

Service Manual

B3.3 Diesel Engine

Lift Trucks

D20S-3(B3.3), D25S-3(B3.3), D30S-3(B3.3)

D32S-3(B3.3), D33S-3(B3.3)

D20G, D25G, D30G

Important Safety Information

Most accidents involving product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Read and understand all safety precautions and warnings before operating or performing lubrication, maintenance and repair on this product.

Basic safety precautions are listed in the "Safety" section of the Service or Technical Manual. Additional safety precautions are listed in the "Safety" section of the owner/operation/maintenance publication. Specific safety warnings for all these publications are provided in the description of operations where hazards exist. WARNING labels have also been put on the product to provide instructions and to identify specific hazards. If these hazard warnings are not heeded, bodily injury or death could occur to you or other persons. Warnings in this publication and on the product labels are identified by the following symbol.



Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Operations that may cause product damage are identified by NOTICE labels on the product and in this publication.

DOOSAN cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are therefore not all inclusive. If a tool, procedure, work method or operating technique not specifically recommended by DOOSAN is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance or repair procedures you choose.

The information, specifications, and illustrations in this publication are on the basis of information available at the time it was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service given to the product.

Obtain the complete and most current information before starting any job. DOOSAN dealers have the most current information available.

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About the Manual

This Troubleshooting and Repair Manual is intended to aid in determining the cause of engine-related problems and to provide recommended repair procedures.

The material in this manual covers all Signature engines. The manual is divided into sections. Each section is equivalent to a group used in Cummins filmcard system. Some sections contain **reference** numbers and **procedure** numbers. **Reference** numbers provide general information, specifications, diagrams, and service tools where applicable. Procedure numbers are used to identify and reference specific repair **procedures** for correcting the problem.

This manual is designed so the troubleshooting trees are used to locate the cause of an engine problem. The troubleshooting trees then direct the user to the correct repair procedure. The repair procedures within a section are in numerical order. However, the repair steps within a given procedure are organized in the order the repair must be performed, regardless of the numerical order of the steps. The user **must** use the Section Contents pages or the Index at the back of the manual to locate specific topics when **not** using the troubleshooting trees.

How to Use the Manual

This manual is organized to provide an easy flow from problem identification to problem correction. A list of troubleshooting symptoms containing the most common engine problems is in the Troubleshooting Symptoms, Section TS. The manual is designed to use the Troubleshooting Symptoms as a guide to locating the problem and directing the end user to the correct procedure for making the repair. Complete the following steps to locate and correct the problem.

- | | |
|----------|--|
| (Step 1) | Locate the symptom on the Section Contents pages of Section TS.
Reference to the page number where the Troubleshooting Symptom Tree is found is made to the right of the symptom tree title. |
| (Step 2) | The left column of boxes in the Troubleshooting Symptom Charts indicates a probable cause of the problem, starting at the top with the simplest and easiest to repair, and continuing downward to the most difficult.
The right column of boxes provides a brief description of the corrective action with a reference number to the correct procedure used to make the repair. |
| (Step 3) | Locate the probable cause in the left column; then turn to the procedure referenced in the right column. |
| (Step 4) | The Troubleshooting Symptom Charts are based on the following assumptions:
1. The engine has been installed according to the manufacturer's specifications.
2. The easiest repairs are done first.
3. "Generic" solutions cover problems with the most common applications and original equipment manufacturer (OEM). |

Symbols

The following symbols have been used in this manual to help communicate the intent of the instructions. When one of the symbols appears, it conveys the meaning defined below:



WARNING – Serious personal injury or extensive property damage can result if the warning instructions are not followed.



CAUTION – Minor personal injury can result or a part, an assembly or the engine can be damaged if the Caution instructions are not followed.



Indicates a **REMOVAL** or **DISASSEMBLY** step.



Indicates an **INSTALLATION** or **ASSEMBLY** step.



INSPECTION is required.



CLEAN the part or assembly.



PERFORM a mechanical or time **MEASUREMENT**.



LUBRICATE the part or assembly.



Indicates that a **WRENCH** or **TOOL SIZE** will be given.



TIGHTEN to a specific torque



PERFORM an electrical **MEASUREMENT**.



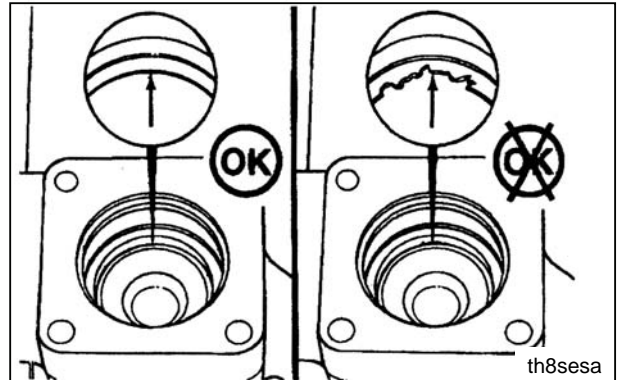
Refer to another location in this manual or another publication for additional information.



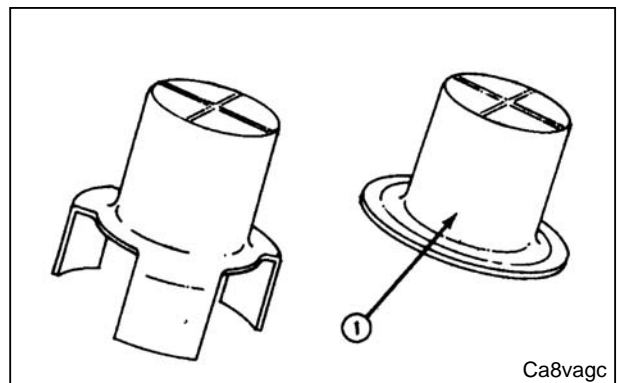
The component weighs 23kg [50lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

Illustrations

Some of the illustrations throughout this manual are generic and will **not** look exactly like the engine or parts used in your application. The illustrations can contain symbols to indicate an action required and an acceptable or **not** acceptable condition.



The illustrations are intended to show repair or replacement procedures. The procedure will be the same for all applications, although the illustration can differ.

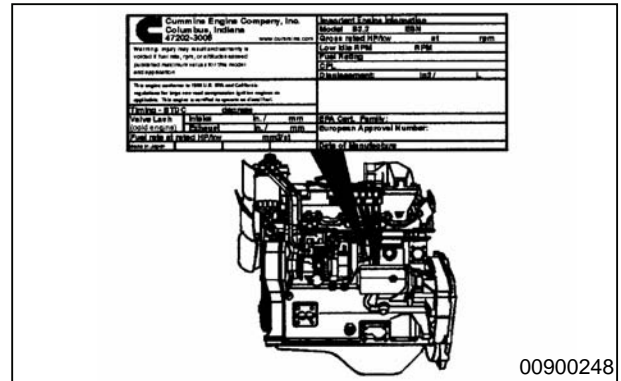


Engine Identification

Engine Dataplate

The engine dataplate shows specific information about the engine. The engine serial number (ESN) and control parts list (CPL) provide information for ordering parts and for service needs.

NOTE: The engine dataplate **must not** be changed unless approved by Cummins Engine Company, Inc.



00900248

 Cummins Engine Company, Inc. Columbus, Indiana 47202-3005 www.cummins.com		Important Engine Information Model B3.3 ESN 1 Gross rated HP/kw 100 at 1800 rpm Low idle RPM 750 RPM Fuel Rating CPL Displacement: 10.8 in ³ / 1.8 L	
Warning: injury may result and warranty is voided if fuel rate, rpm, or altitudes exceed published maximum values for this model and application.		This engine conforms to 1999 U.S. EPA and California regulations for large non-road compression ignition engines as applicable. This engine is certified to operate on diesel fuel.	
Timing - BTDC 22 degrees		EPA Cert. Family:	
Valve Lash (cold engine)	Intake 0.004 in. / 0.10 mm Exhaust 0.004 in. / 0.10 mm	European Approval Number:	
Fuel rate at rated HP/kw 24 mm ³ /st		Date of Manufacture	
Made in Japan			

00900249

Specifications

Performance			D20/25/30/32/33S-3 D20/25/30G-3
Rated Power		kW(PS)	43.4 (59) @ 2200 rpm
Max Torque		Nm(kgf-m)	202 (20.6) @ 1600 rpm
Torque Rising			7.4 % for 2200rpm rating
BSFC	@Rated Power	g/kWh	227 @2200rpm
	@Max Torque	g/kWh	219 @1600rpm
Low Idle rpm	@Dynamo	rpm	2500 ±25
	@Truck	rpm	2470 ±50
High Idle rpm	@Dynamo	rpm	800 ±25
	@Truck	rpm	770 ±25

General Engine Data			Naturally Aspirated
Engine Weight (Dry) Less Flywheel and Electronics			245 kg [540 lb]
Compression Ratio			18.8
Bore			95 mm [3.74 in]
Stroke			115 mm [4.528 in]
Displacement			3.26 liters [199 in ³]
Firing Order			1-2-4-3
Valve Clearance:	Intake		0.35 mm [0.014 in]
	Exhaust		0.50 mm [0.020 in]
Rotation Viewed from the Front of the Engine			Clockwise

Lubrication System			Naturally Aspirated
Regulating Valve Opening Pressure			490 kPa [71 psi]
Lubricating Oil Capacity:	Total System		7.5 liters [8.0 qt]
	Standard Oil Pan Only		7.0 liters [7.4 qt]
Lubricating Oil Pressure at Idle (Minimum Allowable)			69 kPa [10 psi]
Lubricating Oil Pressure at Rated (Minimum Allowable)			245 kPa [35 psi]
Oil Filter Differential Pressure to Open Bypass Valve			98 kPa [14 psi]
Number of liters [qt] from Low to High			1.5 liters [1.6 qt]

Cooling System			Naturally Aspirated
Coolant Capacity (Engine Only)			4.5 liters [4.75 qt]
Standard Modulating Thermostat Range:	Start		82° C [180° F]
	Fully Open		95° C [203° F]
Maximum Pressure Cap @ Sea Level			50 kPa [7 psi]

Air Induction System			Naturally Aspirated
Maximum Allowable Intake Restriction at Rated Speed and Load with Dirty Filter Element			762 mm H ₂ O [30 in H ₂ O]

Exhaust System			Naturally Aspirated
Maximum Allowable Exhaust Restriction at Rated Speed and Load with Dirty Filter Element			75 mm Hg [3 in Hg]

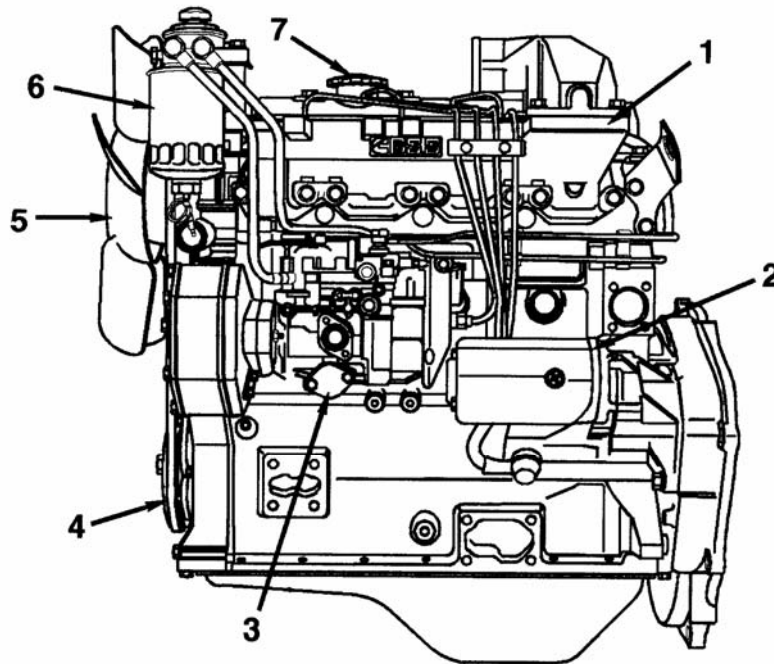
Fuel System			Naturally Aspirated
Maximum Allowable Restriction to the Fuel Transfer Pump or Filter Head Must Not Exceed			75 mm Hg [3 in Hg]
Maximum Allowable Return Line Restriction Must Not Exceed			190.5 mm Hg [7.5 in Hg]
Inlet Pressure to the Injection Pump Range			0.00 kPa [0.00 psi] to 39.0 kPa [5.00 psi]

Electrical System			Naturally Aspirated
Minimum Recommended Battery Capacity with Light Accessories*:	12-VDC Starter		550 CCA
Minimum Recommended Battery Capacity with Heavy Accessories**:	12-VDC Starter		730 CCA
Maximum Allowable Resistance of the Starting Circuit:	12-VDC Starter		0.0012 ohms
*Typical light accessories include: Alternator, small steering pump, and disengaged clutch.			
**Typical heavy accessories include: Hydraulic pump and torque converter.			

Engine Diagrams

Engine Views

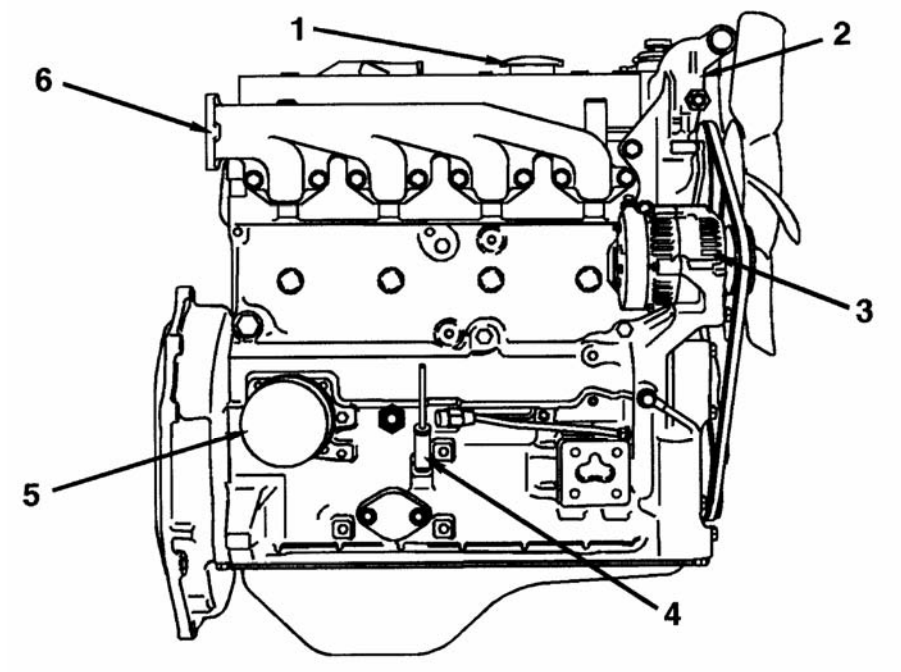
The following illustrations show the locations of the major external engine components, filters, and other service and maintenance points. Some external components will be at different locations for different engine models.



**Intake Side
(Naturally Aspirated)**

00900138

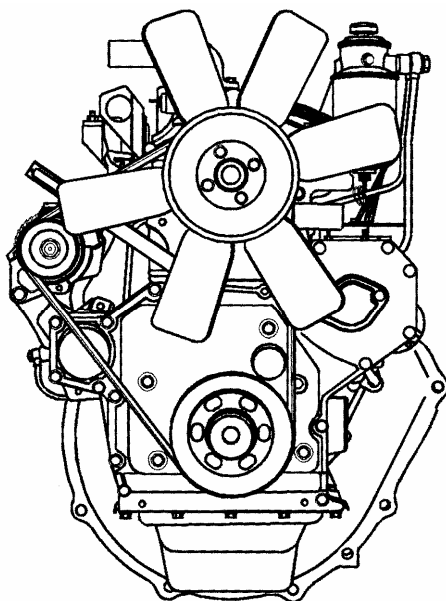
- | | |
|------------------------|------------------|
| 1. Intake Manifold | 5. Fan |
| 2. Starting Motor | 6. Fuel Filter |
| 3. Fuel Injection Pump | 7. Oil Fill Cap. |
| 4. Crankshaft Pulley | |



**Exhaust Side
(Naturally Aspirated)**

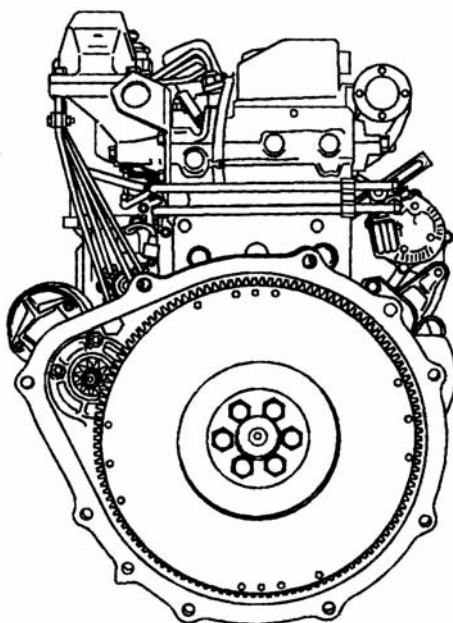
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- | | |
|-----------------------|----------------------|
| 1. Oil Fill Cap | 4. Dipstick |
| 2. Thermostat Housing | 5. Oil Filter |
| 3. Alternator | 6. Exhaust Manifold. |



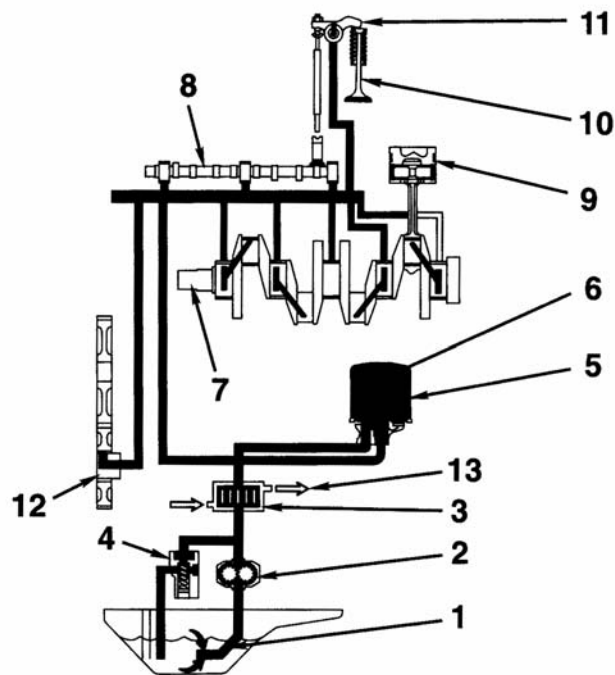
**Front View
(Naturally Aspirated)**

00900140



**Rear View
(Naturally Aspirated)**

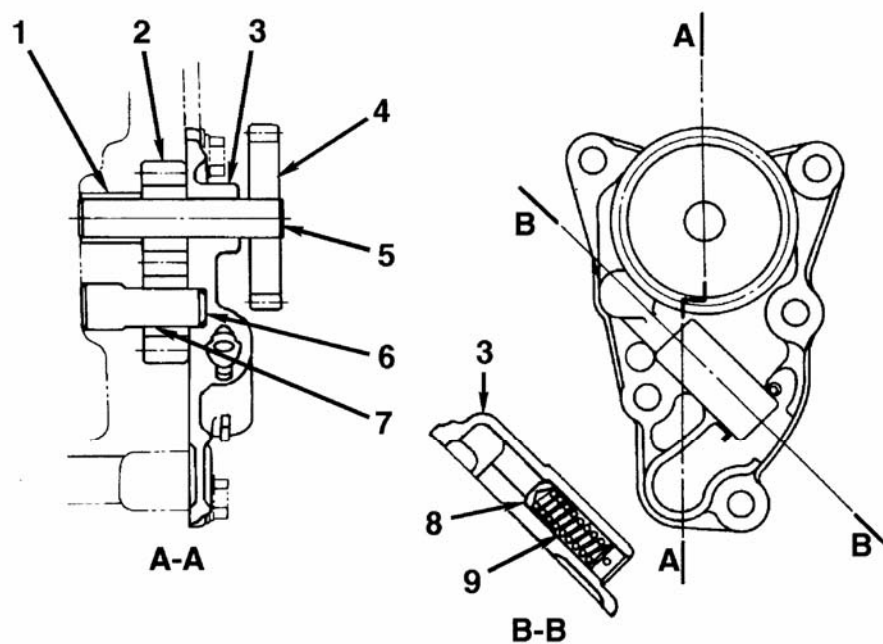
00900141



**Exhaust Side
(Naturally Aspirated)**

00900146

- | | |
|--------------------------|------------------------------|
| 1. Oil Strainer | 8. Camshaft |
| 2. Oil Pump | 9. Piston |
| 3. Oil Cooler (Optional) | 10. Intake and Exhaust Valve |
| 4. Regulator Valve | 11. Rocker Arm |
| 5. Oil Filter | 12. Timing Gear |
| 6. Safety Valve | 13. Cooling Water. |
| 7. Crankshaft | |



