SIDE CLEARANCE**

B. Replace any piston that is badly scored or burred, cracked, has badly worn ring grooves, or otherwise is not in good condition.

C. Proper piston to cylinder clearance must be maintained for satisfactory operation.

D. Check piston to cylinder bore clearances 90° from the axis of piston pin and below oil control ring when piston is in the TDC position.

**If piston rings are removed from the cylinders, even after a short period of operation, do not reinstall the same rings. Often used rings will not seat properly. New rings wear or lap themselves to fit with the cylinder walls and seat, after a period of engine operation.**

2. Piston Ring Clearance

A. Ring end gap should be measured before the rings are installed on pistons. Insufficient end gap will cause scored rings and cylinders. Excessive end gap will cause additional oil consumption and blowby.

B. Check ring end gap by inserting each ring into cylinder in the location it is to be used. Use a piston to push ring squarely down in cylinder bore far enough to be in the ring travel area. Check ring end gap with a feeler gauge.

C. The practice of filing ring ends to increase end gap is not recommended. If ring end gap does not meet specifications, check for the correct set of rings and correct bore size. A cylinder bore that is 0.03 mm (0.0012 inch) under size will reduce the end gap 0.08 mm (0.0031 inch).

3. Calculating Piston to Cylinder Wall Clearance

Measurements of the pistons, cylinder bores, and clearances between pistons and cylinder bores should be taken at 21°C (70°F). Pistons must be fitted to their respective cylinder bores before the rings are installed to provide a specific clearance.

A. Using an inside micrometer, dial bore gauge, or telescopic gauge, measure the inside diameter of cylinder bores. Measurement should be taken halfway down the bore and at a right angle to crankshaft axis. Refer to *Cylinder Bore Inspection* for cylinder bore measuring procedure.

B. Using an outside micrometer, measure outside diameter of piston skirt 13 mm (0.5. inch) below oil ring at a right angle to the piston pin.

C. The difference between the two readings is the piston to cylinder clearance. If clearance exceeds wear limit, cylinder bore should be resized to the smallest standard oversize diameter at which it will clean up. Oversize pistons and rings are available in 0.25 mm, 0.50 mm, 0.75 mm, and 1.00 mm.

## Inspection (Connecting Rod and Bearings)

1. Clean connecting rod and cap of all oil and crankcase deposits. Make certain funnel oil hole is clean and open.

2. Check connecting rods for nicks, cracks, and damaged bolt threads. Replace as necessary.

3. Measure the outside diameter of piston pin and the inside diameter of connecting rod bushing. Replace connecting rod bushing if clearance is greater than specified.

4. Inspect connecting rod bearing shells for scoring, chipping, cracking, or signs of overheating. If any of these conditions are present, replace the bearing shells. Backs of the bearing shells should be checked for bright spots and replaced if any bright spots are found. Bright spots usually indicate that the bearing shells have been moving in the connecting rod.
5. Measure connecting rod bearing shells for wear (Figure 30), with bearing shells installed and connecting rod nuts torqued to 85 Nm (63 Ft.-Lb.).

If crankshaft is worn or damaged and must be reground on naturally aspirated engines, rod bearings are available in undersizes of 0.25 mm, 0.50 mm, and 0.75 mm.

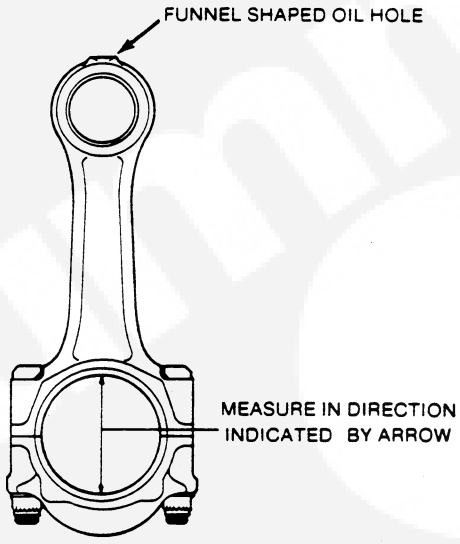



**FIGURE 30. CONNECTING ROD**

Due to the method of grinding and fillet rolling of the turbocharged engine crankshaft, Onan recommends that the crankshaft not be ground and used again in turbocharged engines. Regrinding of a turbocharged engine crankshaft for use in a naturally aspirated engine is acceptable.

## Connecting Rod Bushing Replacement

If connecting rod bushing is worn, it must be pressed out and a new one pressed into connecting rod. When new bushings are installed, be sure oil hole lines up with the connecting rod oil hole.

After installing a new connecting rod bushing, it must be reamed to obtain the correct inside diameter. A new piston pin installed in a new bushing at 21°C (70°F) should be a thumb push fit.

## Connecting Rod to Piston Assembly

1. Install one piston pin retainer in the piston pin hole with sharp edge of retainer facing outward.
2. Insert upper end of connecting rod into piston, with piston swirl chamber positioned opposite connecting rod identification numbers (Figure 31).


**FIGURE 31. PISTON TO ROD ASSEMBLY**

3. Lubricate piston pin and push it into piston and connecting rod.
4. Install the other piston pin retainer with sharp edge facing outward.

***Piston Ring Installation:*** After piston rings have been properly fitted to the cylinder bore, lubricate piston and rings with engine oil. Install rings on piston, using a piston ring installer as shown in Figure 32.

**⚠CAUTION** ***Whenever a connecting rod assembly is secured in a vise, be careful that the bottom of piston skirt is not nicked. Use protective jaws, wooden blocks, or a cloth to protect rod and piston from nicks, which may lead to piston or connecting rod failure.***

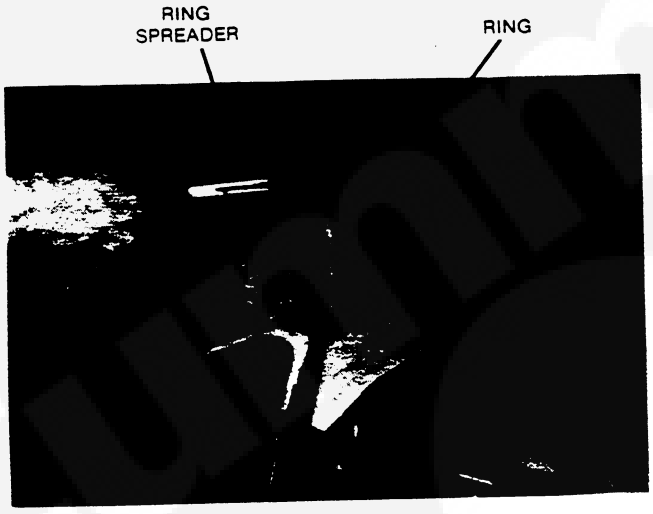



**FIGURE 32. INSTALLING RINGS**

1. Install oil control ring expander in bottom groove of piston, with the guide pin inserted inside expander.
2. Install chrome oil control ring in bottom groove over expander, with end gap opposite (180 degrees) the guide pin in expander.
3. Install second compression ring in second groove of piston, with side stamped "Up 2nd" or with a dot towards top of piston.
4. Install the top chrome compression ring or keystone ring in top groove of piston with side stamped "Up Top" or with a dot towards top of piston.

### Piston Assembly Installation

Install each piston, with rings and connecting rods, as an assembly. Each connecting rod and bearing cap should have been numbered during disassembly for identification and must be installed in the cylinder from which it was originally removed. Install piston assembly in the engine with connecting rod identification numbers facing camshaft side of engine and the piston swirl chamber towards intake side.

1. Stagger piston ring gaps evenly around piston and apply lubricant to the piston and rings.
2. Turn crankshaft to position number one rod bearing journal at the bottom of its stroke.
3. Position a bearing shell in connecting rod, with tang of bearing shell in the recess of connecting rod. Lubricate bearing shell and crankshaft journal. Protect crankshaft rod journals by placing a piece of rubber tubing over rod bolts during installation (Figure 33).

**⚠CAUTION** ***Make certain the backs of bearing shells and bearing seats are free from dirt and grit particles. Foreign material under a bearing shell will cause high spots and early bearing failure.***

4. Compress the rings with a ring compressor and install piston assembly in cylinder bore by tapping on top of piston with a wooden hammer handle (Figure 33).

**If any difficulty is experienced in installing piston assembly, the ring compressor must be removed and the ring set inspected for correct installation in piston ring grooves. Align lower end of connecting rod with crankshaft journal before inserting piston assembly into cylinder bore.**

5. Install a bearing shell in connecting rod bearing cap, with tang of bearing shell in recess of bearing cap and lubricate.
6. Install bearing cap and shell, making certain identification numbers stamped in bearing cap are located on same side as corresponding numbers stamped in connecting rod.
7. Install and alternately tighten rod cap retaining nuts in increments up to the specified torque of 85 Nm (63 Ft.-Lb.).
8. Install remaining piston assemblies in the same manner. Turn engine over by hand after each piston assembly is installed to see that all bearings are free.
9. Install oil pickup and oil pan with a new gasket.
10. Install cylinder head and adjust valve lash clearance. Refer to *Cylinder Head Installation* procedure.
11. Install rocker arm cover and replace crankcase oil.