Oil Pump

00900148

1. Bushing
2. Gear Drive (number of teeth: 7)
3. Pump cover
4. Oil Pump Drive Gear (number of teeth: 22)
5. Driveshaft
6. Drivenshaft
7. Driven Gear (number of teeth: 7)

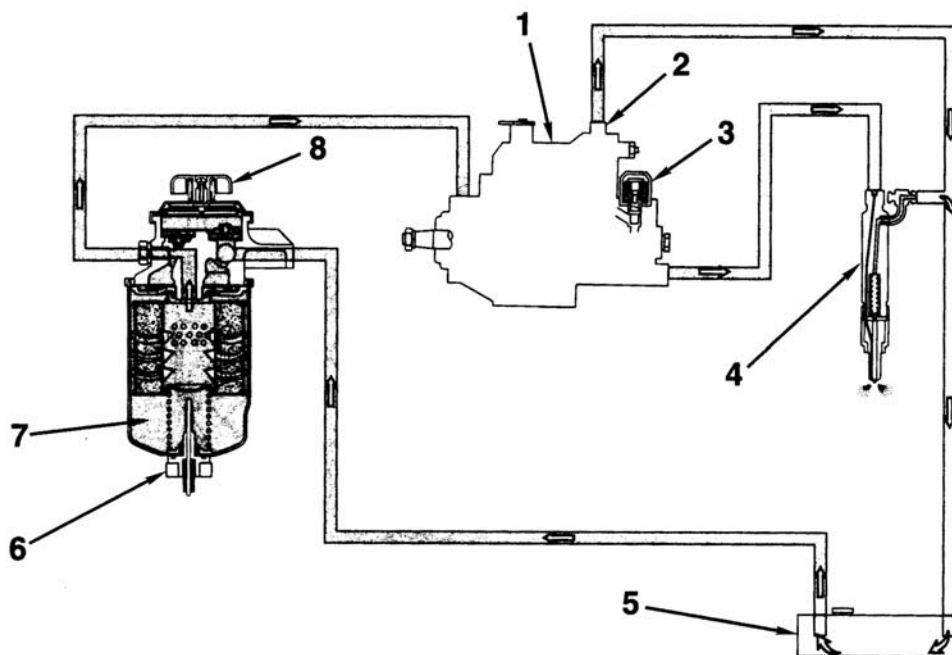
8. Regulator Valve
9. Valve Spring.

Oil pump

- Type: Gear Type
- Pump Speed: Engine Speed x 1.182.

Regulator Valve

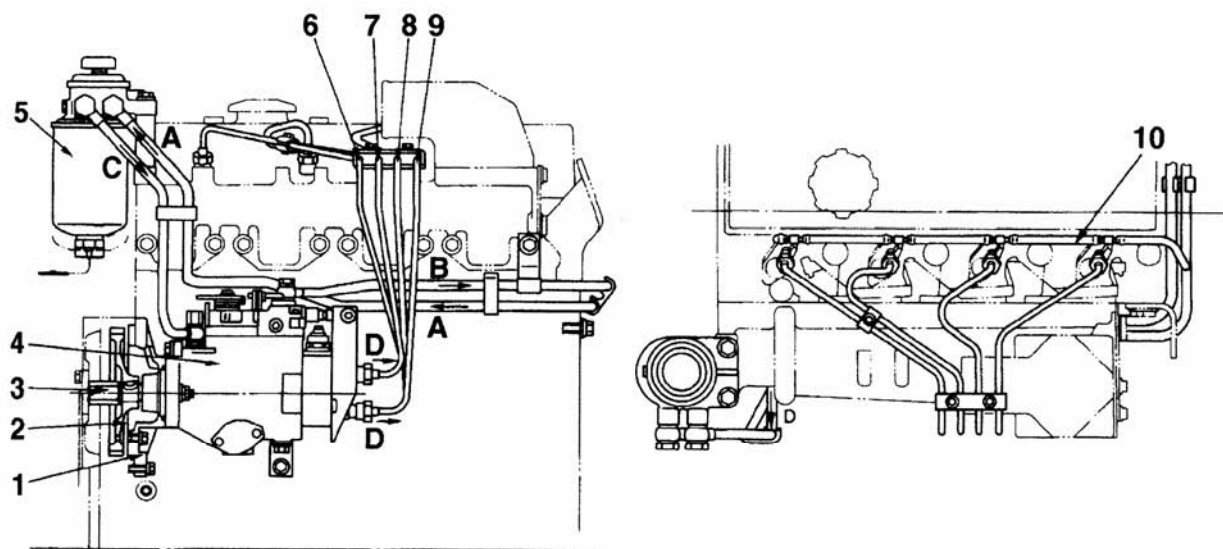
- Set Pressure: $490 \pm 50\text{kPa}$ [$71 \pm 7\text{psi}$].



Fuel System

00900149

- | | |
|--------------------------|-------------------------------|
| 1. Fuel Injection Pump | 5. Fuel Tank |
| 2. Overflow Valve | 6. Water-in-Fuel Sensor (WIF) |
| 3. Fuel Solenoid | 7. Fuel Filter |
| 4. Fuel Injection Nozzle | 8. Hand Priming Pump. |



Fuel Injection Pump

00900150

1. Pump Holder
2. Fuel Injection Pump Drive Gear
(number of teeth: 52)
3. Drive Shaft
4. Fuel Injection Pump (Body)
5. Fuel Filter
6. Fuel Injection Pipe (No. 1)
7. Fuel Injection Pipe (No. 2)
8. Fuel Injection Pipe (No. 3)
9. Fuel Injection Pipe (No. 4)
10. Spill Tube

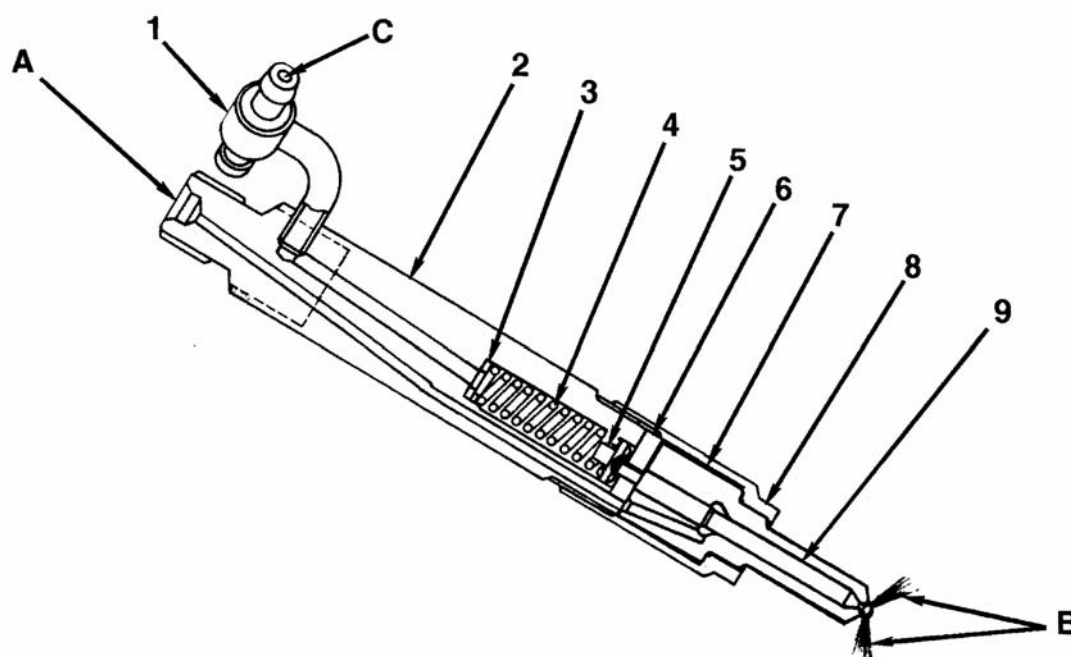
- A. Fuel Inlet (from Fuel Tank)
- B. To. Fuel Tank
- C. To Fuel Injection Pump
- D. To Fuel Injection Nozzle.

Fuel Injection Pump

- Maker: Zexel
- Type: VE
- Lubrication Method: Forced Lubrication with Fuel

Governor

- Type: Mechanical, All-speed Type.



Fuel Injection Nozzle

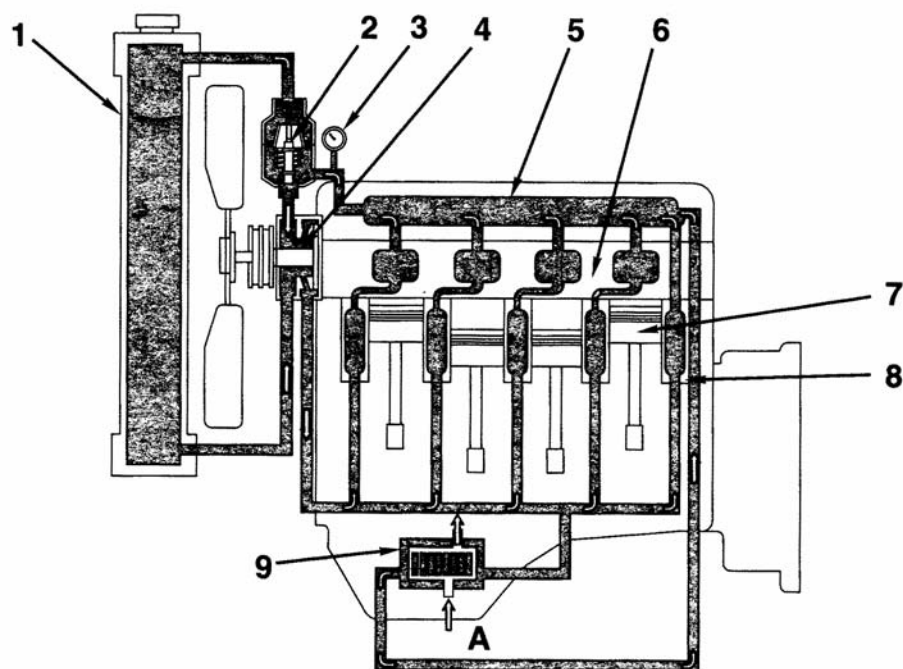
00900151

1. Fuel Drain Line Connector
2. Nozzle Holder
3. Adjusting Shim
4. Nozzle spring
5. Spring seat
6. Intermediate Plate
7. Nozzle Body
8. Retaining Nut
9. Needle.

- A. Fuel Inlet (from injection pump)
B. Fuel Injection (to cylinder)
C. Fuel Return (to fuel tank).

Fuel Injection Nozzle

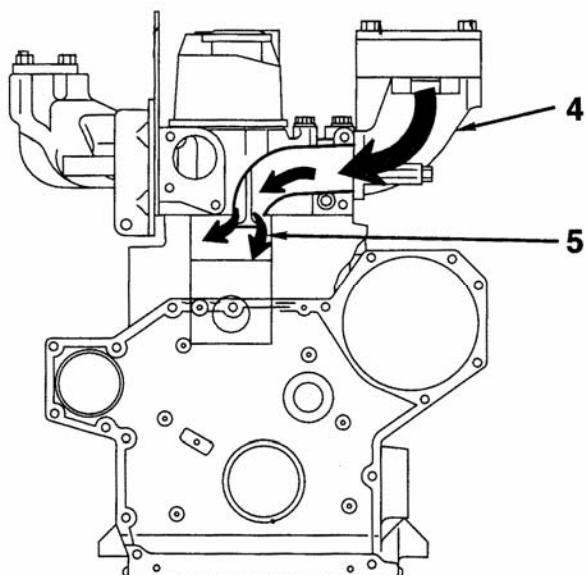
- Maker: Zexel
- Injection Pressure: 40 MPa
- Adjustment of Injection Pressure: By Shim.



Cooling System

00900147

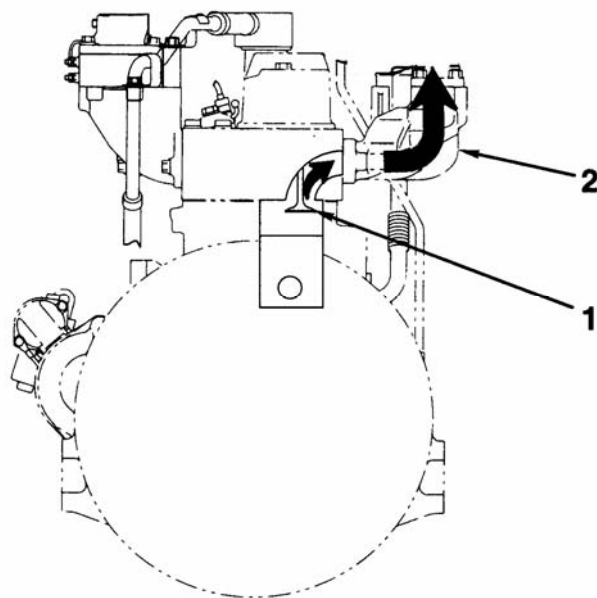
- | | |
|----------------------------|---------------------------|
| 1. Radiator | 6. Cylinder Head |
| 2. Thermostat | 7. Piston |
| 3. Water Temperature Gauge | 8. Cylinder Block |
| 4. Water Pump | 9. Oil Cooler (optional). |
| 5. Water Manifold | A. From Oil Pump (oil). |



Air Intake System

00900227

- 1. Filtered Air
- 2. Intake Manifold
- 3. Intake Valve Port.



Exhaust System

00900232

-
1. Exhaust Valve Port
 2. Exhaust Manifold

Procedures and Techniques

A thorough analysis of the customer's complaint is the key to successful troubleshooting. The more information known about a complaint, the faster and easier the problem can be solved.

The Troubleshooting Symptom Charts are organized so that a problem can be located and corrected by doing the easiest and most logical things first. Complete all steps in the sequence shown from top to bottom.

It is **not** possible to include all the solutions to problems that can occur; however, these charts are designed to stimulate a thought process that will lead to the cause and correction of the problem.

Follow these basic troubleshooting steps:

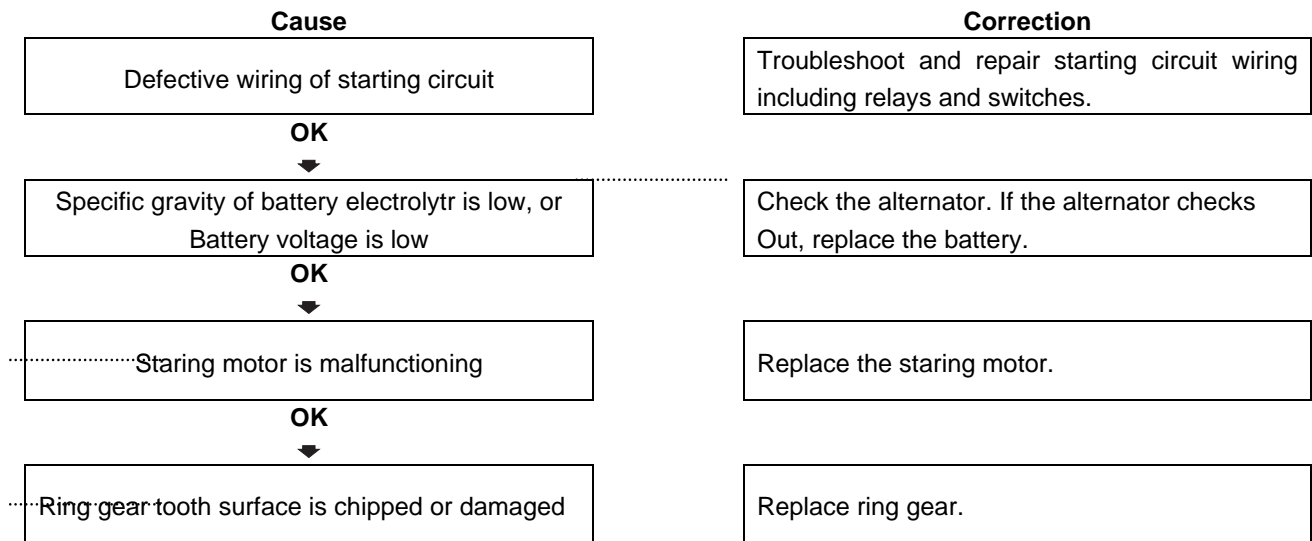
- Get all the facts concerning the complaint
- Analyze the problem thoroughly
- Relate the symptoms to the basic engine systems and components
- Consider any recent maintenance or repair action that can relate to the complaint
- Double-check before beginning any disassembly
- Solve the problem by using the symptom charts and doing the easiest things first
- Determine the cause of the problem and make a thorough repair
- After repairs have been made, operate the engine to make sure the cause of the complaint has been corrected

Troubleshooting Symptoms Charts

Use the charts on the following pages of this section to aid in diagnosing specific engine symptoms. Read each row of blocks from top to bottom. Follow through the chart to identify the corrective action.

Engine Will Not Crank or Cranks Slowly

This is symptom tree T-002.



Engine Cranks But Will Not Start (No Exhaust Smoke)

This is symptom tree T-003.

Cause	Correction
Fuel level low in the tank	Fill the supply tank.
OK ↓	
Improper fuel is being used	Drain fuel and replace with correct fuel.
OK ↓	
Clogged fuel tank air breather hole	Clean the fuel tank breather.
OK ↓	
Engine does start when voltage is applied to the fuel cut solenoid valve	Troubleshoot and repair the circuit wiring.
OK ↓	
Engine does not start when voltage is applied to the fuel cut solenoid valve	Replace the fuel cut solenoid valve.
OK ↓	
Clogged prefilter	Clean the prefilter.
OK ↓	
Clogged fuel filter or strainer	Clean or replace the fuel filter or strainer.
OK ↓	
Clogged or leaking fuel piping	Clean and repair the fuel piping.
OK ↓	
Feed pump is damaged or seized	Replace the feed pump.
OK ↓	
Injector are plugged	Replace the injectors.
OK ↓	
Injection pump driveshaft or driveshaft key is damaged	Repair or replace the injection pump.

Engine Difficult to Start or Will Not Start (Exhaust Smoke)

This is symptom tree T-004.

Cause	Correction
Starting aid malfunctioning or heater mount Does not become warm	Replace the starting aid.
OK ↓	
Crank speed is too slow (minimum crank Speed: 150 rpm)	Verify drive units are not engaged. Check the Battery and recharge or replace.
OK ↓	
Improper fuel is being used	Drain fuel and replace with correct fuel.
OK ↓	
Clogged air cleaner element	Clean or replace the air cleaner element.
OK ↓	
Clogged prefilter	Clean the prefilter.
OK ↓	
Clogged fuel filter or strainer	Clean or replace the fuel filter or strainer.
OK ↓	
Leakage, clogging, air in fuel system	Repair and clean the fuel filter or strainer.
OK ↓	
Injection pump timing is incorrect	Retime the injection pump.
OK	

(Continued)

Engine Difficult to Start or Will Not Start (Exhaust Smoke) (Continued)

Cause	Correction
.....Overhead adjustments are not correct	Measure and adjust the overhead settings.
OK ▼	
.....Overhead components are damaged	Inspect the rocker levers, rocker shafts, and valve for excessive damage. Replace as necessary.
OK ▼	
.....Defective or clogged injection nozzle	Replace the defective or clogged injection nozzle
OK ▼	
.....Injection pump is malfunctioning	Repair or replace the injection pump.
OK ▼	
.....Worn piston ring or cylinder resulting in low compression	Replace the worn piston ring or cylinder.

Engine Has Poor Responses

This is symptom tree T-005.

Cause	Correction
Clogged air cleaner element	Clean or replace the air cleaner element
OK ↓	
Clogged fuel tank air breather hole	Clean the fuel tank breather.
OK ↓	
Clogged prefilter	Clean or replace the fuel filter or strainer.
OK ↓	
Clogged fuel filter or strainer	Clean and repair the fuel piping
OK ↓	
Clogged or leaking fuel piping	Clean and adjust the overhead settings.
OK ↓	
Overhead adjustments are not correct	Measure and adjust the overhead settings.
OK ↓	
Defective contact of valve or valve seat Resulting in low compression	Replace the cylinder head.
OK ↓	
Defective or clogged injection nozzle	Replace the defective or clogged injection nozzle.
OK ↓	
Injection pump is malfunctioning	Repair or replace the injection pump.
OK ↓	
Worn piston ring or cylinder resulting in low Compression	Replace the worn piston ring or cylinder.

Engine Stops During Operation

This is symptom tree T-006.

Cause	Correction
Chassis powertrain is damaged or overloaded	Refer to the OEM's service manuals.
OK ↓	
Fuel level low in the tank	Fill the supply tank.
OK ↓	
Clogged fuel tank air breather hole	Clean the fuel tank breather.
OK ↓	
Clogged prefilter	Clean the prefilter.
OK ↓	
Clogged fuel filter or strainer	Clean and or replace the fuel filter or strainer.
OK ↓	
Clogged or leaking fuel piping	Clean and repair the fuel piping.
OK ↓	
Feed pump piston is damaged or seized	Replace the feed pump.
OK ↓	
Overhead components are damaged	Inspect the rocker levers, rocker shafts, and valves for excessive damage. Replace as necessary.
OK ↓	
Injection pump is malfunctioning	Replace the injection pump.
OK ↓	
Gear train damaged or seized	Refer to OEM's service manuals.
OK ↓	
Piston or connecting rod is damaged	Replace damaged piston or connecting rod.
OK ↓	
Crankshaft bearing is damaged	Replace damaged crankshaft bearing.

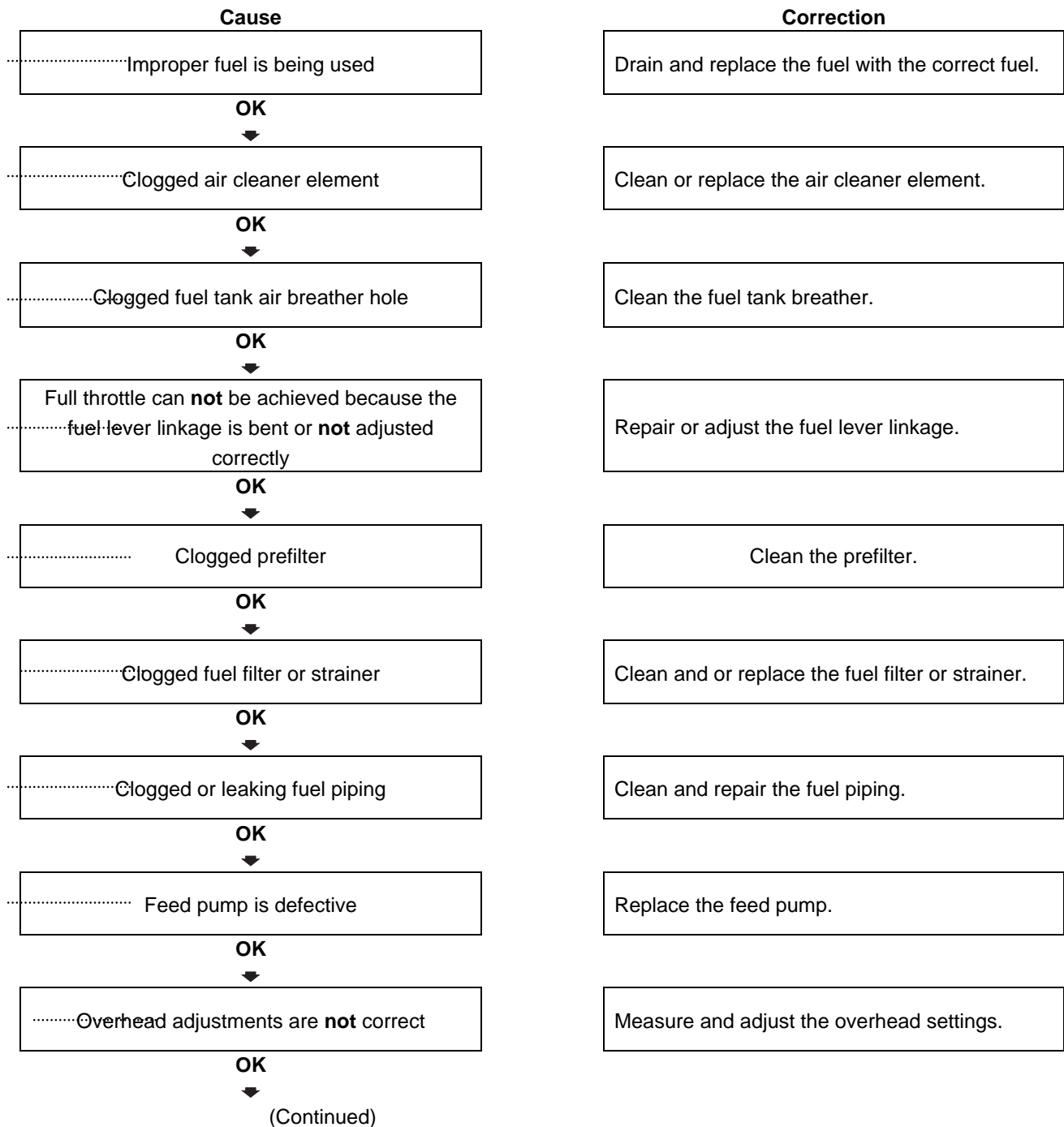
Engine Runs Rough or Misfires

This is symptom tree T-007.

Cause	Correction
Fuel level low in the tank	Fill the supply tank.
OK ↓	
Clogged fuel tank air breather hole	Clean the fuel tank breather.
OK ↓	
Low idle speed is adjusted too low	Adjust the low idle speed.
OK ↓	
Clogged prefilter	Clean the prefilter.
OK ↓	
Clogged fuel filter or strainer	Clean or replace the fuel filter or strainer.
OK ↓	
Line between the fuel tank and feed pump are clogged or have air in them	Clean and repair the lines.
OK ↓	
Line between the feed pump and the injector nozzle are clogged or have air in them	Clean and repair the lines.
OK ↓	
Injection pump is malfunctioning	Replace the injection pump.

Engine Power Output Low

This is symptom tree T-008.



Engine Power Output Low (Continued)

Cause	Correction
Defective contact of valve or seat Resulting in low compression	Replace the cylinder head.
OK ↓	
Defective or clogged injection nozzle	Replace the defective or clogged injection nozzle.
OK ↓	
Injection pump is malfunctioning	Replace the injection pump.
OK ↓	
Worn piston ring or cylinder resulting in low compression	Replace the worn piston ring or cylinder.

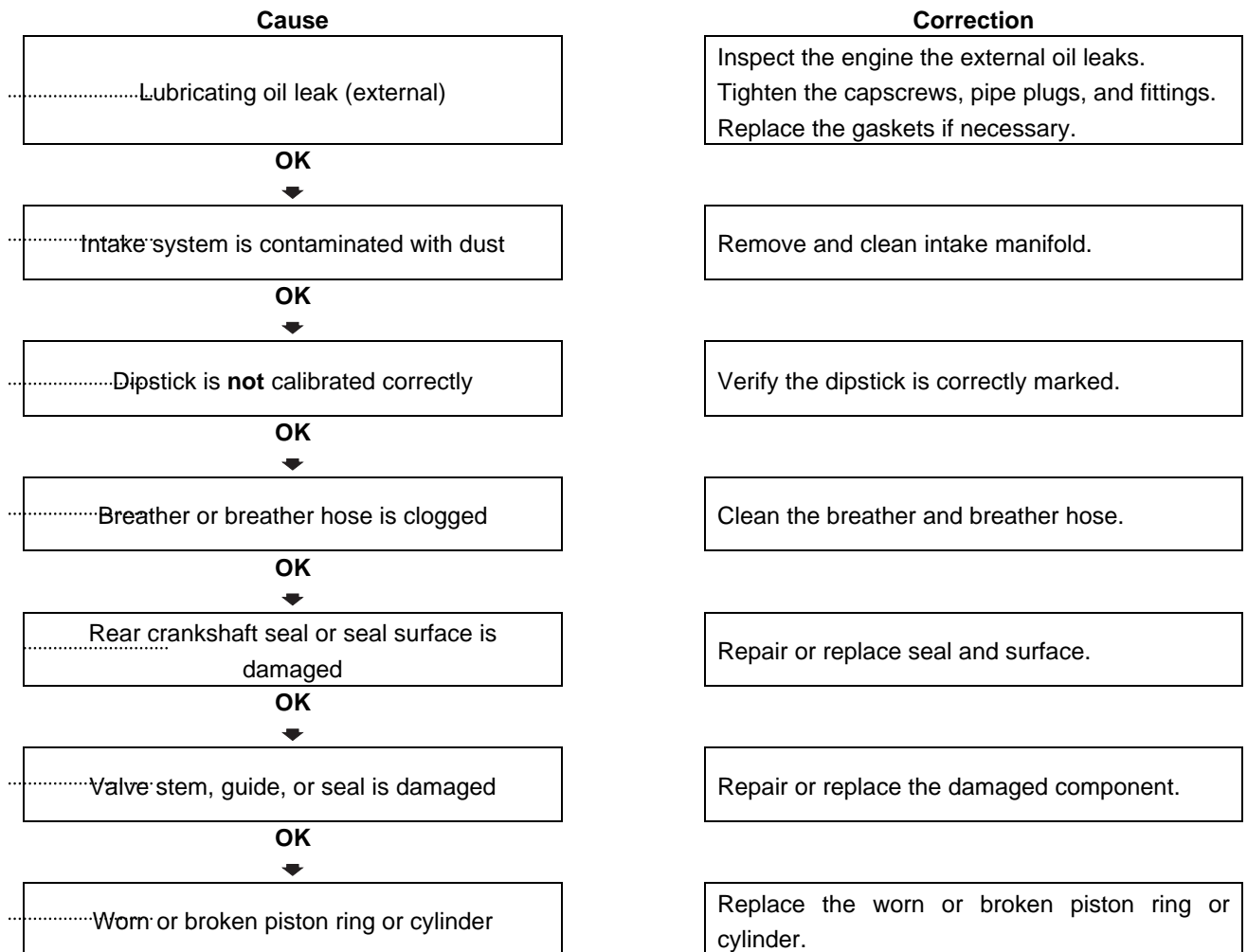
Excessive Exhaust (Black Smoke)

This is symptom tree T-009.

Cause	Correction
.....Engine is being lugged down	Use lower gear.
OK ↓	
.....Clogged air cleaner element	Clean or replace the air cleaner element.
OK ↓	
.....Muffler is crushed or clogged	Replace the muffler. Refer to the OEM's service manual.
OK ↓	
.....Defective or clogged injection nozzle	Adjust or replace the injection pump.
OK ↓	
.....Worn piston ring or cylinder (blue smoke)	Replace the worn piston ring or cylinder.
OK ↓	
.....Incorrect injection timing	Adjust injection timing.
OK ↓	
.....Overhead adjustments are not correct	Measure and adjust the overhead settings.

Lubricating Oil Consumption Excessive

This is symptom tree T-010.



Lubricating Oil Contaminated

This is symptom tree T-011.

Cause	Correction
Breather or breather hose is clogged	Clean the breather and breather hose.
OK ↓	
Lubricating oil filter is clogged	Replace the filter.
OK ↓	
Exhaust gas is black	Refer to Exhaust Gas Is Black (Incomplete Combustion).
OK ↓	
Defective contact of valve or valve seat resulting in low compression	Repair the valve or valve seat.
OK ↓	
Worn piston ring or cylinder resulting in low Compression	Replace the worn piston ring or cylinder.

Fuel consumption Is Excessive

This is symptom tree T-012.

Cause	Correction
Overloading from malfunctioning accessories	Check and repair the accessories. Refer to the OEM's service manuals.
OK ↓	
Operator technique is not correct	Refer to the operation and maintenance manual for proper operating speeds and loads.
OK ↓	
Fuel leaks (external)	Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines to the supply tanks. Refer to the OEM's service manual.
OK ↓	
Poor-quality fuel or No.1 fuel is being used	Assure good-quality No.2 diesel fuel is being used.
OK ↓	
Intake or exhaust restriction	Refer to troubleshooting logic for Exhaust Gas is Blake.
OK ↓	
Defective or clogged injection nozzle	Replace the defective or clogged injection nozzle.
OK ↓	
Incorrect injection timing	Adjust injection timing.
OK ↓	
Injection pump is adjusted incorrectly causing excessive injection	Adjust or replace the injection pump.

Coolant Contamination

This is symptom tree T-013.

Cause	Correction
..... Coolant is rusty	Review the coolant change interval. Drain and flush the system. Fill the system with the Correct mixture of coolant and water.
OK ▼	
..... Lubricating oil cooler for powertrain is damaged	Refer to the OEM's service manual.
OK ▼	
..... Cylinder head gasket is cracked or damaged	Replace the cylinder head or gasket.
OK ▼	
..... Cylinder block is cracked or porous	Replace the cylinder block.

Coolant Loss

This is symptom tree T-013.1

Cause	Correction
Radiator or cab heater is leaking	Inspect the radiator heater, hoses, and connection to locate the leak. If oil is present in the coolant, check for a transmission or lubricating oil cooler leak.
OK ↓	
External engine leak	Inspect the engine and components for seal, gasket, or drain cock leaks.
OK ↓	
Overheating or compression gases are leaking Resulting in loss through the radiator overflow	Review the operation for overheating and low power. Refer to troubleshooting logic for Coolant Temperature Above Normal.
OK ↓	
Transmission cooler is leaking (if equipped)	Check for mixing of coolant and transmission fluid.
OK ↓	
Cylinder head gasket is leaking	Check or replace the head gasket.
OK ↓	
Cylinder head is cracked or porous	Check or replace the cylinder head.
OK ↓	
Cylinder block coolant passages are leaking	Check or replace the cylinder block.

Lubricating Oil Pressure Is Low

This is symptom tree T-014.

Cause	Correction
Lubricating oil lever is below specification	Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level.
OK ↓	
Oil level or pressure sensor is damaged	Replace the oil lever or oil pressure sensor.
OK ↓	
Lubricating oil filter is clogged	Replace the filter
OK ↓	
Fuel or coolant is in the lubricating oil.	Refer to Oil Level Rises symptom tree.
OK ↓	
Regulator or relief valve is not adjusted Correctly	Adjust the regulator or relief valve.
OK ↓	
Lubricating oil pan strainer is clogged	Clean the strainer.
OK ↓	
Lubricating oil suction tube is damaged	Repair or replace the suction tube.
OK ↓	
Lubricating oil pump is damaged	Replace the oil pump.
OK ↓	
Main or rod bearing is worn or damaged	Replace the bearing

Oil Level Rises

This is symptom tree T-015.

Cause	Correction
.....Rear crankshaft seal or seal surface is damaged	Repair or replace seal and surface
OK ↓	
.....Auxiliary equipment has damaged pump seal	Replace the auxiliary pump. Refer to the OEM's service manual.
OK ↓	
.....Injector sleeve is damaged	Replace the injector sleeve.
OK ↓	
.....Fuel injector is leaking inside cylinder head	Replace the injector.
OK ↓	
.....Injector pump seal is leaking	Remove and repair the injection pump.
OK ↓	
.....Cylinder head or head gasket is cracked or damaged	Replace the cylinder head or gasket.
OK ↓	
.....Cylinder block is cracked or porous	Replace the cylinder block.

Coolant Temperature above Normal

This is symptom tree T-016.

Cause	Correction
.....Coolant level is below specification	Inspect the engine and radiator for external coolant leaks.
OK ↓	
.....Fan belt is slipping or the fan pulley is worn	Replace the fan belt or pulley.
OK ↓	
.....Water temperature gauge is malfunctioning	Replace the water temperature gauge.
OK ↓	
.....Radiator fin is clogged or crushed	Clean, repair, or replace the radiator.
OK ↓	
.....Radiator core is clogged	Clean and repair the radiator.
OK ↓	
.....Thermostat is defective and does not open	Replace the thermostat.
OK ↓	
.....Water pump is damaged	Replace the water pump.
OK ↓	
.....Cylinder head or head gasket is cracked or damaged	Replace the cylinder head or graket.

Excessive Noise

This is symptom tree T-017.

Cause	Correction
Belt is squeaking due to insufficient tension or abnormally high loading	Check and adjust belt tension. Make sure all the pulleys rotate freely.
OK ↓	
Exhaust leaks	Refer to Exhaust Gas is Black troubleshooting tree.
OK ↓	
Gear train backlash is not adjusted correctly	Adjust the backlash for the gear train.
OK ↓	
Idler gear bushing is damaged or missing	Replace the idler gear bushing.
OK ↓	
Defective or clogged injection nozzle	Replace the defective or clogged injection nozzle.
OK ↓	
Overhead adjustments are not correct	Measure and adjust the overhead settings.
OK ↓	
Overhead components are damaged	Inspect the rocker levers, rocker shafts, and valves for excessive damage.
OK ↓	
(Continued)	

Excessive Noise (Continued)

Cause	Correction
Injection pump is adjusted incorrectly	Adjust or replace the injection pump.
OK ↓	
Worn piston ring or cylinder resulting in low compression	Replace the worn piston ring or cylinder.