**FIGURE 33. PISTON INSTALLATION**

## CAMSHAFT ASSEMBLY

The camshaft is a high strength alloy iron casting with hardened precision ground journals. Camshaft assembly is located in the cylinder block on left side of engine. A thrust type retaining plate is used between camshaft gear and shoulder of the first journal to position camshaft in cylinder block. A camshaft drive gear is positioned on the camshaft by a key and retained in place with a press fit. The camshaft gear is driven by the crankshaft gear through an idler gear.

### Removal (With Cylinder Head Removed)

1. Remove valve cover and cylinder head assembly, keeping rocker arms, tappets, push rods, etc. in their proper order. Refer to *Cylinder Head Removal* procedure.
2. Remove the components necessary to gain access to gearcase cover and remove cover. Refer to *Gear Cover Removal* procedure.
3. Remove the mechanically operated fuel transfer pump and push rod.
4. Check camshaft to idler gear backlash before removing camshaft assembly.
5. Rotate camshaft gear so camshaft retaining plate capscrews are accessible and remove capscrews.
6. Remove camshaft assembly.

**⚠CAUTION** ***Be careful not to scratch or mar the camshaft bearings with cam lobes as camshaft is withdrawn from cylinder block.***

### Removal (Without Removing Cylinder Head)

1. Remove valve cover, loosen rocker arms and remove push rods. Keep push rods in their proper order.
2. Remove the components necessary to remove gearcase cover and remove cover. Refer to *Gearcase Cover Removal* procedure.
3. Remove mechanically operated fuel transfer pump and push rod.
4. Rotate camshaft gear so camshaft retaining plate capscrews are accessible and remove capscrews. Before removing camshaft and gear, rotate crankshaft until timing marks on idler gear, crankshaft gear, and camshaft gear align.
5. Check camshaft to idler gear back lash, before removing camshaft.
6. Before withdrawing camshaft from cylinder block, position the tappets so they do not interfere with camshaft lobes during removal.

   A. With the engine removed from application for overhaul, simply turn engine on stand so front of block is up then push tappets to their uppermost position.

   B. If engine is mounted in a unit, the tappets can be held in their uppermost position by pulling tappets up with a pencil magnet. Pull tappets out of the tappet bore in cylinder block and lay to one side.

7. Remove camshaft assembly.

**⚠CAUTION** ***Do not scratch or mar the camshaft bearings with cam lobes as the camshaft is withdrawn from cylinder block.***

### Inspection

After removing camshaft assembly, check retaining plate clearance (endplay) by inserting a feeler gauge between retaining plate and camshaft gear. If endplay exceeds specifications with a new retaining plate replace camshaft gear.

Visually inspect the intake and exhaust lobes for roughness, scoring or excessive wear. Using a micrometer, check lobes for wear by measuring the lobes from nose to base (A to A). See Figure 34. If exhaust or intake lobe measurements are worn beyond specifications, replace camshaft and tappets.

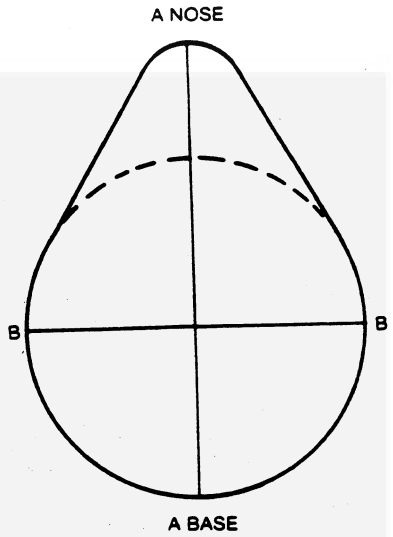



**FIGURE 34. CAMSHAFT LOBE MEASUREMENT**

Check camshaft bearing journals for excessive wear using a micrometer. If bearing journals are worn, replace both the camshaft and bearings. Inspect retaining plate for wear. Replace if thrust surface is rough or wear is excessive. New retaining plate thickness is 11.8mm to 12mm (.4646 inch to .4724 inch).

### Camshaft Gear

To remove the camshaft gear, place camshaft assembly in a press. Support camshaft retainer and push camshaft out of gear. Inspect gear for nicked, scored or broken teeth. Replace if necessary.

### Camshaft Bearings

The steel backed, alloy lined camshaft bearings are the precision type which do not require machining after installation. The camshaft bearings are a press fit into the cylinder block and support the camshaft. The camshaft bearings are lubricated through oil passages from the main oil galley.

With camshaft removed, use a micrometer to measure diameter of camshaft journals. Use a dial bore gauge or a telescopic gauge and micrometer to measure inside diameter of cam bearings. Replace camshaft bearings if the clearance is greater than specified, the bearings show cracks, or breaks.

***Removal:*** The crankshaft and gearcase backplate must be removed before cam bearings can be replaced. Refer to *Crankshaft* and *Gearcase Removal* procedures.

1. Drive the camshaft rear plug out from the inside of cylinder block.
2. Assemble cam bearing puller through cylinder block from the rear. Place shoulder of puller on outside of front bearing. All bearings except the rear one are pulled toward the rear of cylinder block.
3. Gradually tighten puller nut until bearing is removed from the block. Remove old bearing from puller before removing the next bearing.
4. Remove the remaining bearings leaving the rear bearing for last.
5. To remove rear bearing, reverse position of puller, so rear bearing is pulled towards front of cylinder block.

***Installation:*** Pull new bearings into place using the cam bearing puller. Start installing bearings at front (pull from rear) leaving the rear for last. Cam bearings are pulled in without lubrication.

**⚠CAUTION** ***The camshaft bearings must be properly positioned in cylinder block so oil hole in bearing lines up with oil passage in cylinder block. Blockage of the bearing oil hole will cause early bearing failure.***

On engines with solid tappets the front bearing is wider and has two oil holes in it. Be sure the two oil holes are lined up, one hole with oil passage from main bearing and the other with oil passage to rocker arm oiling system.

On engines with hydraulic tappets the third cam bearing has two oil holes and a circumferential groove. Be sure the two oil holes are lined up, one hole with oil passage from main bearing and the other with oil passage to hydraulic tappet oil gallery. Third cam bearing must be installed at a dimension of 214.2 to 214.8 mm (8.43 to 8.46 inch) from front face of cylinder block to the forward edge of cam bearing. This will ensure alignment of circumferential groove in third cam bearing journal.

Pull in the other bearings until oil hole is completely visible through oil passage from main bearing (Figure 35). Reverse position of bearing puller and install rear bearing, aligning oil hole with oil passage from main bearing.

**⚠CAUTION** ***When installing the rear cam bearing, use caution not to score or scratch the other bearings since bearing puller must pass through all of them. Place protective sleeving on threaded puller shaft to protect bearings.***

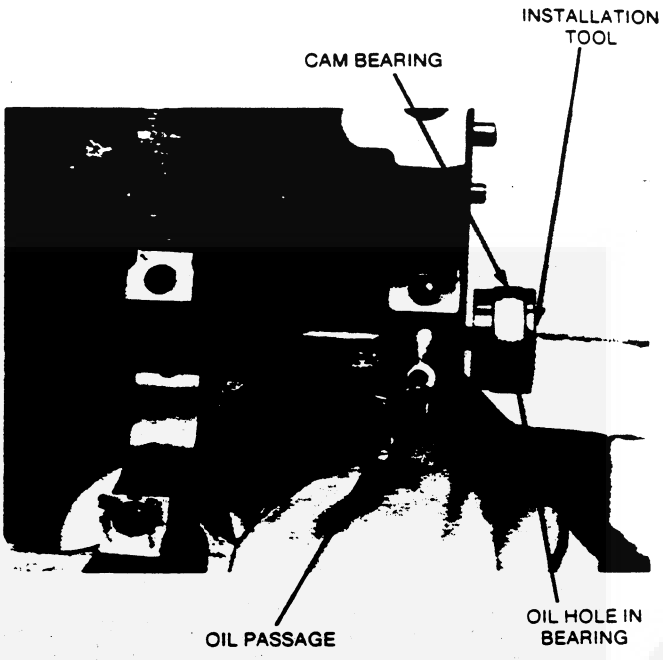



**FIGURE 35. CAM BEARING INSTALLATION**

Do not attempt to ream cam bearings as they are a precision type. After installing rear bearing, insert a new expansion plug in recess. Apply Permatex sealing compound to edges and expand it into place with a light blow to its center. A few light blows is all that is normally required to install expansion plug. If the plug is hit too hard and becomes concave it will contact camshaft when installed. If plug touches camshaft after installation remove plug and replace with a new one.