Engine Vibration Excessive

This is symptom tree T-018.

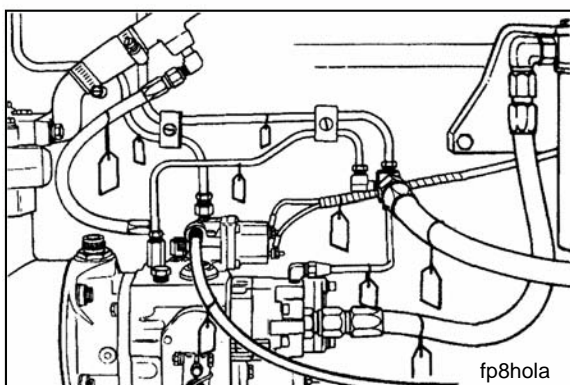
Cause	Correction
Engine mounting bolts are loose or the engine mounting cushion is broken	Replace the engine mounting bolts or cushion.
OK ↓	
Engine and powertrain is out of alignment	Repair the alignment. Refer to the OEM's service manual.
OK ↓	
Gear train backlash is not adjusted correctly	Adjust the backlash for the gear train.
OK ↓	
Overhead components are damaged	Inspect the rocker levers, rocker shafts, and valves for excessive damage. Replace as necessary.
OK ↓	
Cam bushing is worn	Replace the cam bushing.
OK ↓	
Injection pump is adjusted incorrectly	Adjust or replace the injection pump.
OK ↓	
Main bearing or connecting rod is worn or damaged	Replace the connecting rod or main bearing.

Complete Engine

Engine Disassembly

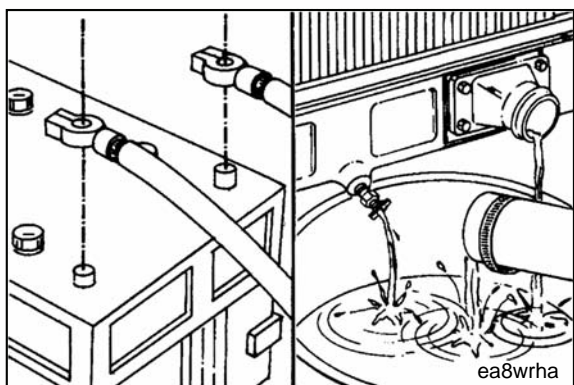
Service Tool

Part No.	Part Name	Quantity
3375193 or 3375194	Unit Repair Stand or Engine Overhaul Stand	1
3163625	Bracket	1
3163292	Valve Spring Compressor	1
3397890	Flange Puller	1
3823137	Piston Ring Expansion Tool	1



Engine Removal

NOTE: Put tag on all hoses, lines, linkage, and electrical connections as they are removed to identify location and aid the installation process.



WARNING

Always disconnect the negative (-) cable first.

Disconnect the battery cables.

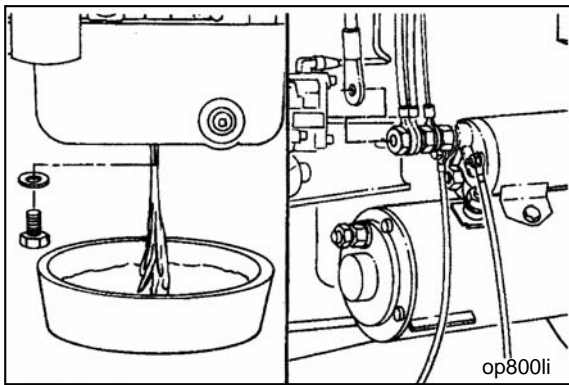
WARNING

Allow the engine to cool before draining to avoid burns from hot liquid.

WARNING

Coolant is toxic. Keep away from children and animals. Save for reuse or dispose of in accordance with local regulations.

Drain the engine coolant.



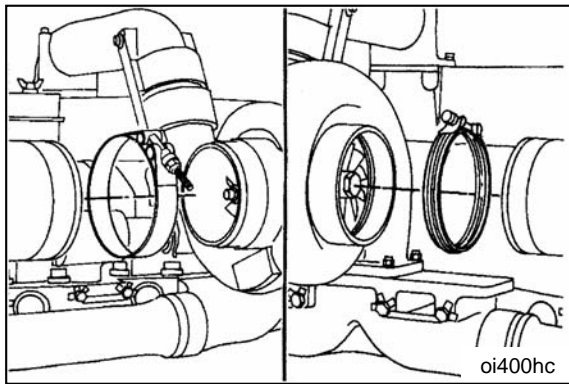
⚠ WARNING

Some state and federal agencies in the United States of America have determined that used oil is carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. Always use the proper procedures to dispose of the oil.

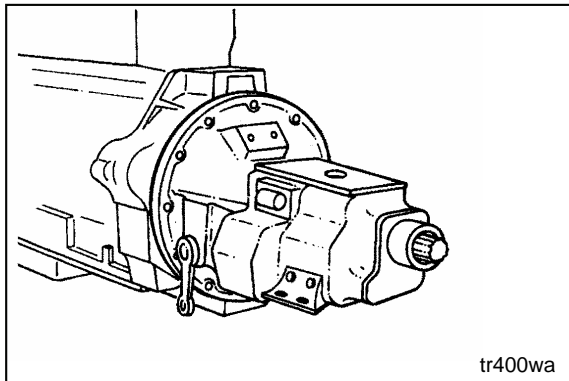
Drain the lubricating oil.

Engine Oil: 7.5 liters [1.98 U.S.gal]

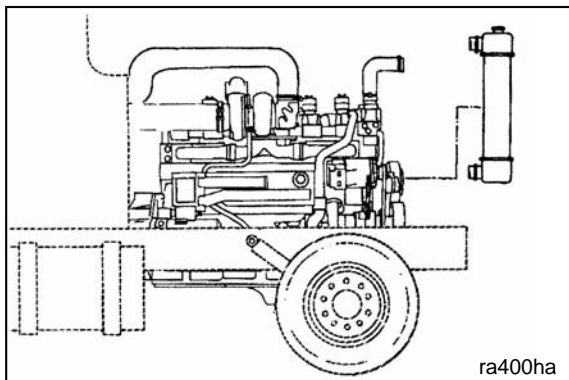
Disconnect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires and hydraulic lines.



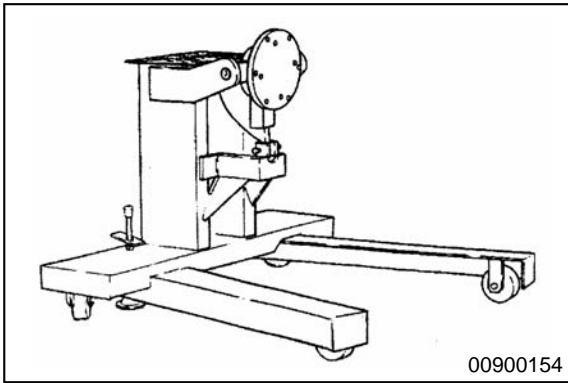
Disconnect the intake and exhaust system pipes.



Disconnect the drive units from the flywheel housing and flywheel.

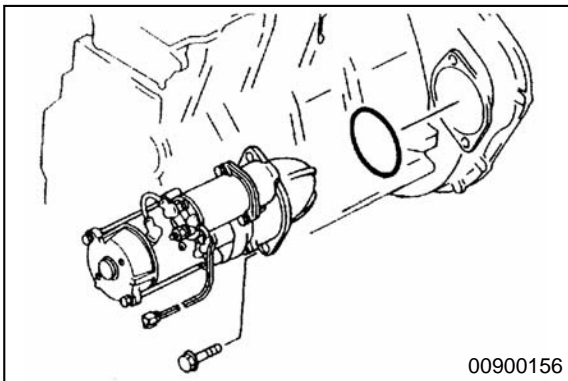


Remove all chassis components necessary to remove the engine from the equipment.

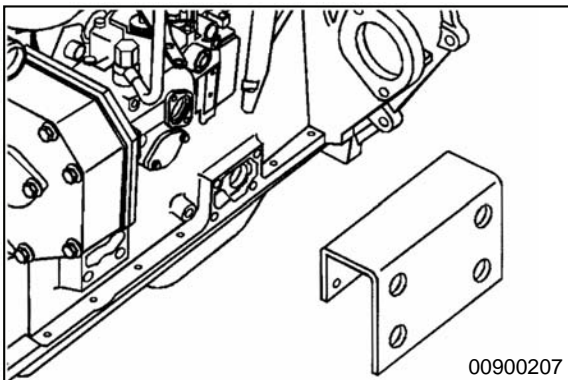


Prepare a stable stand, Part No. 3375193 or 3375194, which will prevent the engine from falling over.

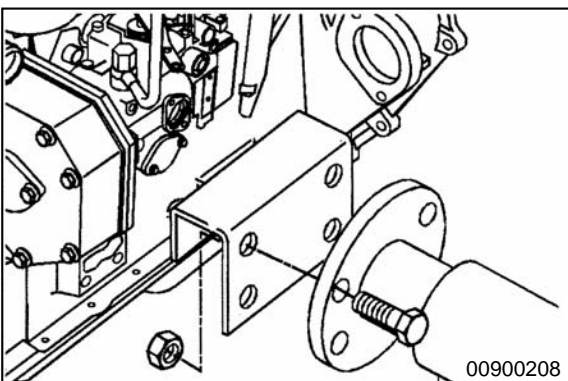
Engine Weight (approx.): 255 kg [562 lb]



Remove the starting motor.



Install the bracket, Part No. 3163625, on the engine.

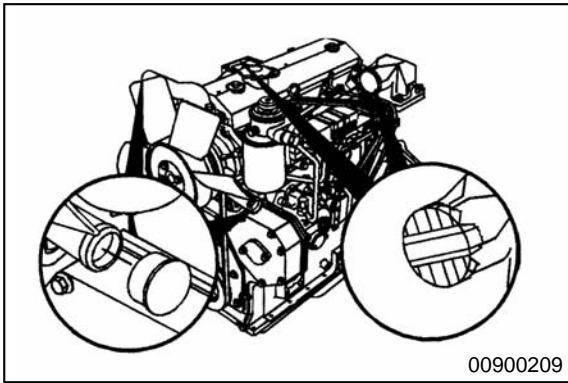


⚠ WARNING

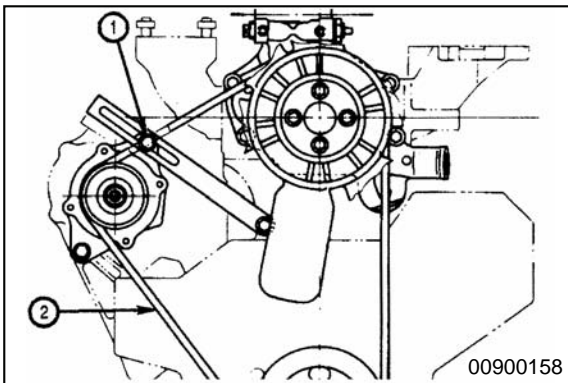


This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component. The engine lifting equipment must be designed to lift the engine without causing personal injury.

Put the engine on the stand.



Cover all the engine openings to prevent dirt and debris from entering the engine.



Fan Pulley

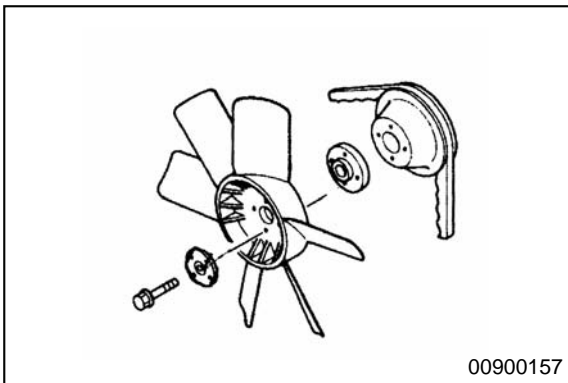
⚠ WARNING

Be careful not to injure your fingers or damage the alternator when moving the alternator toward the cylinder block.

Loosen the mounting capscrew of the adjustment plate (1). Loosen the alternator mounting capscrew and nut.

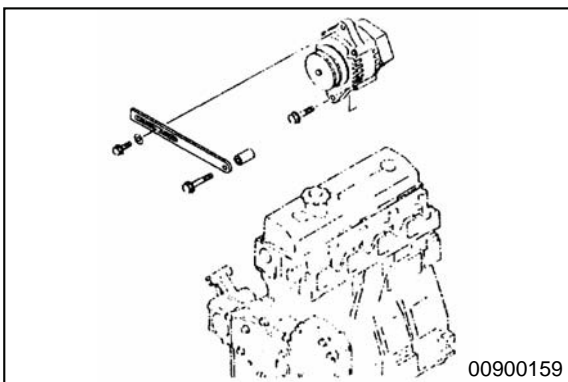
Move the alternator toward the cylinder block, and remove the belt (2).

Remove the fan pulley.



Fan

Remove the four capscrews, retainer plate, fan, and spacer.

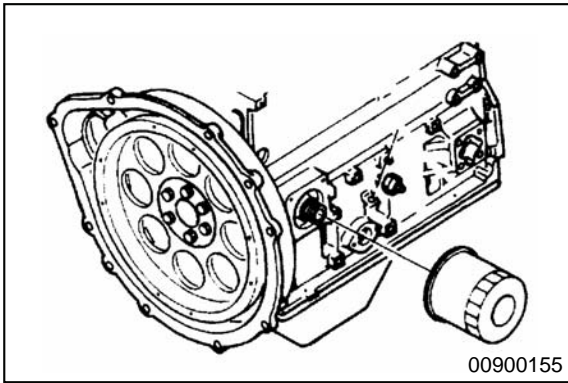


Alternator

Remove the adjusting capscrew and washer.

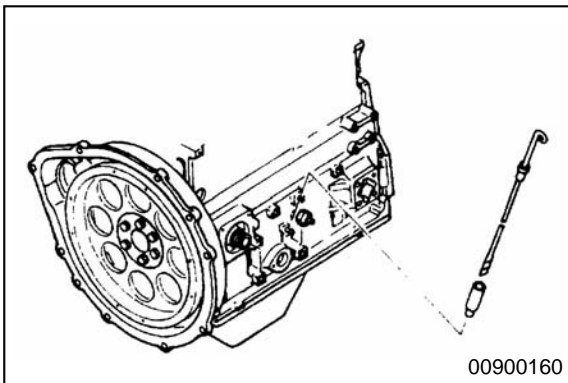
Remove the capscrew, adjustment plate, and spacer.

Remove the remaining capscrew and alternator.



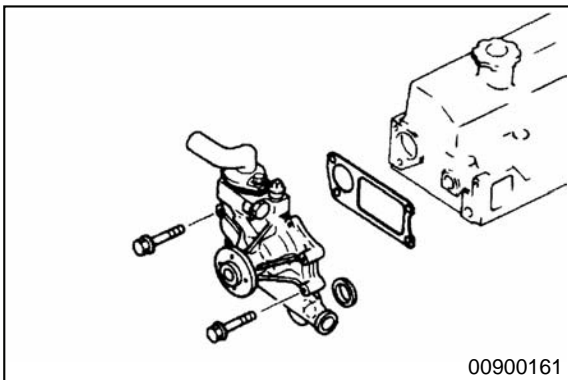
Lubricating Oil Filter

Remove the lubricating oil filter.



Dipstick Guide

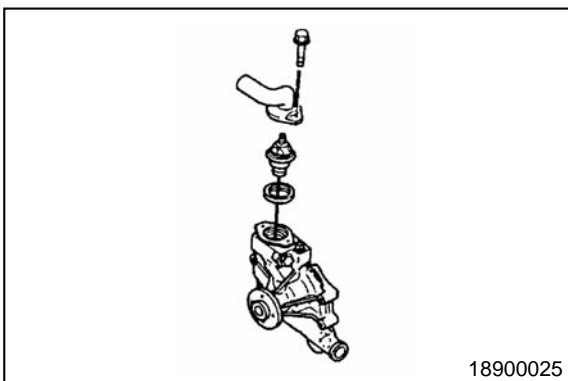
Remove the dipstick and dipstick guide.



Water Pump

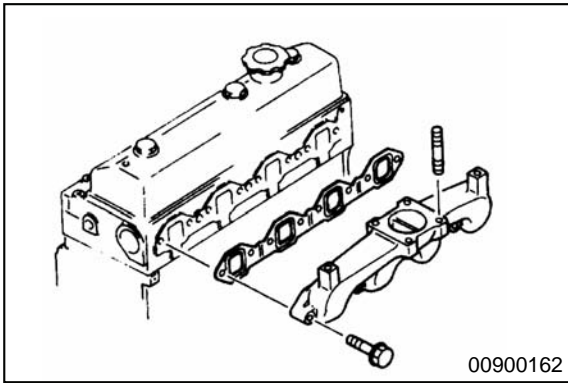
Remove the mounting capscrews, water pump, gasket, and o-ring.

Discard the gasket and o-ring.



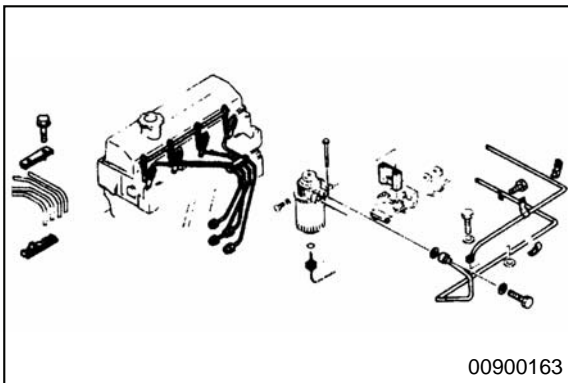
Thermostat

Remove the two mounting capscrews, thermostat housing, thermostat and seal.



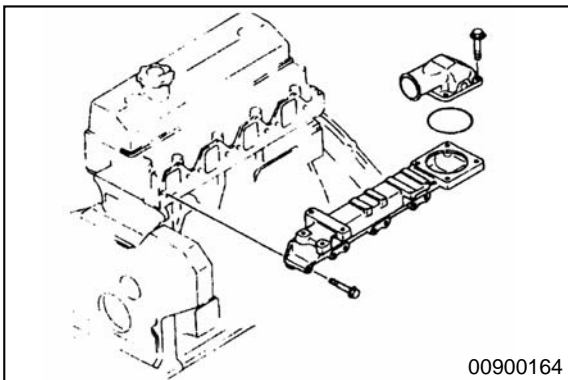
Exhaust Manifold

Remove the eight capscrews, exhaust manifold, and gasket.
Discard the gasket.



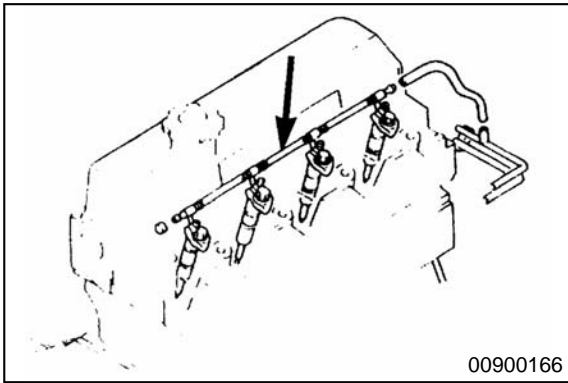
Fuel Injection Tubing

Remove the clamp.
Remove the sleeve nuts and the fuel injection tubing from the fuel injection pump and the cylinder head.