## Camshaft Assembly, Installation and Timing

1. The camshaft gear is a press fit onto the camshaft. To install camshaft gear to camshaft, proceed as follows:
   A. Place camshaft in a press with shoulder of front bearing journal resting on parallel bars.
   B. Place camshaft retaining plate on camshaft with flat machined surface toward journal shoulder.
   C. Install the key and press camshaft gear onto camshaft until it bottoms on shoulder with no clearance.
   D. Check retaining plate clearance (endplay) by inserting a feeler gauge between retaining plate and camshaft gear.
2. Install crankshaft and mount gearcase backplate. Refer to *Crankshaft* and *Backplate Installation* procedures.
3. Lubricate camshaft bearings in cylinder block and carefully insert camshaft. Be careful not to scratch or mar camshaft bearings.
4. Install capscrews through retaining plate and tighten to the specified torque.
5. Align timing marks on idler gear with timing marks on camshaft gear and crankshaft gear (Figure 36) and install idler gear.


**Line up single dot on idler gear with single dot on crankshaft gear and two dots on idler gear with two dots on camshaft gear.**

**FIGURE 36. TIMING MARKS**

6. Check camshaft gear backlash and camshaft endplay.
7. Install all other parts, which were removed during disassembly, by a direct reversal of the removal procedure. See *SECTION 10, FUEL SYSTEM* for correct injection pump mounting and timing.

## TAPPETS

The tappets are positioned in the cylinder block above the camshaft. The top of each tappet is machined to accept a push rod. The tappets ride on intake and exhaust camshaft lobes, changing camshaft rotary motion to a reciprocating motion opening and closing the valves.

### Removal

1. Remove rocker arm cover.
2. Remove rocker arm assemblies. Keep rocker arms, rocker arm nuts and push rods in order, so they go back in the same valve train position.
3. Remove cylinder head. Refer to *Cylinder Head Removal* procedure.
4. Remove tappets and identify them as to their location in cylinder block so they can be reinstalled in their original location.

### Inspection Solid Tappet

Very little wear takes place on tappet diameters or in tappet bores. If the clearance between tappet and bore in cylinder block exceeds specifications, replace the tappet.

Inspect the tappet faces which contact camshaft lobes for roughness, scuffing, or conclave wear. Replace any worn tappets. If tappets are worn, replace tappets and camshaft.

### Hydraulic Tappet

Inspect and clean each tappet separately do not interchange internal parts. If any part of the hydraulic tappet assembly needs replacing, replace the entire assembly.

***Disassembly:***

1. Hold the push rod socket down with a push rod, use the blade of a small screwdriver to remove retaining ring.
2. Remove push rod socket and metering plate.
3. Remove plunger and plunger spring.

***Inspection:*** Thoroughly clean all parts in cleaning solvent, and inspect carefully. If any parts are damaged or worn the entire tappet assembly should be replaced. If the tappet body wall is scuffed or worn, inspect the cylinder block tappet bore, if the bottom of the tappet is scuffed or worn replace the camshaft.

***Assembly:***

1. Place plunger spring and plunger in tappet body.
2. Lubricate, but do not fill, the assembly with clean engine oil.
3. Install metering plate and push rod socket.
4. Press down on push rod socket with a push rod. Install retaining ring.

The tappet is now completely assembled, lubricated and ready for installation.

### Installation

1. Lubricate each cam lobe with a special cam and tappet lubricant. New tappets are filled with a light oil. This oil will not harm the engine and should not be replaced before installation.
2. Lubricate the bottom of each tappet with a special cam and tappet lubricant.
3. Install tappets in their original location in cylinder block.
4. Install parts removed during disassembly, by a direct reversal of the removal procedure.

## GEARCASE COVER

The gearcase cover encloses the gear train and front end of engine. A fuel injection pump gear cover plate is installed over opening provided for it in the gearcase cover.

### Removal

1. Release tension on fan belt. Remove belt, alternator, and alternator bracket.
2. Remove crankshaft pulley or damper assembly and front engine support (if used).
3. Remove capscrews and Belville washers securing oil pan to gearcase cover. For ease of removal and installation of cover, loosen the other oil pan capscrews enough to lower front end of oil pan. If the oil pan gasket is damaged during removal of gear cover, oil pan must be removed and gasket replaced.
4. Remove fuel injection pump gear cover plate capscrews and cover plate.
5. Remove capscrews securing gearcase cover to back plate. Tap cover loose with a soft faced hammer.
6. Remove gearcase cover from engine, being careful not to damage front portion of oil pan gasket.

### Installation

1. Inspect, clean, and remove any burrs from crankshaft sealing surface.
2. Coat crankshaft lightly with lubricating oil.
3. Place a new gasket on back plate. Apply a bead of "RTV" Sealant to the junctions of cylinder block, oil pan, gearcase backplate, and gearcase cover.
4. Position gearcase cover on backplate. Complete the installation of cover and related parts. Torque all capscrews securing cover to backplate. Also torque oil pan capscrews securing oil pan to gearcase cover and block.
5. Install crankshaft pulley and damper assembly when used.
6. Install and tighten fan belt. Refer to *SECTION 9, COOLING SYSTEM, Fan Belt Adjustment* procedure.

## GEARCASE AND BACKPLATE

Located under gearcase cover on front end of engine is a completely enclosed train of precision machined helical gears. The crankshaft gear, which is pressed and keyed onto crankshaft, drives two idler gears. The lower (small) idler gear drives the oil pump drive gear. The upper (large) idler gear drives both the camshaft and fuel injection pump. The gear train is splash lubricated by oil thrown by the rotating gears. The gear train will run quietly if gears and bearings are in good condition. The gear train may be exposed by removing gearcase cover as described earlier in this section.

### Idler Gear and Idler Gear Shaft (Cam and Injection Pump Drive)

The idler gear has a steel backed bronze bearing pressed into it. This bearing is lubricated with engine oil from the block. Oil travels through the center of idler shaft and around retaining bolt to an oil passage bored through the shaft to the bearing surface.

The idler shaft is pressed into the bore in cylinder block. The idler gear and shaft are secured with a large washer and capscrew that threads into cylinder block.

***Idler Gear Removal and Replacement:***

1. Remove capscrew and washer retaining idler gear.
2. Remove idler gear from shaft.
3. Inspect idler gear for nicked, worn, or broken teeth. Replace if necessary.
4. Measure the inside diameter of idler gear bearing. Replace bearing if it is nicked, scored, or worn. After pressing a new bearing into gear, ream to the correct inside diameter.

***Idler Gear Shaft Removal and Replacement:*** Inspect idler gear shaft. If shaft is worn or scored it must be replaced. A slide hammer and metric adapter will aid in the removal of idler gear shaft.

1. To remove idler shaft, install a 14mm adapter in end of idler gear shaft.
2. Install slide hammer into adapter and pull idler gear shaft from cylinder block.
3. To install a new idler gear shaft, position it in bore of cylinder block. Insert washer and retaining capscrew into idler shaft. Tighten capscrew until idler gear shaft bottoms in cylinder block bore.
4. Remove washer and capscrew.
5. Apply a light coat of oil to idler gear shaft. Position idler gear on idler shaft making certain timing marks on idler gear are lined up with the crankshaft and camshaft timing marks. Install flat washer and capscrew. DO NOT USE A CAPSCREW THAT IS LONGER THAN 75mm (2.95 inches).

**See camshaft assembly, installation, and timing procedure for complete gear train timing instructions.**

### Backplate

The gearcase backplate is made of cast iron and supports the gears and gear cover. The backplate also provides a mounting surface for the fuel injection pump and oil pump. The backplate is secured to cylinder block by three capscrews and two socket head screws located under large idler gear. The backplate is sealed to cylinder block with a backplate gasket.

***Removal, Inspection, and Installation:***

1. Drain crankcase oil and remove oil pan and oil pick-up tube. Refer to *SECTION 8, OIL SYSTEM.*
2. Remove cylinder head, tappets, and gearcase cover. Refer to *Cylinder Head and Gearcase Cover Removal* procedures.
3. Remove fuel injection pump, mechanical fuel transfer pump, and push rod. Refer to *SECTION 10, FUEL SYSTEM* for removal procedures.
4. Remove camshaft and large idler gear.

## CRANKSHAFT FRONT OIL SEAL AND WEAR SLEEVE

The crankshaft front oil seal is located in gearcase cover. The lip-type seal fits tight on crankshaft or wear sleeve. The outer diameter is tight in gearcase cover. A front seal wear sleeve is available for servicing a damaged or seal grooved crankshaft.

### Seal Removal

1. Remove gearcase cover as described in preceding paragraphs.
2. Support gearcase cover and drive old seal out from the back side of cover.
3. Clean opening in cover to receive a new seal.