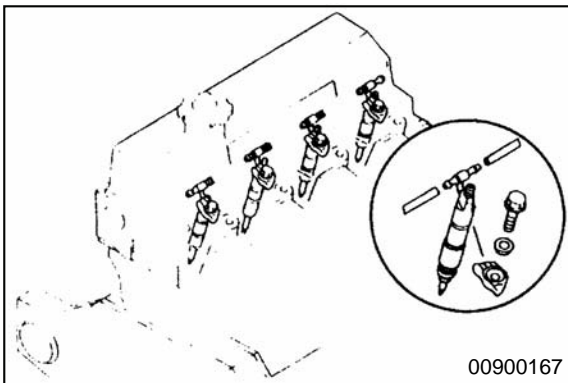
Intake Manifold

Remove the eight capscrews, intake manifold, and air inlet connection. Remove the grid heated, if equipped.
Remove the four capscrews, air inlet connection, and o-ring. Discard the o-ring.



Spill Tube

Remove the spring hose clamps and hose.
Remove the spill tube.



Injector

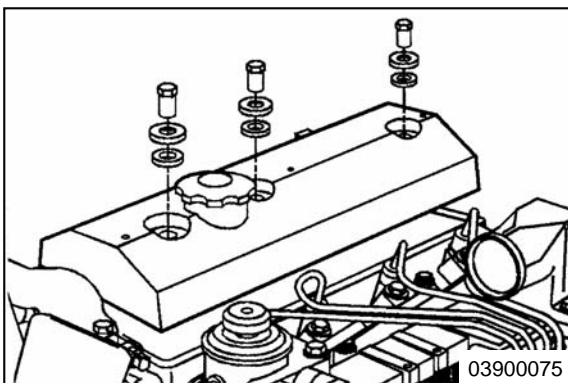
⚠ CAUTION

Be careful not to damage the tip of the injector when removing.

Remove the mounting capscrew, washer, and injector.

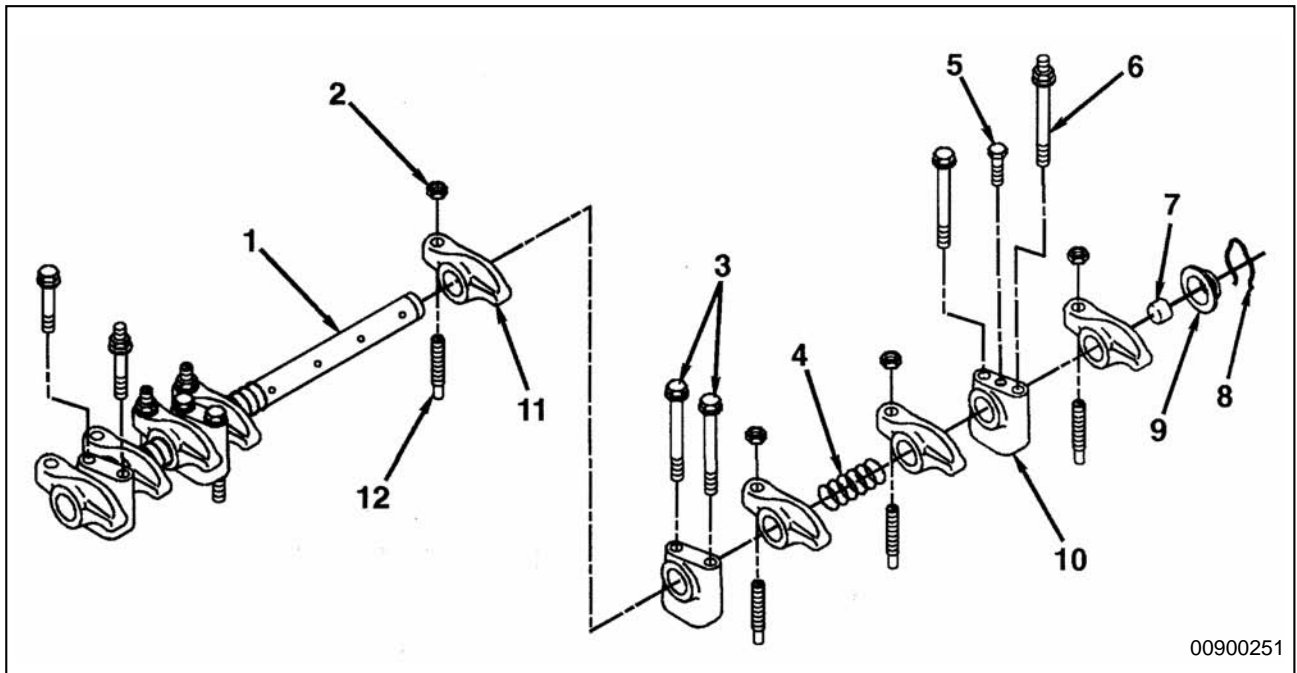
NOTE: When removing the injector, clean around the injector, and insert a blind plug to prevent dust or dirt from entering the engine.

NOTE: Mark the injectors with tags showing the cylinder number, and keep it in a safe place. If there is no abnormality in the injector, install it in the same position during assembly.



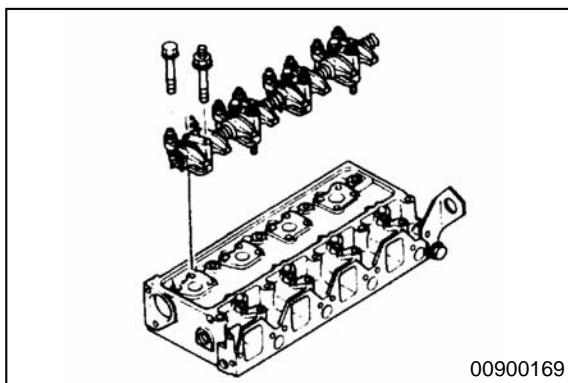
Rocker Lever Cover

Remove the three capscrews, isolator assemblies, rocker lever cover, and o-ring.



Rocker Arm Assembly

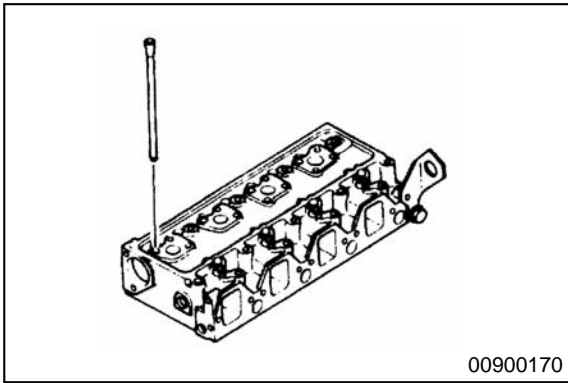
- | | |
|--------------------------------|--------------------------------|
| 1. Rocker Shaft | 7. Cup Plug |
| 2. Adjusting Screw Lock Nut | 8. Snap Ring |
| 3. Pedestal Mounting Capscrews | 9. Thrust Washer (if equipped) |
| 4. Separating Spring | 10. Rocker Lever Pedestal |
| 5. Rocker Shaft Indexing Screw | 11. Rocker Lever |
| 6. Pedestal Mounting Stud | 12. Adjusting Screw. |



Rocker Arm Assembly

Remove the mounting capscrews and the rocker arm assembly.

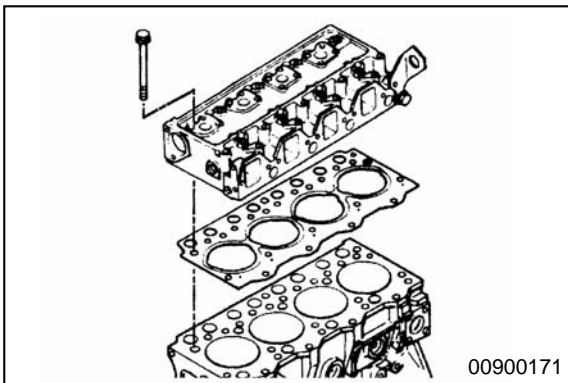
NOTE: When removing the rocker arm, loosen the locknut, and turn the adjustment screw **counterclockwise** 2 to 3 turns.



Pushrods

Remove the pushrods from the cylinder head.

NOTE: Mark the pushrods with tags showing the cylinder number, and keep it in a safe place. If there is no abnormality in the push rod, install it in the same position during assembly.



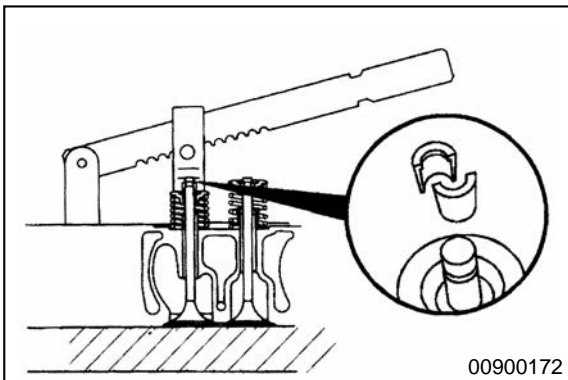
Cylinder Head Assembly

⚠ WARNING

This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.

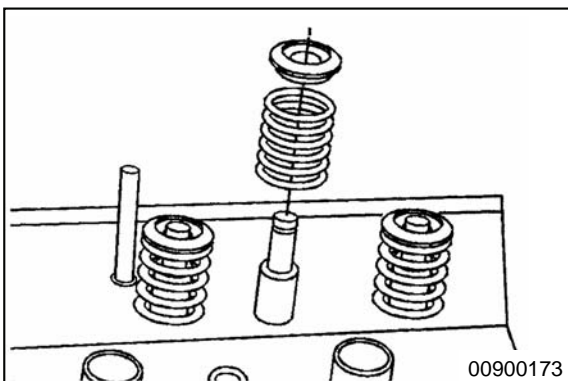
Remove the mounting capscrews, cylinder head assembly, and gasket.

Discard the gasket.

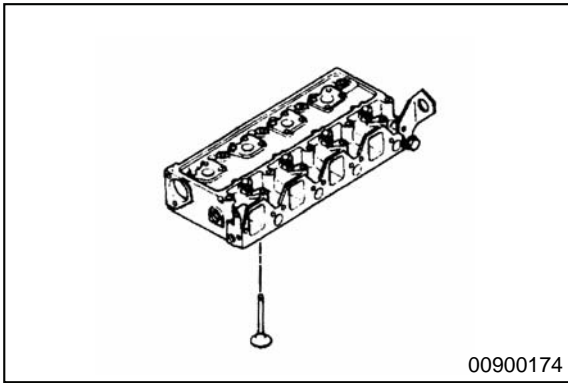


Cylinder Head Assembly - Disassembly

Using the spring pusher, Part No. 3398179, compress the valve spring, and remove the valve collets.

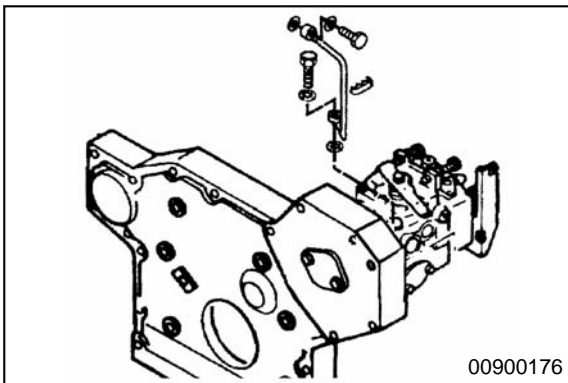


Loosen the spring, and remove the spring seat and valve spring.



Raise the cylinder head, and remove the valve.

NOTE: Mark the valves with tags to show the place of installation and keep in a safe place.



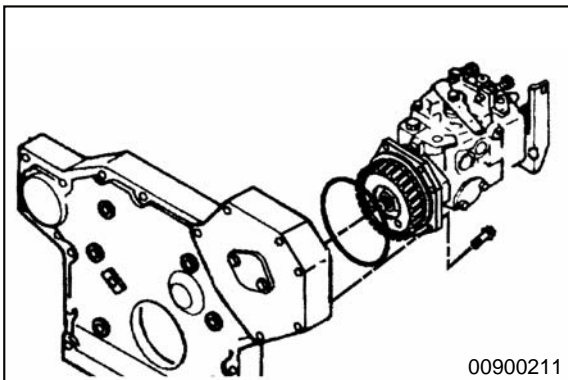
Fuel Injection Pump

⚠ CAUTION

Do not allow dirt or dust to enter the oil and fuel inlet and outlet ports. Severe engine damage will occur if contaminants are allowed to enter the engine.

Remove the fuel supply tube from the fuel injection pump.

Remove the mounting capscrew from the bracket and fuel injection pump.

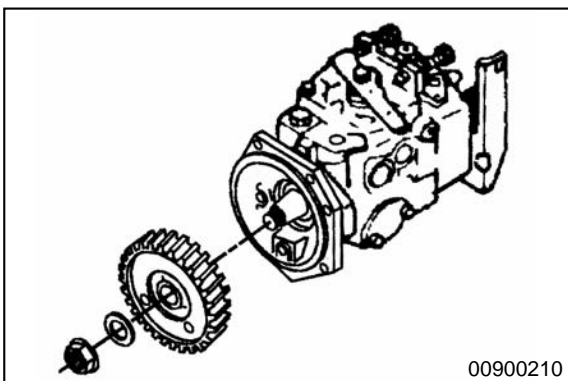


NOTE: The fuel injector pump, adapter plate, and gear are removed as an assembly. The gear can then be removed from the pump if necessary.

Remove the mounting capscrews of the fuel injector pump adapter plate.

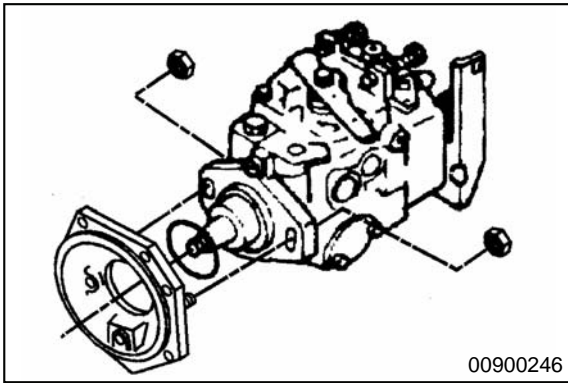
Remove the fuel injector pump assembly, adapter plate, and o-ring from the gear housing.

Discard the o-ring.

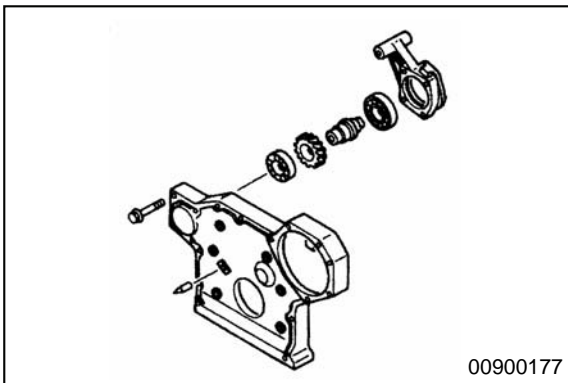


Remove the nut and washer from the fuel injection pump.

Remove the fuel injection pump gear from the fuel injection pump.

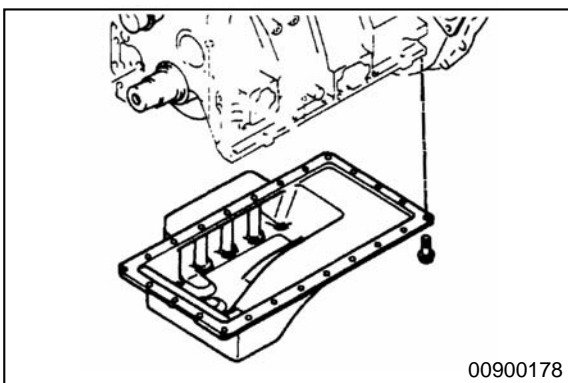


Remove the two mounting nuts, fuel injection pump, and o-ring from the adapter plate. Discard the o-ring.



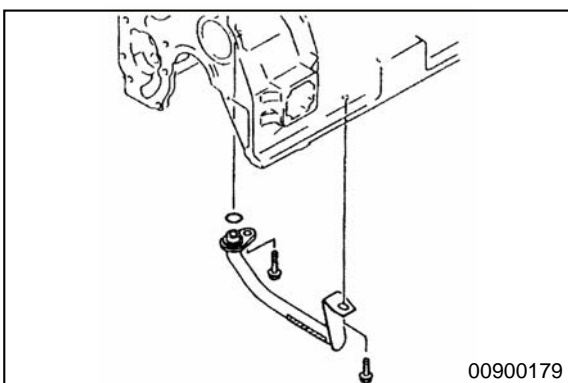
PTO Shaft (if applicable)

Remove the two capscrews, flange, o-ring, and PTO shaft.



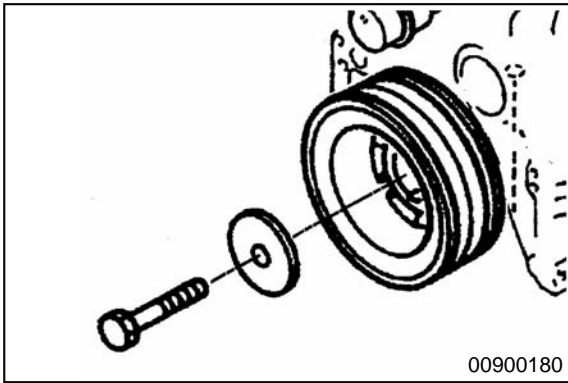
Lubricating Oil Pan

Remove the 24 capscrews, lubricating oil pan, and gasket. Discard the gasket.



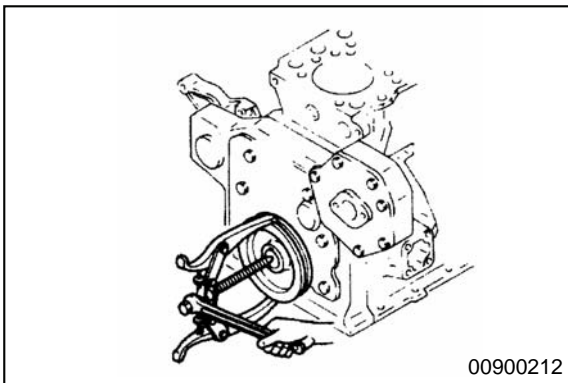
Lubricating Oil Suction Tube

Remove the two mounting capscrews, lubricating oil suction tube, and o-ring. Discard the o-ring.

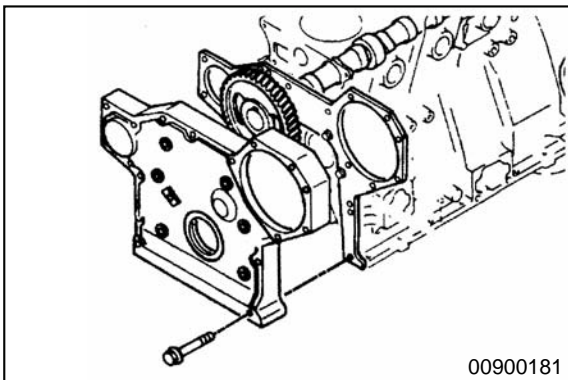


Crankshaft Pulley

Remove the capscrew and mounting plate.