### Wear Sleeve Removal and Installation

1. Inspect wear sleeve or crankshaft for nicks, burrs, and wear grooves. Replace or install a wear sleeve if necessary.
2. If wear sleeve replacement is required, use a hammer and a chisel, that is only as wide as the wear sleeve, to make one or two chisel marks across wear sleeve about three-quarters of the way through. This will expand wear sleeve allowing for removal from crankshaft.

**⚠CAUTION** ***Do not nick or gouge crankshaft with chisel. If crankshaft is damaged it must be removed and repaired or replaced.***

3. Apply Loctite number 271 to crankshaft and inside of new wear sleeve before installing. Position wear sleeve on crankshaft with outside chamfer toward front of engine.
4. Using front wear sleeve installing tool, pull wear sleeve onto crankshaft. Tighten bolt until tool bottoms on crankshaft.
5. Clean any surplus Loctite off wear sleeve and crankshaft.

### Seal Installation

The outside diameter of front oil seal has a layer of colored sealant which forms a seal between the seal and seal bore in cover. This eliminates the need for using a sealing compound before pressing a new seal into cover. The inside diameter of oil seal has a lip made from a rubber compound to prevent oil leakage between seal and crankshaft or wear sleeve.

1. Place cover on a solid surface so back of seal bore is supported.
2. Position seal in cover with open side of seal facing inside of cover and positioned squarely in bore of cover.
3. Drive or press seal into cover bore until it bottoms on shoulder, using the front wear sleeve-oil seal installing tool and arbor press as illustrated in Figure 37.

**⚠CAUTION** ***A new seal must be installed with a new wear sleeve. The seal should not be positioned in a wear groove on the crankshaft. Positioning a seal on a worn, dirty, rough, or grooved crankshaft surface will cause the seal to leak.***

**⚠CAUTION** ***Make certain the seal seats squarely on shoulder in cover bore. A seal that is cocked in bore will leak.***

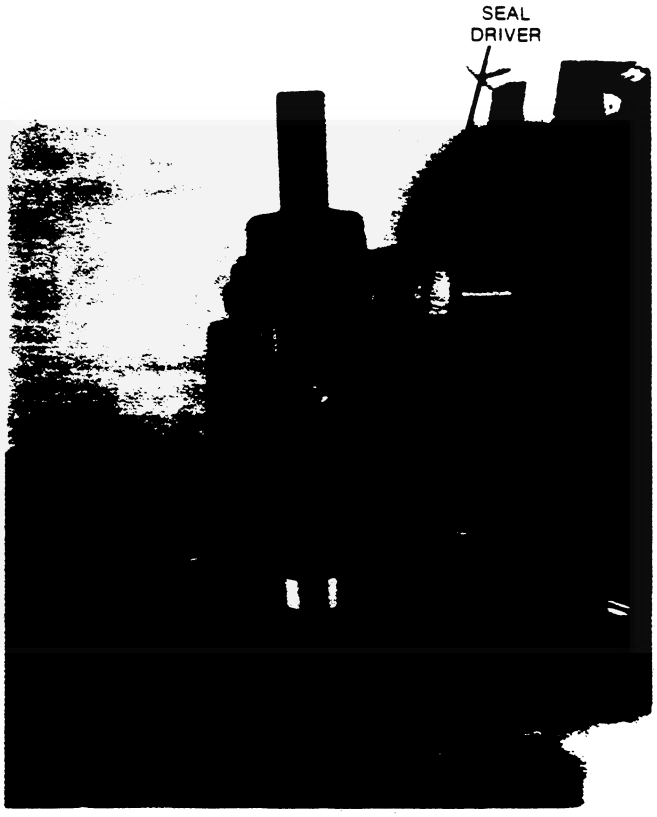



**FIGURE 37. GEAR COVER OIL SEAL INSTALLATION**

5. Remove the three capscrews and two socket head screws from backplate (Figure 38).

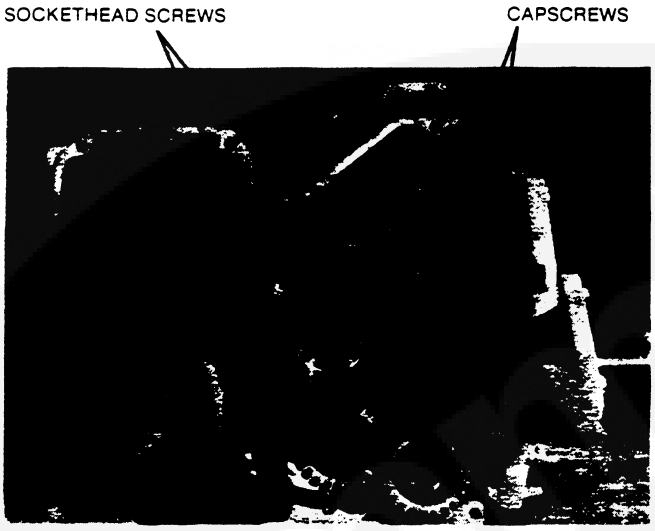



**FIGURE 38. BACKPLATE MOUNTING SCREWS**

6. Gently work backplate off alignment pins and idler gear shaft.
7. Inspect backplate for cracks, damage or wear, and replace if necessary.
8. Use a new gasket for the installation and install backplate by reversing the removal procedure. Refer to Figure 38 for the location of capscrews and socket head screws. After installing oil pick-up assembly, make certain that oil pump turns freely. If the oil pick-up mounting screws are improperly tightened they will prevent oil pump from turning. Refer to *SECTION 8, OIL SYSTEM* for correct installation procedure.
9. Install fuel injection pump. Refer to *SECTION 10, FUEL SYSTEM* for correct installation and timing procedures.

## CRANKSHAFT

The cast nodular iron dynamically balanced crankshaft is carefully cast and machined to assure the best possible strength and durability.

**⚠CAUTION** ***The crankshaft is a very strong but fragile part of the engine. Do not scratch, dent or drop the crankshaft, doing so may cause severe damage to crankshaft bearing journals. The bearing journals are not hardened and are easily damaged.***

Crankshaft end play is taken up by thrust flanges on the rear main bearing. The crankshaft is drilled for pressure lubrication from the main bearings to the connecting rod bearings.

### Removal

1. Remove oil filter and drain oil pan. Remove oil pan and oil pick-up tube. Refer to *SECTION 8, OIL SYSTEM.*
2. Disconnect wiring and remove starter. Remove flywheel and flywheel housing. Refer to *Flywheel Housing Removal* procedure.
3. Remove cylinder head assembly. Refer to the *Cylinder Head Removal* procedure.
4. Remove tappets and camshaft. Refer to the *Tappet* and *Camshaft Removal* procedures.
5. Remove gearcase cover and backplate. Refer to the *Gearcase Cover* and *Backplate Removal* procedures.
6. Remove connecting rod bearing caps, connecting rod bearing shells, and piston assemblies. Refer to *Piston Removal* and *Disassembly* procedure.

   **Mark bearing shells, connecting rods, and rod caps as to their original location in the cylinder block.**

7. Remove main bearing caps and lower main bearing shells.
8. Remove crankshaft. Some crankshaft rotation may be necessary during removal.
9. Remove upper main bearing shells from cylinder block.

### Inspection and Repair

Clean crankshaft thoroughly and inspect journals for scoring, chipping, cracking, or signs of overheating. If crankshaft has overheated, is scored, or excessively worn, reconditioning or replacement will be required. Examine bearing journals for cracks if overheating has occurred.

Measure crankshaft main bearing and connecting rod journals at several places on their diameter to check for roundness and taper. If out-of-round or taper of journals exceeds .005mm (.0002 inch), crankshaft must be reground or replaced.

Due to the method of grinding and fillet rolling of the turbocharged engine crankshaft, Onan recommends that the crankshaft not be ground and used again in turbocharged engines. Regrinding of a turbocharged engine crankshaft for use in a naturally aspirated engine is acceptable.

The only recommended method of reconditioning the crankshaft is regrinding, as required to accommodate undersize bearings. Metallizing of bearing journals is not recommended.

If regrinding of crankshaft journals is necessary, the work should be done by a reputable machine shop that has suitable equipment to handle precision work of this type. Undersize main bearing shells are available in sizes of 0.25mm, 0.50mm, 0.75mm and 1.00mm. Clean out all oil passages in crankshaft after regrinding.

### Installation

Make certain bearing seats and bearing shells (front and back) are clean and free from dirt and grit particles.

1. The upper main bearing halves are marked FRONT UPPER, INTER. UPPER, CTR. UPPER, and UPPER REAR. Position the upper main bearing shells in their appropriate location making certain bearing tang is in slot of bearing seat in cylinder block. The rear main bearing shell has a saddle type thrust surface. This thrust surface controls crankshaft endplay.
2. Lubricate all crankshaft bearing journals with oil. Lower crankshaft into position. Some crankshaft rotation may be necessary to miss the casting bosses in crankcase. Make certain flywheel flange end of crankshaft is toward the rear.
3. The bearing caps are numbered 1,2,3, etc., indicating their respective positions in block. The front and rear bearing caps are also marked F and R respectively.