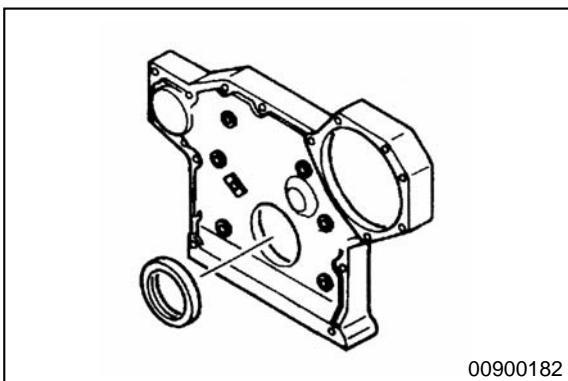


Remove the crankshaft pulley using flange puller, Part No. 3397890.



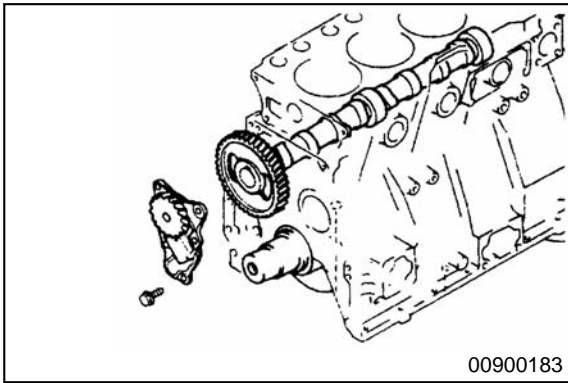
Gear Housing Cover

Remove the 17 capscrews and the gear housing cover.



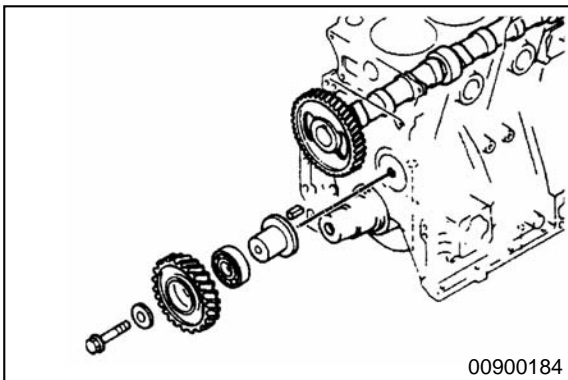
NOTE: A noise damper is installed on some engines. The noise damper **must** be removed prior to removing the front oil seal.

Remove the front oil seal from the gear housing cover.



Lubricating Oil Pump

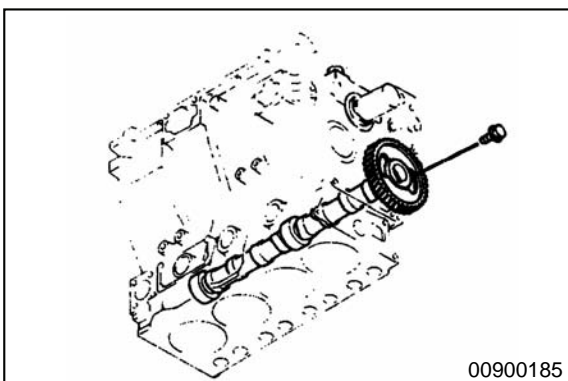
Remove the five capscrews and the lubricating oil pump.



Idler Gear

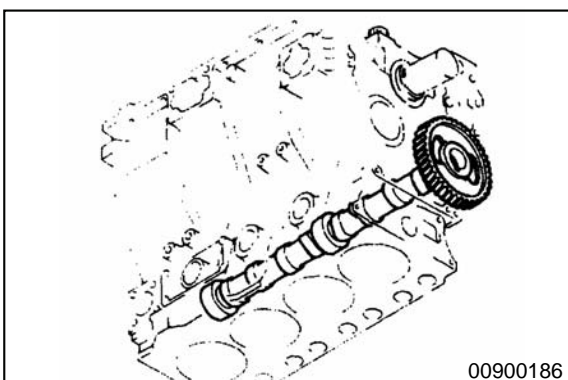
Remove the capscrew, retainer plate, and idler gear.

NOTE: If a PTO is installed, the idler gear uses a bearing.



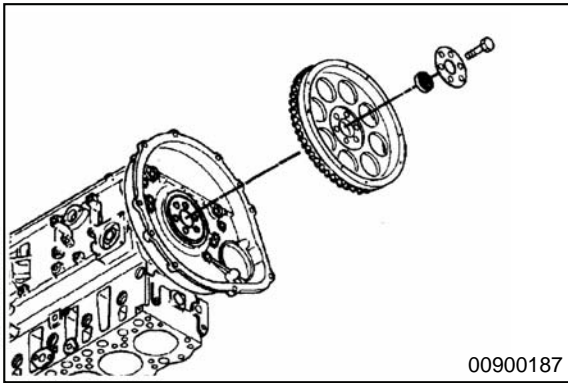
Camshaft Assembly

Remove the two mounting capscrews through the casting holes in the camshaft gear.



Remove the thrust plate and camshaft assembly.

NOTE: When removing the camshaft, lightly rotate the shaft while being careful **not** to damage the bushing.



Flywheel

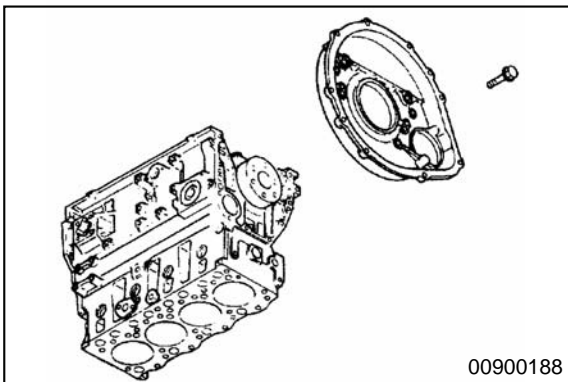
⚠ WARNING

This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.

⚠ WARNING

The pilot is short, so the flywheel can come off suddenly.

Remove the six capscrews, retaining plate, coupling, and flywheel.

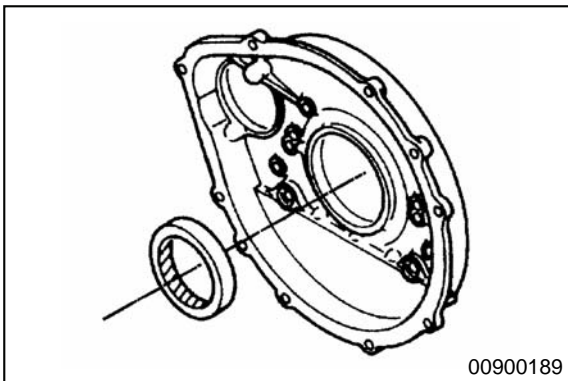


Flywheel Housing

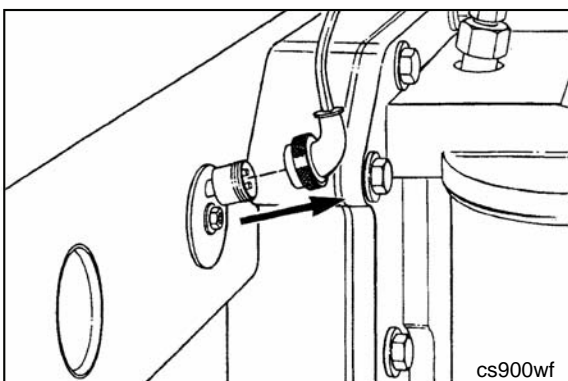
⚠ WARNING

This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.

Remove the nine capscrews, rear oil seal, and flywheel housing.



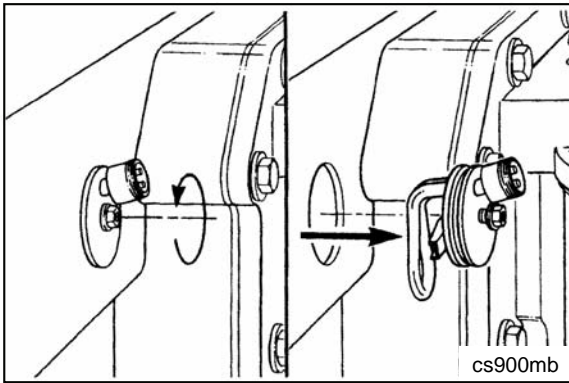
Remove the rear oil seal.



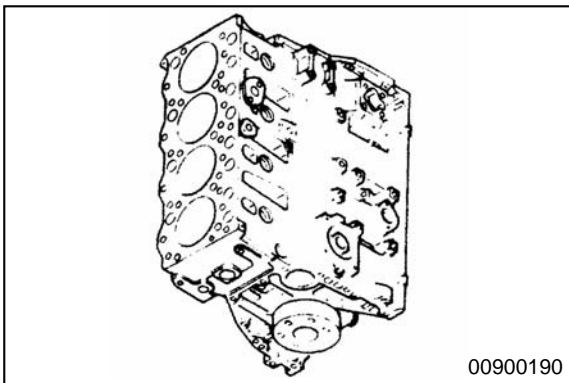
Block Water Heater

NOTE: Be sure the engine coolant has been drained.

Disconnect the block heater electrical cord.

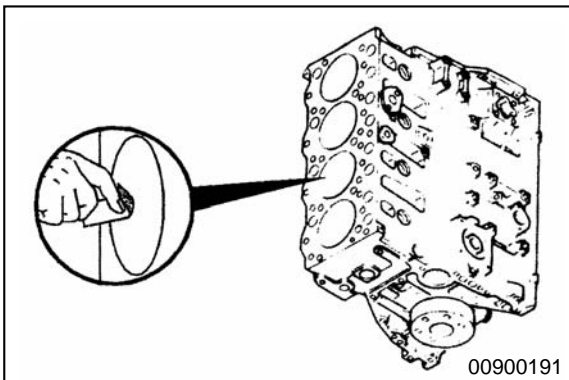


Loosen the block heater retaining nut.
Remove the block heater from the block.



Piston, Connecting Rod Assembly

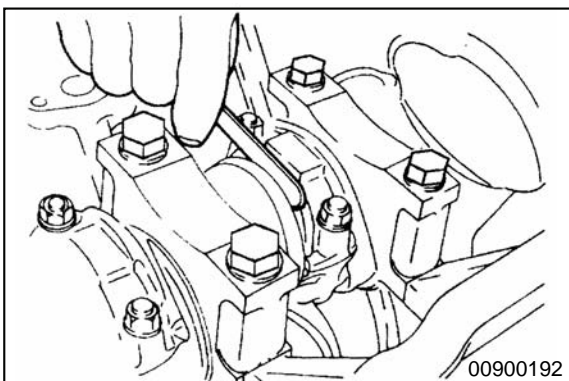
Turn the cylinder block on its side with cylinders positioned horizontally.



⚠ CAUTION

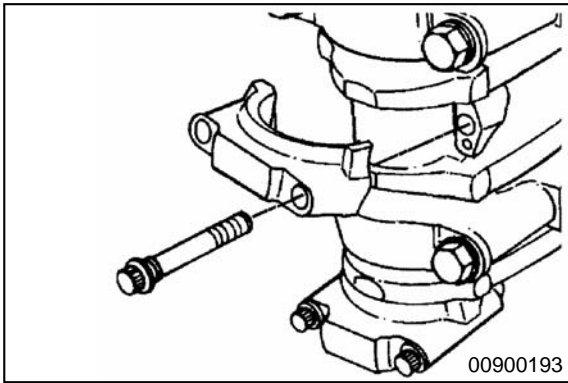
Be careful not to damage the inside of the cylinder.

Remove the carbon at the top of the cylinder using fine sandpaper.



Measure the side clearance of the connecting rod with a dial gauge before removing the piston and connecting rod assembly.

Side Clearance		
mm		in
0.20	MIN	0.0079
0.40	MAX	0.016



Rotate the camshaft to set the piston at bottom dead center.



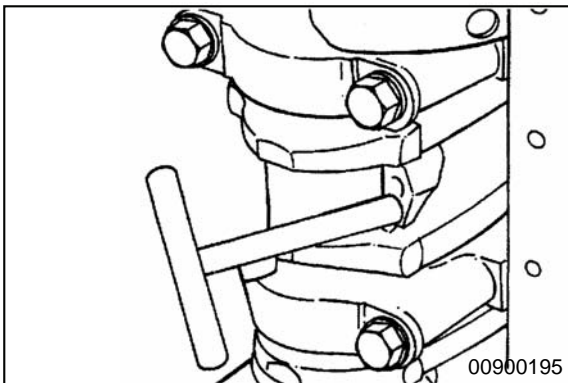
Remove the mounting capscrews of the connecting rod cap.



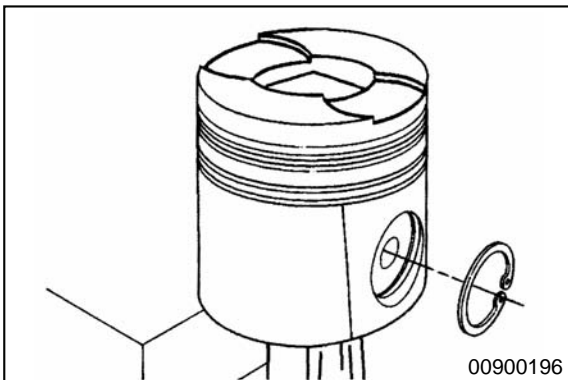
Check the number stamped on the connecting rod cap and the cylinder. The numbers **must** match.

NOTE: If there is no number stamped on the connecting rod cap, stamp the correct number on the camshaft end of the cap.

Tap the cap with a plastic hammer, and remove the connecting rod cap and bearing.

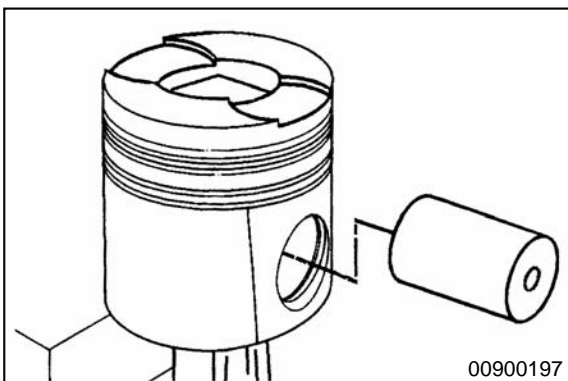


Push a wooden bar or hammer handle through the cylinder from the lubricating oil pan side of the block. Support the piston at the cylinder head side of the block, and push the bar in far enough to remove the piston and connecting rod assembly.



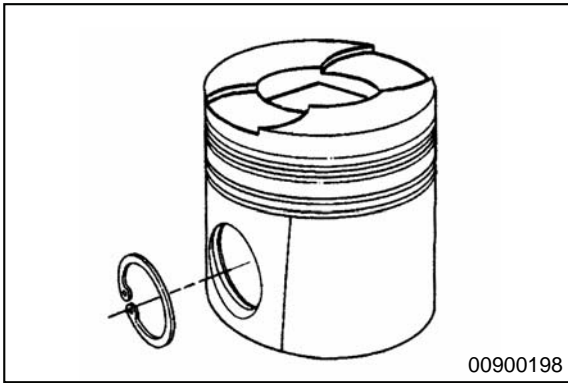
Piston and Connecting Rod Assembly - Disassembly

Remove the snap ring on one side of the piston using pliers.

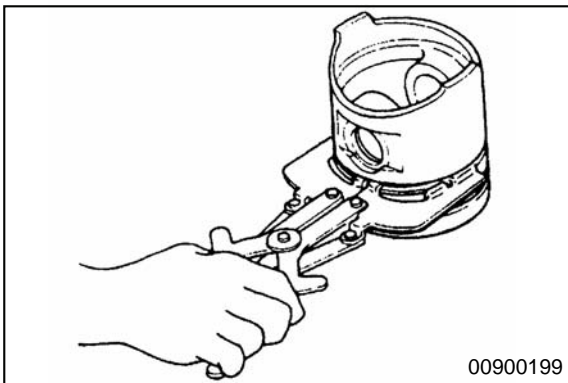


Remove the piston pin, and separate the piston and connecting rod.

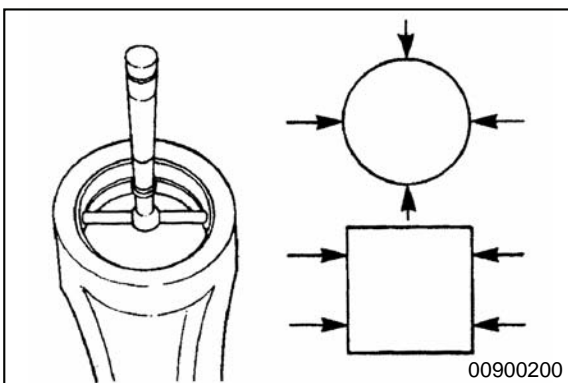
NOTE: If the pin does **not** come out, place the assembly in hot water prior to disassembly.



Remove the snap ring on the other side of the piston using pliers.



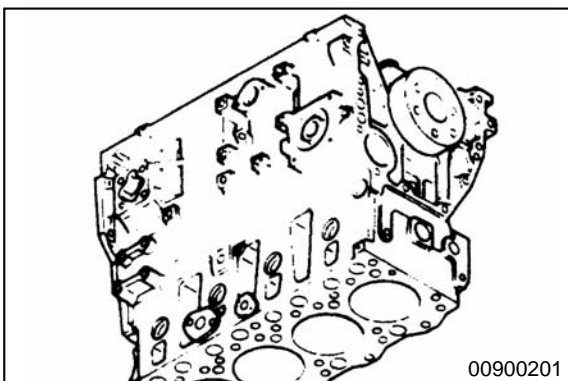
Remove the piston ring from the piston using piston ring tool, Part No. 3823137.



If the bushing is worn, the connecting rod must be replaced.

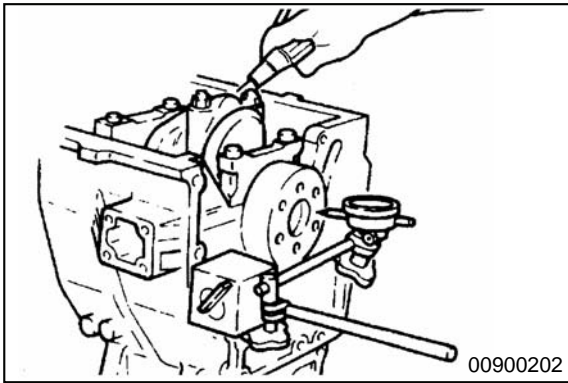
Inside Diameter: 30.00 mm [1.18 in]

NOTE: Keep the pistons, connecting rods, bearings, piston rings, piston pins, and bushings in sets for each cylinder number.



Main Bearing Cap

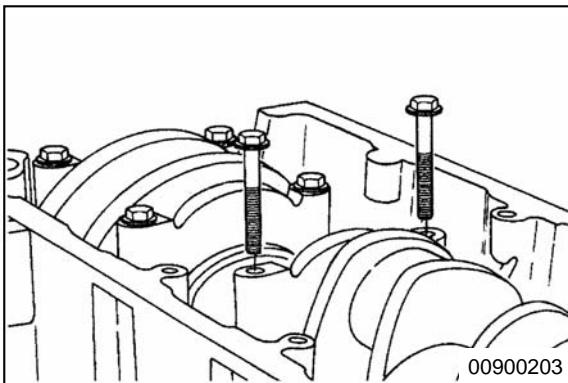
Rotate the cylinder block so that the bottom of the block is facing up.