## CRANKSHAFT GEAR

The crankshaft gear may be removed from crankshaft by using a gear separator and puller. See Figure 41. Gear may be removed either with crankshaft installed (backplate removed) or after crankshaft has been removed from engine.

To install crankshaft gear on crankshaft, install woodruff key in crankshaft. Heat gear on an electric burner or oven to about 175° C (350° F). Drive or press gear onto crankshaft. Timing marks must be visible from front end of the crankshaft.

**⚠WARNING** ***When handling the heated gear, wear asbestos gloves to prevent burns.***

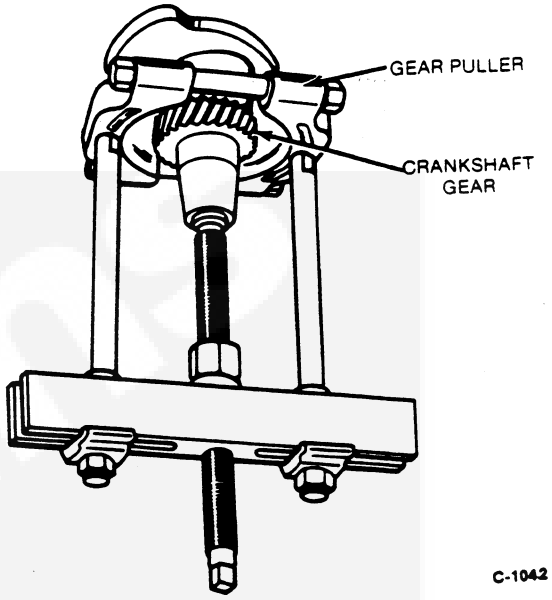



**FIGURE 41. CRANKSHAFT GEAR REMOVAL**

4. The lower main bearing halves are marked LOWER FRONT, LOWER INTR & CTR, and LOWER REAR.

   Position the lower bearing shells in the appropriate bearing cap. Make sure bearing tang is seated in slot of bearing cap. Lubricate bearing shells with clean engine oil.

5. Install main bearing caps with raised arrow facing camshaft side of engine starting with number one at front of engine (Figure 39). Push crankshaft toward front of engine, this will bring rear bearing thrust surfaces into alignment.


**FIGURE 39. MAIN BEARING CAPS**

6. Install main bearing capscrews and washers. Using a torque wrench, alternately and in steps tighten capscrews evenly to a torque of 123 Nm (90 Ft.-Lb.).

**⚠CAUTION** ***Do not over-torque main bearing capscrews. If these capscrews are over-tightened, bearing caps may be distorted, causing bearings to be drawn tight against crankshaft which can result in premature bearing failure.***

The crankshaft must turn freely after all capscrews are properly torqued. Never file or shim a bearing cap to make the bearing shell fit. Install new bearing shells if the fit on crankshaft is unsatisfactory. Refer to *SECTION 2, DIMENSIONS AND CLEARANCES* for clearance specifications.

7. Check crankshaft endplay using a dial indicator (Figure 40). Push the crankshaft in one direction to take up endplay. After dial indicator is set to zero and in place, pull crankshaft in opposite direction to obtain endplay reading. Endplay is controlled by thrust flanges on rear main bearing. If endplay is not within specification, replace rear main bearing.

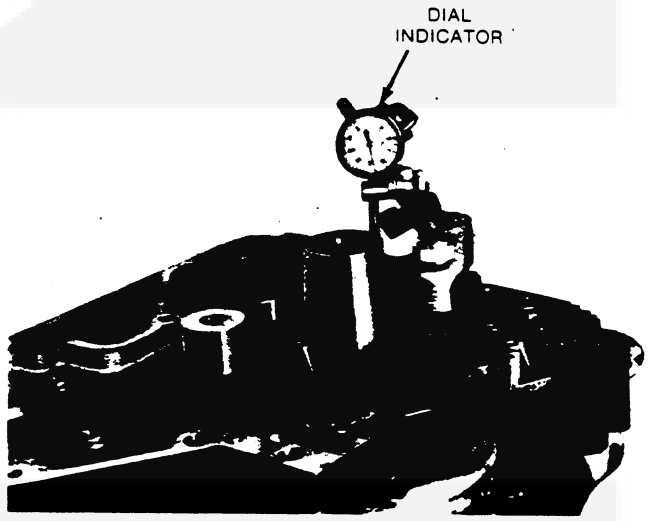



**FIGURE 40. MEASURING CRANKSHAFT END PLAY**

8. Install piston assemblies, connecting rod bearing caps, and bearing shells.
9. Complete installation by reversing the removal procedure.

## MAIN BEARINGS

The precision main bearings are replaceable without machining. Rear main bearing has two thrust flanges. These flanges control crankshaft endplay. All standard main bearings have an inside diameter of 76.040mm to 76.090mm (2.9937 inch to 2.9957 inch) when installed with bearing caps properly torqued.

The upper halves of main bearing shells are seated in lower part of cylinder block. The lower halves of main bearing shells are held in place by main bearing caps, which are secured to cylinder block by capscrews. The bearing shell is positioned by a tang in the shell that locates in a slot in bearing seat of cylinder block and bearing cap. The upper front bearing shell has two oil holes in it. The other upper bearings have only one oil hole. Lower bearing shells do not have any oil holes and are installed in the bearing caps.

### Removal

1. Remove crankshaft. Refer to *Crankshaft Removal* procedure. Identify bearing shells as to their original location in main bearing caps and cylinder block in the event bearing inspection proves they can be reused.
2. Remove upper bearing shells from their seats in cylinder block.
3. Remove lower bearing shells from their seats in main bearing caps.

### Inspection

Any bearing shell that is scored, chipped, pitted or worn beyond the specified limits must be replaced. Inspect backs of shells for bright spots. Bright spots on the backs of shells indicate shells have moved in their supports and are not fit for further use. With crankshaft removed, bearing cap installed and tightened to the specified torque, measure inside diameter of bearing at a point 90° from the parting line. The shells have a pressure fit in their bore in the block and must be tight when bearing cap is secured in place. Do not measure inside diameter at bearing parting line.

The inside diameter of installed new standard main bearings is 76.040mm to 76.090mm (2.9937 inch to 2.9957 inch) and any measurement above 76.090mm (2.9957 inch) indicates the amount of bearing wear. Measure diameter of crankshaft journal at the corresponding bearing location and subtract this dimension from inside diameter measurement of bearing as measured above. The difference between these two measurements is the crankshaft to bearing clearance.

The specified clearance between main bearing shells and crankshaft journal is .03mm to .10mm (.0012 inch to .0039 inch).

### Installation

Make certain bearing seats and bearing shells (front and back) are clean and free from dirt and grit particles.

1. Place a main bearing shell in each bearing seat in cylinder block. Make certain tang of bearing shell is properly seated in bearing seat recess. See *Crankshaft Installation* procedure for correct bearing locations.
2. Lubricate all crankshaft main bearings and crankshaft journals.
3. Install main bearing caps and bearing shells. Check crankshaft endplay and reassemble engine. Refer to *Crankshaft Installation* procedure.

### Main Bearing Replacement With Crankshaft Installed

It is unwise to replace main bearings without removing the crankshaft. If removal of crankshaft is impractical or in emergency cases, the following procedure may be used.

1. Remove glow plugs. This will relieve compression and allow free turning of the crankshaft.
2. Drain crankcase oil and remove oil pan and oil pick-up tube. See *SECTION 8, OIL SYSTEM.*
3. Remove only one bearing cap at a time. Install new bearing shells and reinstall bearing cap before removing the next bearing cap.
4. Lower bearing shell can be removed from bearing cap and replaced after cap is removed from engine.
5. Remove upper bearing shells as follows:

   A. Insert a cotter pin with head flattened, into crankshaft main bearing oil hole (Figure 42).

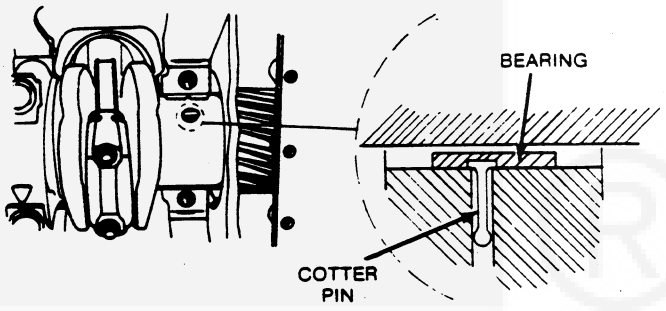



**FIGURE 42. REMOVING UPPER MAIN BEARING SHELL**

B. Rotate crankshaft in direction that will remove tang end of bearing shell first. Continue rotating crankshaft until bearing shell has been pushed all the way out.