Measure the end play of the crankshaft using a dial gauge.

NOTE: The end play measurement is necessary for determining the wear of the thrust bearing and abnormal wear of the crankshaft.

Crankshaft End Play		
mm		in
0.131	MIN	0.0052
0.351	MAX	0.0138

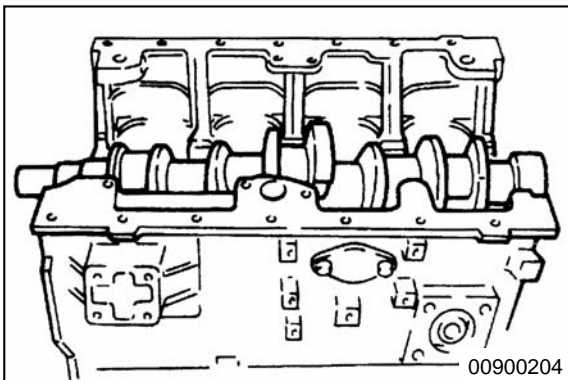


Remove the mounting cap screws of the main bearing cap.

Remove the main bearing cap and lower bearing.

NOTE:

- Mark the thrust bearings so that they can be installed into the correct position.
- The main bearing cap mounting cap screws **must** be replaced after each use.

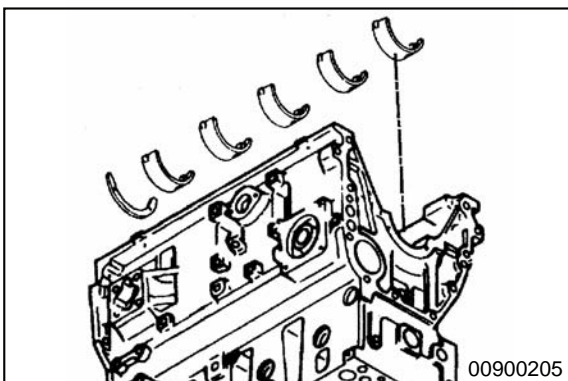


Crankshaft

⚠ CAUTION

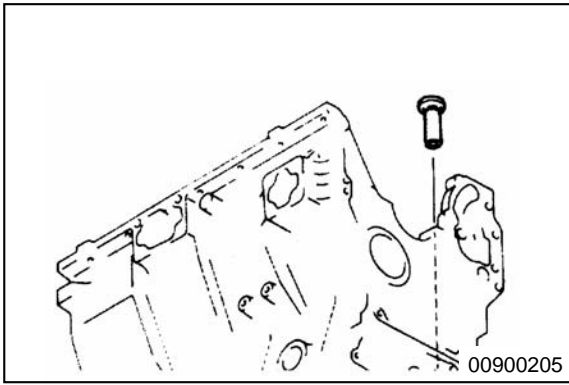
Be careful not to hit the crankshaft against the cylinder block and damage the sliding surface.

Remove the crankshaft.



Remove the upper main bearing.

NOTE: Mark the main bearings and thrust bearing so that they can be installed into the correct position.



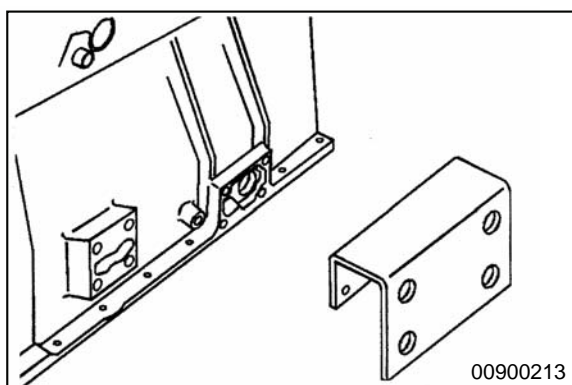
Tappet

Remove the tappet.

Engine Assembly

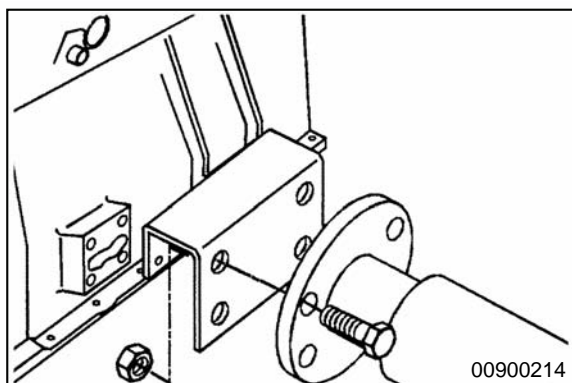
Service Tools

Part No.	Part Name	Quantity
3375193 or 3375194	Unit Repair Stand or Engine Overhaul Stand	1
3163625	Bracket	1
3163292	Valve Spring Compressor	1
3823137	Piston Ring Expansion Tool	1
3397773	Piston Ring Compressor	1



Setting the Unit in the Repair Stand

Install bracket, Part No. 3163625, to the cylinder block.

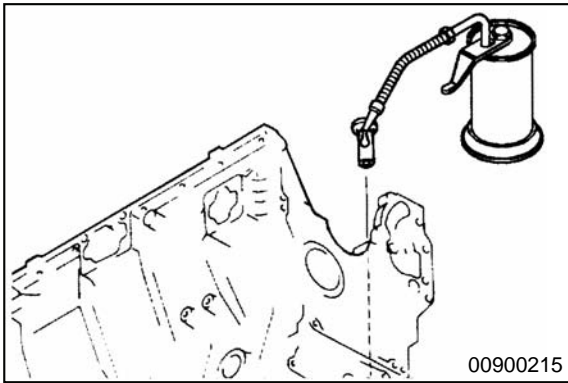


⚠ WARNING



This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component. The engine lifting equipment must be designed to lift the engine without causing personal injury.

Put the engine block on the stand.

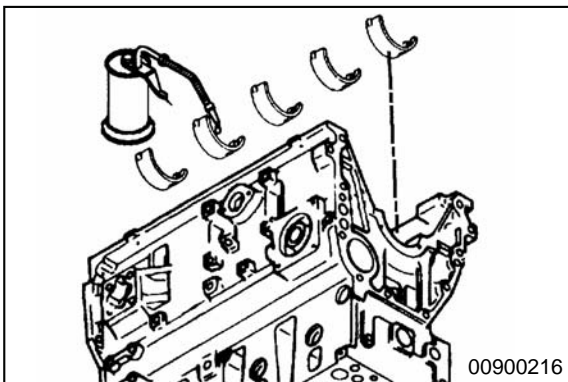


Tappet



NOTE: Rotate the engine block so that the cylinder head side is down.

Coat the tappet with engine oil and install into the block.



Crankshaft



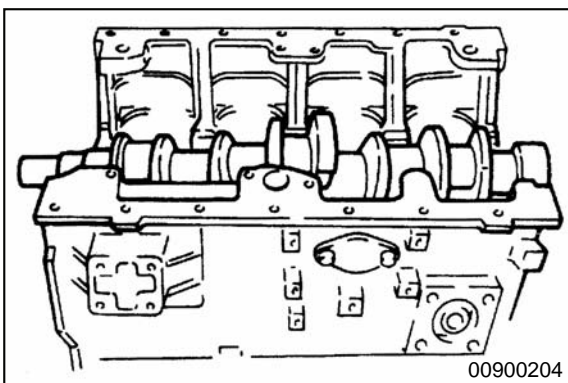
⚠ CAUTION

Confirm that there is no dirt or dust stuck to the rear face of the bearing before installation. Debris behind the bearing can cause severe engine damage.

NOTE: Coat the inside face of the bearing with engine oil (SAE 30) before installation.

Align the protrusion of the upper main bearing with the notch in the cylinder block.

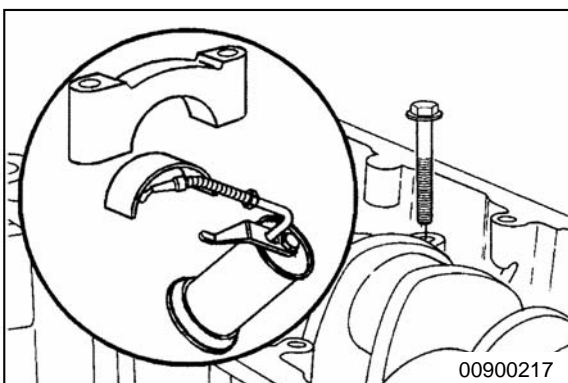
Install the upper main bearings.



⚠ CAUTION

Do not hit the crankshaft against the cylinder block. Damage to the block or crankshaft can occur.

Position the crankshaft and gear in the cylinder block.



Main Bearing Cap



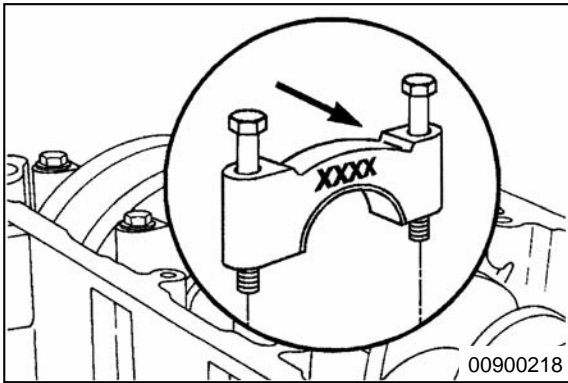
⚠ CAUTION

Confirm that there is no dirt or dust stuck to the rear face of the bearing before installation. Debris behind the bearing can cause severe engine damage.

NOTE: Coat the inside face of the bearing with engine oil (SAE 30) before installation. The number stamped on the main bearing cap must be the same as the number stamped on the cylinder block.

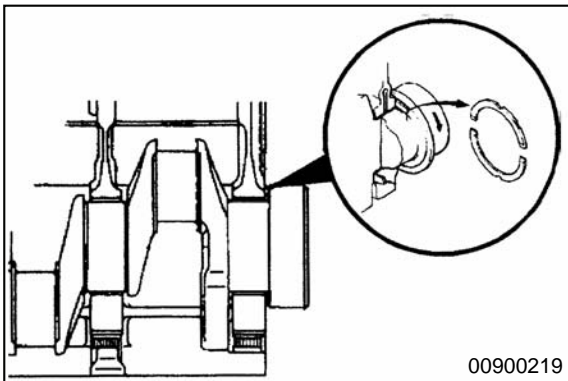
Align the protrusion in the lower main bearing with the notch in the cap.

Install the lower main bearing into the main bearing cap.



- Casting number or cast arrow on the main bearing cap must face toward the front of the engine.
- New main bearing mounting capscrews must be used.
- Coat the capscrew threads and seat face with engine oil.

Position the main bearing caps and capscrews.



⚠ CAUTION

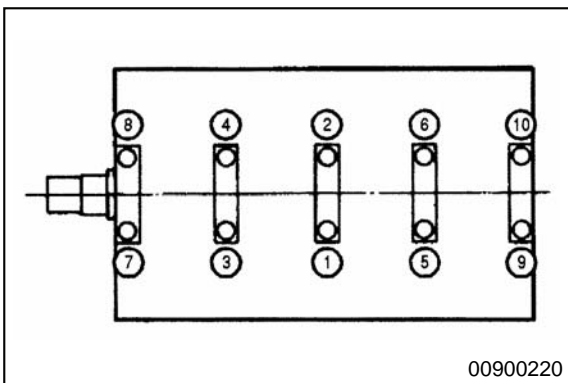
Install each thrust bearing with the oil groove on the outside. Failure to do so will cause engine damage or failure.

⚠ CAUTION

Do not let the thrust bearings slip out of place. Engine damage or failure will result if the thrust bearings are not properly installed.

NOTE: Casting number or cast arrow on the main bearing cap **must** face toward the front of the engine. The thrust bearing is located on the main bearing closest to the rear of the engine (No. 5). Align the lower thrust bearing with the dowel pin.

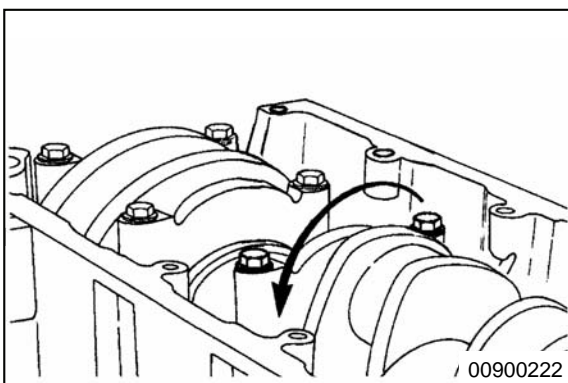
Install the upper thrust bearing.



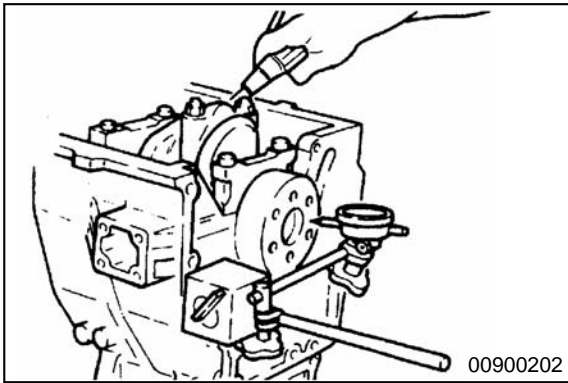
Tighten the mounting capscrews in the order shown.

Torque Value:

Main Bearing Capscrews	Step	1	113 N•m	[83 ft-lb]
	2	Loosen all capscrews completely		
	3		132 N•m	[98 ft-lb]



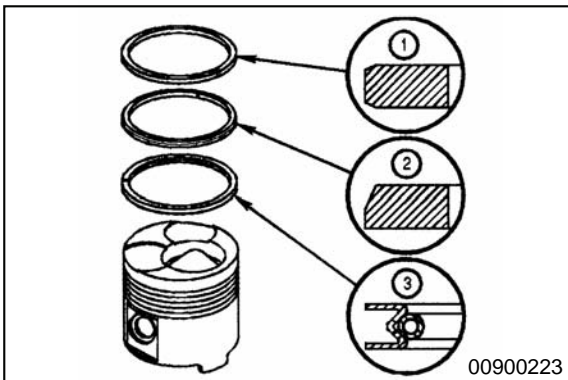
After tightening the mounting capscrews, make sure the crankshaft rotates smoothly



Measure the crankshaft end play using a dial indicator.

Crankshaft End Play

mm		in
0.131	MIN	0.0052
0.351	MAX	0.0138



Piston, Connecting Rod Assembly - Assemble

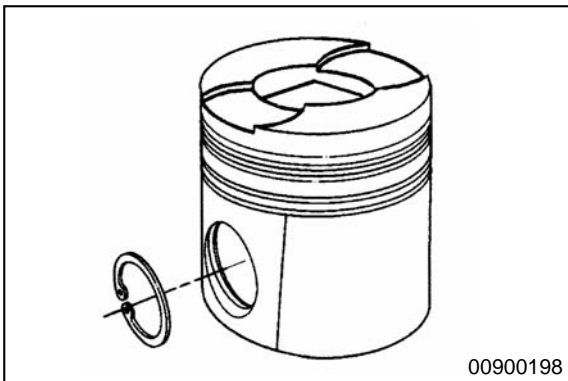


CAUTION

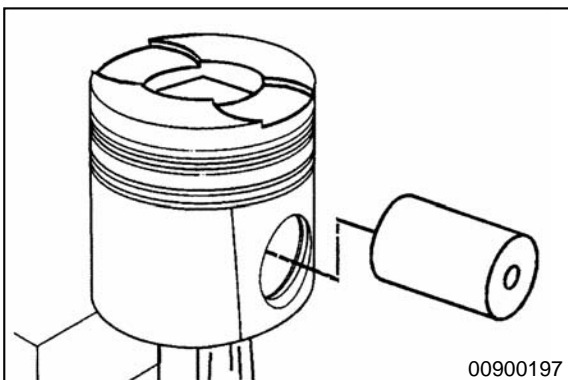
Be careful not to damage the piston or break the piston rings.

Install the piston rings on the piston using piston ring tool, Part No. 3823137.

NOTE: The rings must be set with the stamped mark near the end facing up. The oil ring (bottom ring) must be set with matching part of the expander coil and the end gap of the ring 180 degrees apart.



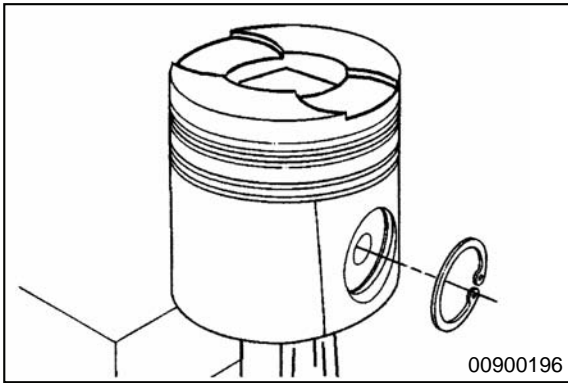
Install one snap ring on one side of the piston into the snap ring groove.



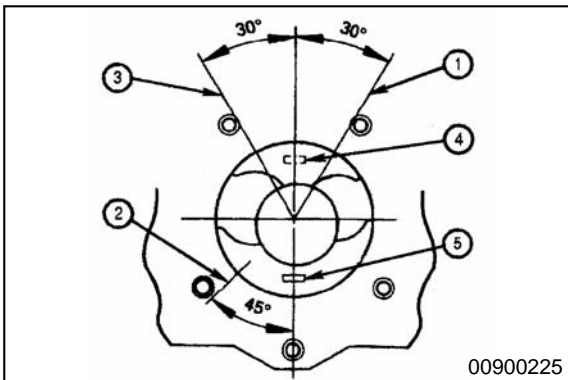
NOTE: The stamped "F" mark on the piston and the match mark (or cast part number) on the connecting rod must face in the same direction.

Assemble the piston on the connecting rod by installing the piston pin.

NOTE: Pistons **do not** need to be heated prior to installing the piston pin. However, placing the piston in hot water prior to installing the pin will ease the installation.

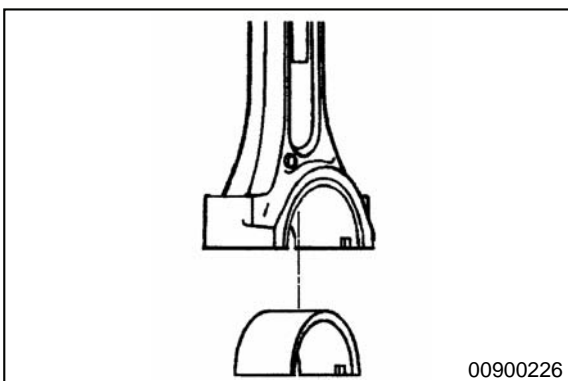


Install the other snap ring into the snap ring groove.
NOTE: Make sure the connecting rod moves freely forward and backward after installing the last snap ring.