C. One of the center main journals will not have an oil hole in it. Use a narrow brass bar to push this upper bearing shell out.

6. Inspect crankshaft journals for scoring, chipping, cracking, or signs of overheating. Remove and regrind or replace crankshaft if it is worn or has overheated.
7. Replace any bearing shell that is scored, chipped, pitted, or worn beyond the specified limits.
8. Install upper bearing shell by lubricating shell with clean oil. Roll shell around crankshaft journal in the opposite direction that it was removed until tang on bearing shell is positioned in cylinder block recess.

**⚠CAUTION** ***Do not scratch bearing back when rolling bearing in. Be sure bearing rolls in free.***

9. Place a lower bearing shell in bearing cap. Bearing caps are numbered 1,2,3, etc., indicating their respective positions in cylinder block. Front and rear bearing caps are also marked F and R respectively.
10. Lubricate bearing shell and place bearing cap in position on cylinder block with raised arrow facing camshaft side of engine.
11. Install main bearing capscrews and washers.
12. Use a torque wrench to alternately tighten capscrew evenly to a torque of 123 Nm (90 Ft.-Lb.).

**⚠CAUTION** ***Do not over-torque main bearing capscrews. If these capscrews are over-tightened, bearing caps may be distorted, causing bearings to be drawn tight against crankshaft which can result in premature bearing failure.***

13. Check bearing clearance with Plastigage. Refer to *Checking Bearing Clearance with Plastigage* for correct procedure.
14. Check crankshaft end play. Refer to *Crankshaft Installation* procedure.
15. Install oil pick-up tube and oil pan. Refill crankcase with clean oil.
16. Install glow plugs.

### Checking Bearing Clearance With Plastigage

The most accurate means of determining bearing clearance is by using micrometers. However, if crankshaft is installed in engine, bearing clearance may be measured by using a plastic strip (Plastigage) manufactured for this purpose.

1. Using a clean, dry rag, thoroughly clean all oil from crankshaft journal and bearing shell. Place a piece of the correct size Plastigage the full width of crankshaft journal surface about 7mm (.2500 inch) off center.
2. Install bearing cap with bearing shell and tighten bolts or nuts to the specified torque. Do not rotate crankshaft.
3. Remove bearing cap. The flattened Plastigage will be found adhering to either the bearing shell or crankshaft.
4. Compare flattened Plastigage with the graduations on Plastigage envelope to determine clearance.

   The number within the matching graduation on the envelope indicates, total clearance in millimetres or thousandths of an inch.

## CYLINDER BLOCK

The cylinder block is the main support for all other basic engine parts. The block is a one piece casting made from cast iron. Transverse end walls and center webs are cast in the block to support the crankshaft and camshaft, assuring alignment of crankshaft and cylinders. Cylinder bores are completely surrounded by water jackets which extend the full length of the cylinder walls for maximum cooling.

### Cleaning

After removing pistons, crankshaft, cylinder head, etc., inspect block for cracks and extreme wear. If block is still serviceable, prepare it for cleaning as follows:

1. Scrape all old gasket material from block. Remove all oil galley plugs to allow cleaning solution to contact inside of oil passages.
2. Remove grease and scale from cylinder block by agitating in a bath of commercial cleaning solution or hot soapy washing solution.
3. Rinse block in clean hot water to remove cleaning solution.
4. Be sure to clean and dry all water passages, oil passages, and drilled holes.
5. Coat pipe threads with teflon pipe sealant. Replace all pipe plugs removed for cleaning of oil passages. Install new freeze plugs as required using green Loctite RC/601 to seal plugs.

### Inspection

When rebuilding the engine, thoroughly inspect block for any condition that would make it unfit for further use. This inspection must be made after all parts have been removed and block has been thoroughly cleaned and dried.

1. Make a thorough check for cracks. Minute cracks may be detected by coating the suspected area with a mixture of 25 percent kerosene and 75 percent light motor oil. Wipe the part dry and immediately apply a coating of zinc oxide (white lead) dissolved in wood alcohol. If cracks are present, the white coating will become discolored at the defective area. Always replace a cracked cylinder block.
2. Check all dowel pins, oil galley plugs, and freeze plugs for wear or damage and replace as necessary.
3. Inspect all machined surfaces and threaded holes. Carefully remove any nicks or burrs from machined surfaces. Clean out tapped holes and clean up any damaged threads.
4. Check top of block for flatness with a straight edge and a feeler gauge (Figure 43). This surface is the critical area for sealing oil, water and compression. If warped, a maximum of .05mm (.002 inch) may be machined from top of cylinder block. If warpage exceeds .05mm (.002 inch) replace block.

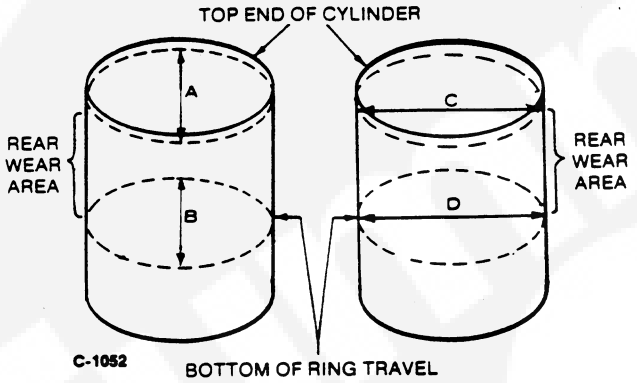

**FIGURE 43. CHECKING TOP OF CYLINDER BLOCK FOR FLATNESS**

***Cylinder Bore Inspection:*** Inspect cylinder bores for scuffing, scratches, wear, and scoring. If cylinder bores are scuffed, scratched, scored, or worn, they must be rebored and honed for the next oversize piston. Main bearing caps must be installed and properly torqued, before measuring cylinder bore. When the appearance of cylinder bores is good and there are no scuff marks, check cylinder bore for wear or out of roundness as follows:

1. Check cylinder bore for taper, out of round and wear, with a cylinder bore gauge, telescope gauge or inside micrometer. These measurements should be taken at four places, top and bottom of piston ring travel, parallel and perpendicular to axis of crankshaft.
2. Record measurements taken lengthwise at top and bottom of piston travel as follows (see Figure 44):

   A. Lengthwise of block, measure and record as "A" the diameter of cylinder at the top of cylinder where greatest ring wear occurs.
   B. Also, lengthwise of block, measure and record as "B" the cylinder diameter at the bottom of piston travel.
   C. Crosswise of block, measure and record as "C" the diameter of the top of cylinder at the greatest point of wear.
   D. Measure and record as "D" the diameter at bottom of cylinder bore and crosswise of block.
   E. Reading "A" subtracted from reading "B" and reading "C" subtracted from reading "D" indicates cylinder taper.

F. If cylinder taper exceeds 0.076mm (0.003 inch) rebore and hone to accommodate the next oversize piston. Reading "A" compared to reading "C" and reading "B" compared to reading "D" indicates whether or not cylinder is out of round. If out of round exceeds 0.025mm (0.001 inch), the cylinders must be rebored and honed for the next oversize piston. Oversize pistons and rings are available in 0.25mm, 0.50mm, 0.75mm, and 1.00mm.



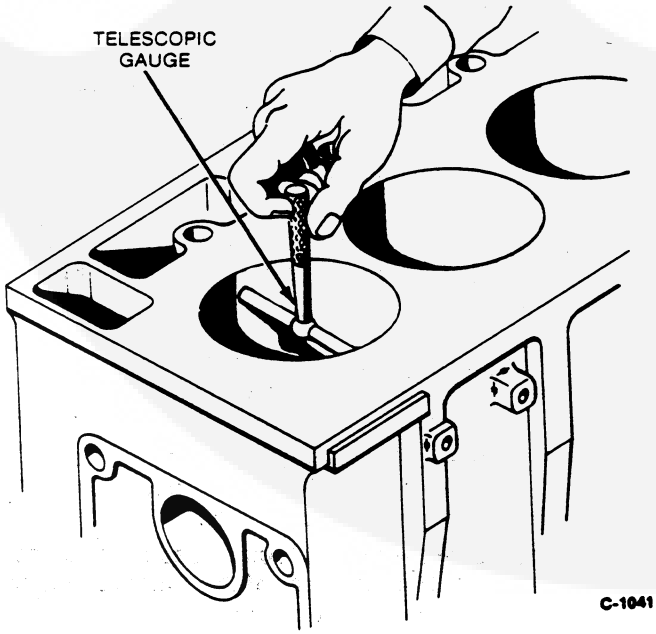




**FIGURE 44. METHODS OF MEASURING THE DIAMETER OF A CYLINDER BORE**

## Reboring the Cylinder

Before boring or honing cylinder bores, all main bearing caps must be properly installed and torqued. Rebore and hone engine whenever cylinder bore is worn, damaged, out of round or if cylinder taper exceeds specifications. A worn cylinder bore should be resized to the smallest standard oversize diameter at which it will clean up. The final finish and bore diameters should then be obtained by honing.

**⚠CAUTION** ***If boring bar is operated incorrectly, it will produce a rough cylinder surface that may not clean up even when honed. Boring should be done only by qualified service personnel who are careful in their work.***

After boring to the correct oversize cylinder bore dimension piston and ring clearance should be appropriate. There is no need to adjust or "fit" pistons and rings.

When reboring cylinders, take the following precautions:

1. Make sure cutting tool is properly ground before using it.
2. Be sure top of engine block is smooth and deposit free.
3. Clean base of boring bar before bar is set up. Deposits under boring bar will cause it to tilt and the cylinder will be distorted after boring.
4. Make an initial rough cut, followed by a finish cut. Then hone cylinder bore to the specified oversize.

## Honing Cylinders (Using Precision Hones)

The L engine is a high speed, high output diesel which requires a quality surface finish for the engine's pistons and rings. This finish can best be provided by using two stage honing with quality equipment intended for honing engine cylinder bores.

The following honing procedure provides a good quality finish that allows maximum engine life and good oil control.

1. Honing Machine Tool Set Up:

   A. Honing rotational speed - 170 rpm.

   B. Honing stroke length — 142mm (5.6") with 3.5" stones. This provides about 30mm of overstroke at both the top and bottom of the cylinder bore. Watch for interference between the honing head and the main bearing bore bulkheads during set up.

   C. For first stage honing, or rough honing, use a soft (fast cutting) 150 grit silicon carbide stone.

   D. For second stage honing, or finish honing, use a medium hardness 400 grit silicon carbide stone.

2. Honing Procedure:

   A. Hone the cylinders to their final size during the rough honing stage. If the cylinder block is bored to an oversize before honing, .05 to .13mm (.002 to .005") of material should be left after boring for clean up during the honing operation.

   B. Check diameter of the cylinder bore regularly during honing. A dial bore gauge is the easiest method but a telescoping gauge can be used. Check size at six places in the bore, measuring twice at the top, middle and bottom 90 degree apart.

   C. Finish hone by installing the finishing stones into the cylinder and expanding until snug. Then hone for 15 to 20 additional strokes at a medium to low feed rate.

   D. Clean the cylinder bores thoroughly with soap, water and clean rags. A clean white rag should not be soiled on the walls after cleaning is complete. Do not use solvent or gasoline since they wash oil from the walls and leave the metal particles.

   E. Dry the crankcase and coat it with oil.

3. Honing Results:

   A. The recommended honing cross hatch pattern is an included angle of 56 ± 12 degrees (Figure 45) when measured perpendicular to the cylinder bore axis.

   B. Surface finish of the completed cylinder bores should range from .4 to 1.0 um Ra.

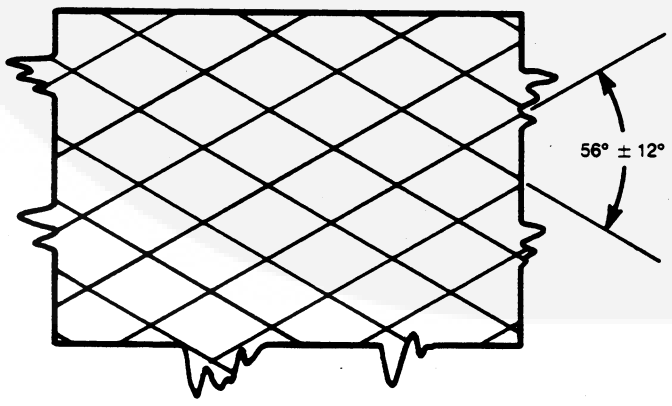



**FIGURE 45. CROSS HATCH ANGLE (MAGNIFIED)**

## Deglazing Cylinder Bores

Deglaze the cylinder bores if there are no scuff marks and no wear or out of round beyond specifications before installing new rings. Deglazing gives a fine finish, but does not enlarge cylinder diameter, so the original pistons with new rings may still be used.

The reason for deglazing a cylinder is to provide cavities to hold oil during piston ring break-in.

1. Wipe cylinder bores with a clean cloth which has been dipped in clean, light engine oil.
2. Use a brush type deglazing tool with coated bristle tips to produce a crosshatch pattern in the cylinder bore.
3. The deglazing tool should be driven by a slow speed drill. Move deglazing tool up and down in cylinder (10 to 12 complete strokes) rapidly enough to obtain a crosshatch pattern as shown in Figure 46.

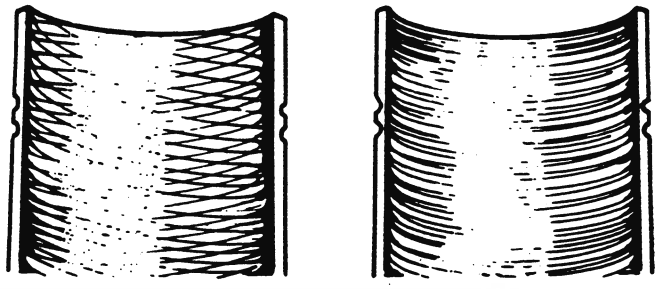



**FIGURE 46. CROSS HATCHING**

4. Clean cylinder bore thoroughly with soap, water and clean rags. Keep on cleaning until a clean white rag shows no discoloring when wiped through cylinder bore.

**⚠CAUTION** ***Never use gasoline or commercial cleaners to clean cylinder bores after deglazing or honing. These solvents will not remove abrasives from the walls. Abrasives not removed from engine will rapidly wear rings, cylinder walls, and bearing surfaces of all lubricated parts.***

# 14. Turbocharger

## TURBOCHARGER

A turbocharger is used to boost the power output of an engine over that of a naturally aspirated engine by increasing the amount of air supplied to the cylinders. The turbocharger uses engine exhaust gases to drive a turbine wheel mounted on a common shaft with a radial air compressor impeller.

The turbocharger feeds denser compressed air directly into the engine intake. This allows the engine to burn fuel more efficiently and to deliver more power per stroke from a given engine capacity.

On some turbochargers a turbine bypass valve or wastegate is used to control boost. Wastegate operation is controlled by an actuator that senses compressor discharge pressure and balances it against a preset spring load. The wastegate valve located in the turbine inlet passage diverts a portion of the exhaust gas away from the turbine wheel to control shaft speed and compressor air output.

## REMOVAL

**⚠CAUTION** ***Clean exterior of entire turbocharger assembly, air intake piping, and oil lines to prevent the entrance of foreign material into engine and turbocharger during removal.***

1. Remove air intake piping from turbocharger compressor housing inlet and outlet.
2. Remove exhaust pipe from turbocharger.
3. Disconnect oil lines from turbocharger. Cover all openings to prevent the entrance of dirt and foreign material.
4. Remove hex nuts that secure turbocharger to exhaust manifold.
5. Remove turbocharger and gasket from exhaust manifold.
6. After removal, using a vice, secure turbocharger at turbine inlet flange.

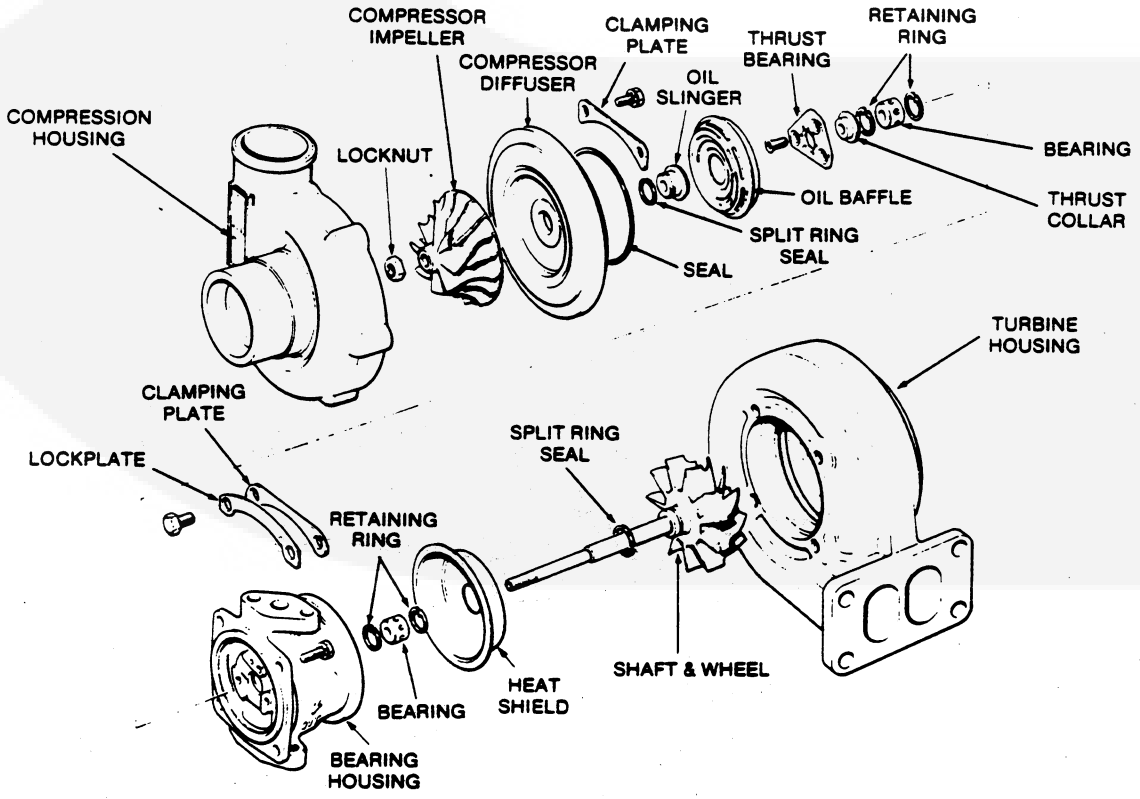



**FIGURE 1. HOLSET TURBOCHARGER**

## INSPECTION

General inspection can be done without removing turbocharger. Inspect turbine wheel and compressor impeller for cracks, erosion, nicked or bent blade tips, and broken or missing blades. Inspect housings for rubbing, scoring, and erosion. If turbocharger damage or wear is evident, replacement or further disassembly and repair is necessary.

Check for oil in exhaust outlet and turbo-to-intake manifold piping. If oil is present it indicates a restriction in air intake system or a turbocharger seal failure. Remove any restriciton found in intake system. If no restriction is found remove turbocharger for replacement or repair.

Check for free rotation of the turbine wheel and compressor impeller. If wheel and impeller do not rotate freely, parts may be damaged, or foreign material may be causing friction, in which instance replacement or further disassembly and inspection is necessary.

If no damage or excessive friction is detected, check end (axial) play and radial play with a dial indicator.

### Holset Bearing Clearance Inspection

Mount dial indicator on end of turbocharger shaft. Push shaft in one direction to take up end play. Set dial indicator to zero and pull shaft in opposite direction to obtain end play reaching. Total end-play reading should be 0.10 mm to 0.16 mm (0.004 inch to 0.006 inch).

To check radial play compressor, housing must be removed.

1. Mark relative position of compressor diffuser and compressor housing.

   **⚠CAUTION** ***Use care to prevent damage to rotating parts of the turbocharger; avoid rough handling. A turbocharger is a precision built piece of equipment. Do not pry on rotating components or set turbocharger on turbine wheel or compressor impeller.***

2. Remove capscrews and clamping plates that secure compressor housing to compressor diffuser. Lift off compressor housing.

3. Mount dial indicator on compressor impeller hub.

4. Check shaft radial play by pushing impeller towards and away from shaft centerline. Total radial play should be within 0.30 mm to 0.46 mm (0.012 inch to 0.018 inch).

5. Install compressor housing, checking the scribe marks for proper alignment.

6. Install clamping plates and capscrews. Torque compressor housing capscrews to 5.7 Nm-(4 Ft.-Lb.).

If end play and radial play are within the limits specified, turbocharger bearings and internal components are within limits.

Remove turbocharger for replacement or repair if end play or radial play are not within the limits.

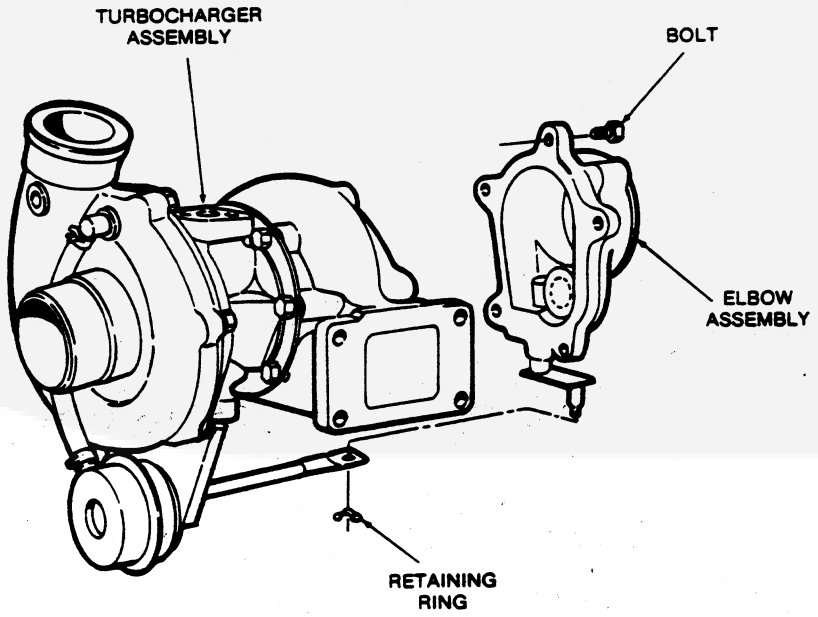



**FIGURE 2. ELBOW ASSEMBLY REMOVAL**

## Airesearch Bearing Clearance Inspection

With turbocharger removed from the engine, check journal bearings for radial clearance as follows:

1. Remove retaining ring (Figure 2) and slip actuator rod eye off wastegate lever pin.

2. Remove capscrews, elbow assembly, and gasket from turbocharger.

3. Position a dial indicator on turbocharger so that the indicator arm extends through oil outlet port and contacts turbine wheel assembly shaft.

4. Manually apply pressure to the compressor and turbine wheels to move the shaft as far away as it will go from the dial indicator arm. Set dial indicator to zero.

5. Manually push compressor and turbine wheels toward dial indicator arm. Record the maximum shaft movement shown on indicator dial.

   To make sure the dial indicator reading is correct, roll the wheels slightly in both directions while applying pressure.

6. Manually apply pressure to the compressor and turbine wheels to move the shaft as far away as it will go from the dial indicator arm. The dial indicator should return to zero.

7. Repeat Steps 4, 5, and 6 several times to verify that the maximum bearing radial clearance has been measured.

8. If the maximum bearing radial clearance is less than 0.08 mm (0.003 inch) or greater than 0.15 mm (0.006 inch), replace turbocharger or have it repaired.

Check thrust bearing for end play (axial) clearance as follows:

1. Position a dial indicator on turbocharger so that the indicator arm rests on end of turbine wheel assembly.

2. Manually move compressor wheel and turbine wheel assembly as far away as it will go from the dial indicator arm. Set dial indicator to zero.

3. Manually move compressor wheel and turbine wheel assembly as far as it will go toward the dial indicator arm. Record the maximum shaft movement shown on indicator dial.

4. Manually move compressor wheel and turbine wheel asembly away from dial indicator arm. The dial indicator should return to zero.

5. Repeat Steps 2, 3, and 4 several times to verify that the maximum bearing end play clearance has been measured.

6. If the maximum bearing end play (axial) clearance is less than 0.03 mm (0.001 inch) or greater than 0.08 mm (0.003 inch), replace turbocharger or have it repaired.

## INSTALLATION

Never replace a turbocharger without first establishing the reasons for any previous failure.

1. Inspect air intake system and exhaust manifold for foreign material and cleanliness.
2. Inspect oil drain line. Make certain line is not blocked.
3. Inspect oil supply line for restrictions, deterioration, or leaks.
4. Clean turbocharger mounting flange surface and mounting surface on exhaust manifold to make certain that all of the old gasket has been removed.
5. Position new gasket on exhaust manifold. Gasket should not protrude into manifold opening.
6. Install turbocharger on manifold. Secure with flatwashers and hex nuts. Torque hex nuts to 52 Nm (39 Ft.-Lb.).
7. Connect oil supply line. Connect oil drain line to turbocharger. Leave oil drain line disconnected at cylinder block at this time.
8. Connect compressor inlet and outlet piping. Connect exhaust piping. Check all joints for possible leaks. Make certain that piping is not placing any strain on torbocharger.
9. Crank engine without firing until a steady flow of oil is coming out of oil drain line.
10. Stop cranking and connect oil drain line to cylinder block.

**⚠WARNING** ***Contact with rotating machinery can cause serious personal injury or death. Stay clear of rotating components and ensure that air intake piping, air cleaner, and exhaust pipe are in place and secured before operating engine.***

**⚠CAUTION** ***Foreign objects may be drawn into turbocharger if air intake piping and air cleaner are not in place. Foreign objects entering the turbocharger can cause serious turbocharger or engine damage.***

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