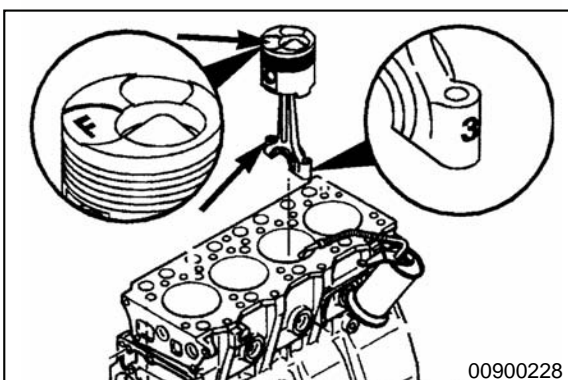


Locate the end gaps of the piston rings as shown.

1. Top Ring
2. Second Ring
3. Oil Ring
4. Part Number Mark - "XXXX"
 - XXXX = Last Four Digits of the Part Number
 - "NA" or "T"
 - NA = Naturally Aspirated
 - T = Turbocharged



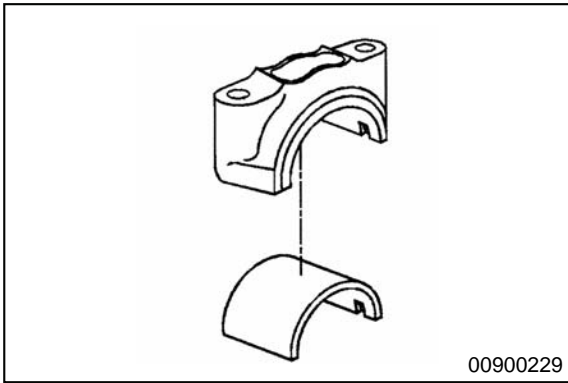
NOTE: Align the notch of the upper bearing with the notch of the connecting rod.
 Install the upper connecting rod bearing into the connecting rod.



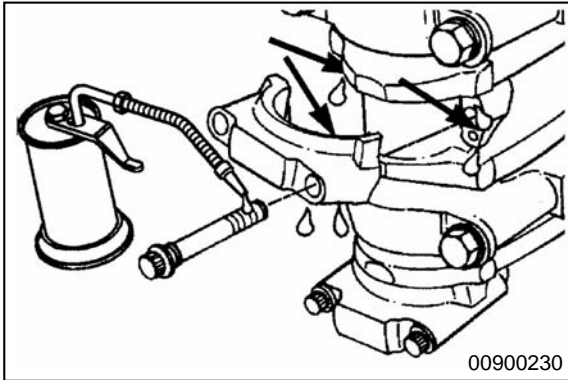
NOTE: Coat the inside face of the cylinder, the piston rings, and the surface of the connecting rod bearing with engine oil (SAE 30). Install the piston and connecting rod assembly with the "F" mark on the piston facing the front of the engine.

NOTE: The connecting rods are stamped with the number of the cylinder in which they are to be installed. This match mark **must** be on the camshaft side of the engine after installation.

Set the crankshaft pin to bottom dead center.
 Install the piston and connecting rod assembly from the top of the cylinder block using piston holder, Part No. 3397773.



Align the notch of the lower bearing with the notch of the connecting rod cap.
Install the lower connecting rod bearing into the connecting rod cap.



NOTE: Coat the lower bearing with engine oil (SAE 30). The connecting rod cap is stamped with a number that must match both the number on the connecting rod and the cylinder in which it is being installed.



Install the connecting rod cap and capscrews.

NOTE: Coat the connecting rod capscrew threads and seat face with engine oil (SAE 30).

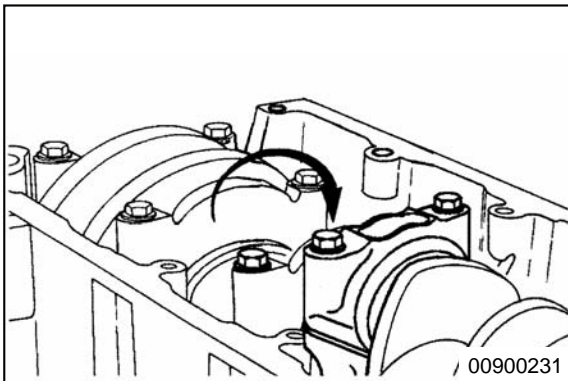
Tighten the capscrews.



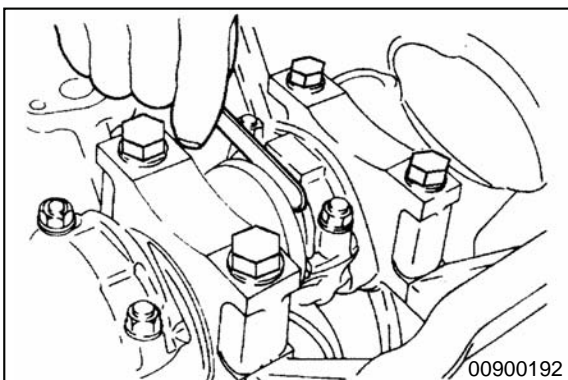
Torque Value:

Main Bearing				
Capscrews	Step 1	39 N•m	[29 ft-lb]	
	2	Rotate 90 degrees		

NOTE: The connecting rod capscrews can be reused five times. Make a punch mark on the capscrew head each time the capscrew is used. If there are already five marks on the capscrew head, the capscrew **must** be replaced.

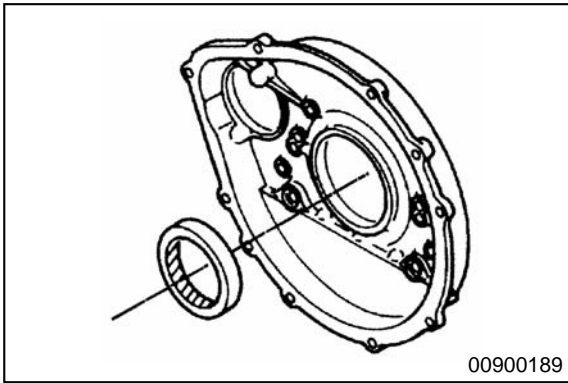


After installing the piston and connecting rod assemblies, check the crankshaft for smooth rotation.



Measure the side clearance of the connecting rod cap.

Connecting Rod Cap Side Clearance		
mm		in
0.20	MIN	0.0079
0.40	MAX	0.0160

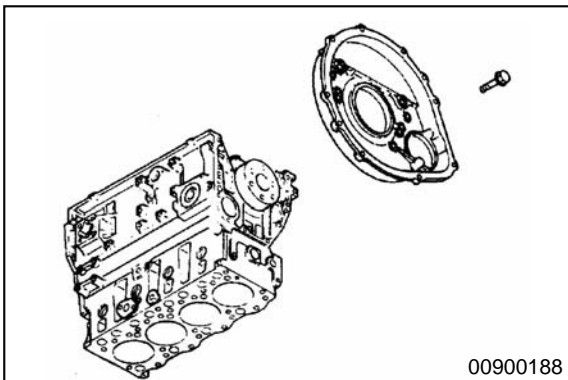


Flywheel Housing



Install the rear seal using oil seal installer, Part No. ST 972.

Fill 40 to 60 percent of the space in the seal lip with grease.



⚠ WARNING



This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.



⚠ CAUTION

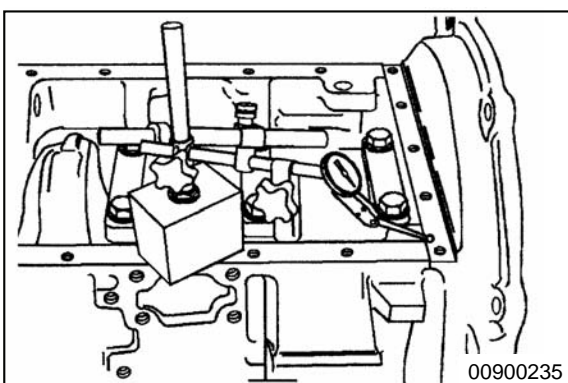
Do not apply excessive force to the seal lip surface when aligning and installing the flywheel. Damage to the engine will occur if the seal is damaged.

NOTE: Apply gasket sealant to the flywheel housing mounting surface.

Align the flywheel housing with the dowel pins.

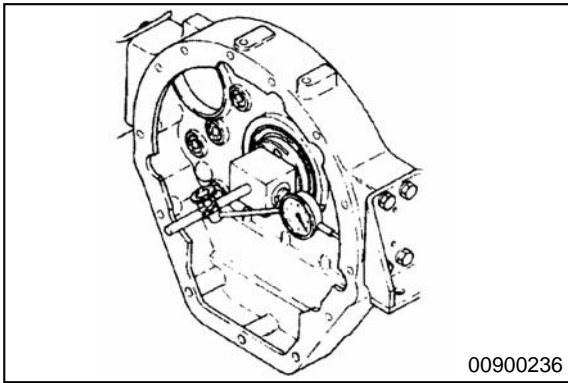
Install the flywheel housing and capscrews. Tighten the capscrews.

Torque Value: 69 N•m [50 ft-lb]



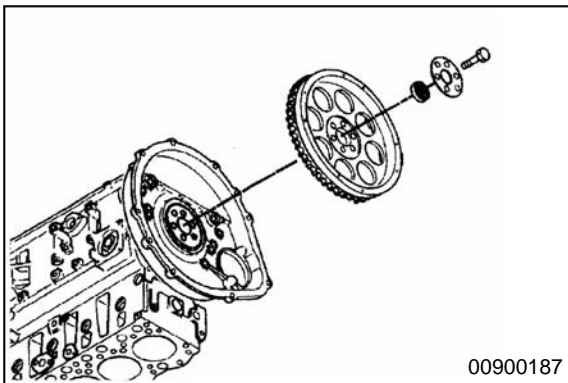
Measure the distance in height between the lubricating oil pan mounting surface and the flywheel housing flange.

Maximum Height Difference: 0.15 mm [0.0059 in]



Measure the radial and face runout of the flywheel housing.

Radial Runout		
mm		in
0.35	MAX	0.014
Face Runout		
mm		in
0.30	MAX	0.012



Flywheel

⚠ WARNING



This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.



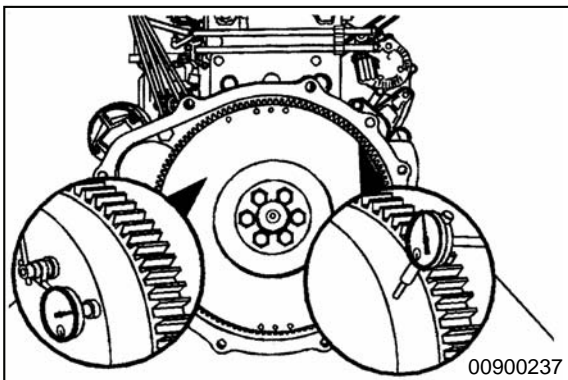
Install the flywheel, coupling, retaining plate, and six capscrews. Tighten the capscrews.

Torque Value:

Main Bearing

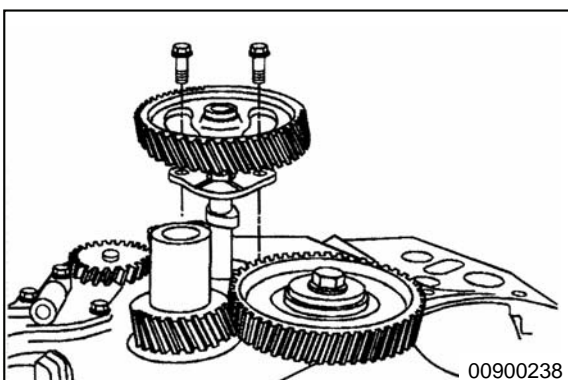
Flywheel

Capscrews	Step 1	108 N•m	[80 ft-lb]
	2	191 N•m	[141 ft-lb]



Measure the radial and face runout of the flywheel.

Radial Runout		
mm		in
0.20	MAX	0.0079
Face Runout		
mm		in
0.15	MAX	0.0059



Camshaft Assembly

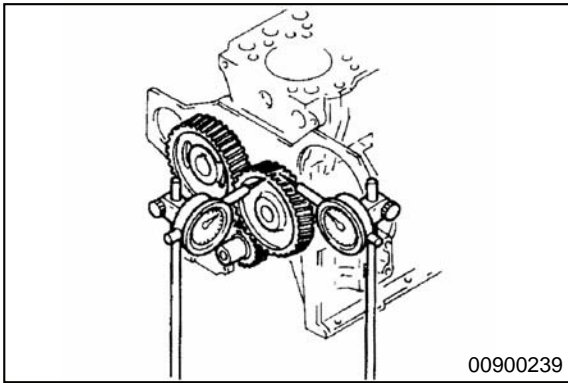
NOTE: When installing the camshaft, lightly rotate the shaft while being careful **not** to damage the bushing.



Install the thrust plate, camshaft assembly, and two capscrews.

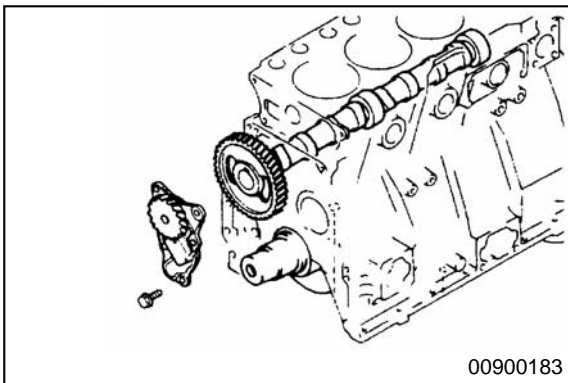
Tighten the capscrews through the casting holes in the camshaft gear.

Torque Value: 19 N•m [14 ft-lb]



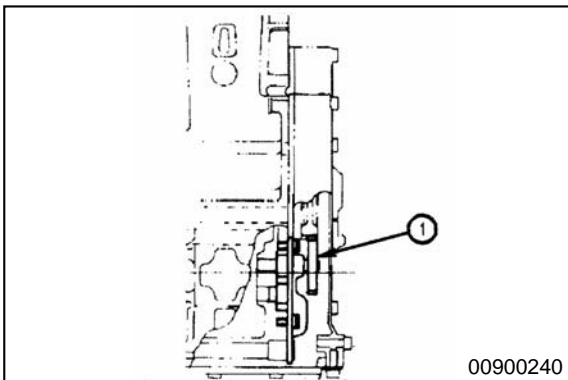
Measure the end play (1) of the camshaft.

Camshaft End Play		
mm		in
0.150	MIN	0.0059
0.350	MAX	0.0138



Oil Pump

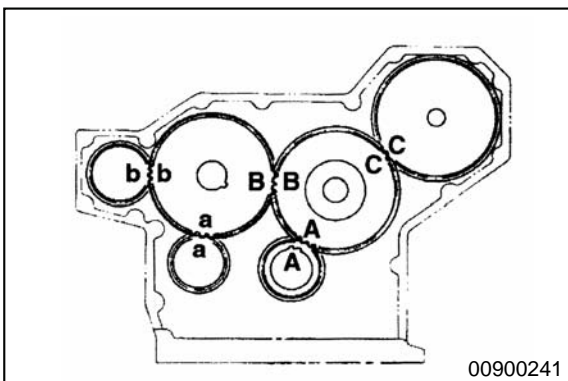
Install the lubricating oil pump and five capscrews.
Tighten the capscrews.



Torque Value: 19 N•m [14 ft-lb]

Measure the end play of the lubricating oil pump drive gear.

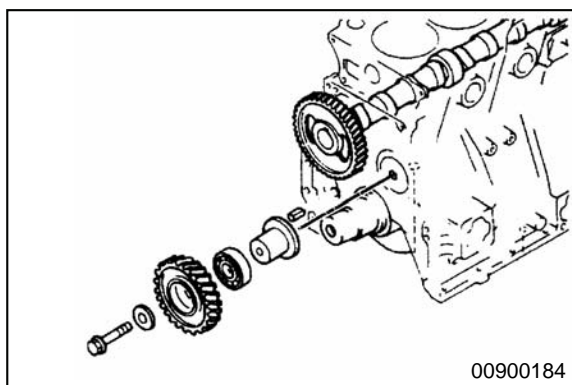
Lubricating Oil Pump Drive Gear End Play		
mm		in
0.020	MIN	0.0008
0.070	MAX	0.0028



Idler Gear

Align the match marks of the idler gear, crankshaft gear, and camshaft gear. The match marks are identified as follows:

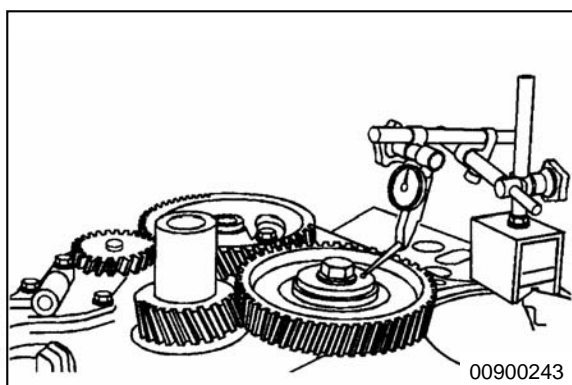
- Crankshaft Gear and Idler Gear: **A**
- Idler Gear and Camshaft Gear: **B**
- Fuel Pump and Idler Gear: **C**
- Lower case letters identify oil pump and accessory drive, which are **not** timed.



Install the retainer plate and capscrew.
Tighten the capscrew.



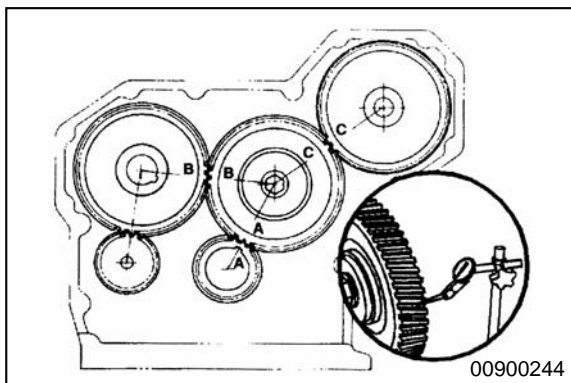
Torque Value: 110 N•m [81 ft-lb]



Measure the end play of the idler gear.

Match mark alignment:

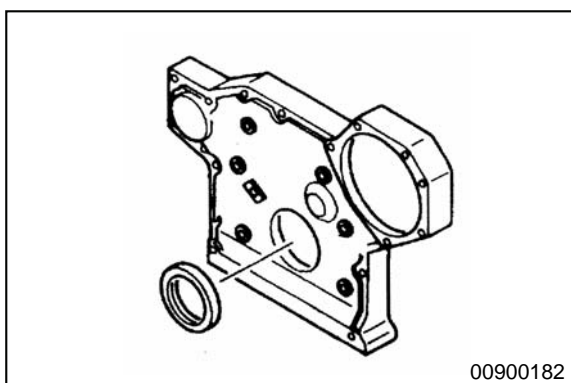
			Naturally Aspirated	
Backlash	A	Crankshaft gear and idler gear	0.08 mm to 0.19 mm [0.0031 in to 0.007 in]	Replacement Limit: 0.40 mm [0.0157 in]
	B	Camshaft gear and idler gear	0.08 mm to 0.19 mm [0.0031 in to 0.007 in] Aspirated	
	C	Injection pump gear and idler gear	0.07 mm to 0.29 mm [0.003 in to 0.011 in]	
	a	Camshaft gear and oil pump gear	0.15 mm to 0.30 mm [0.006 in to 0.012 in]	
	b	Camshaft gear and PTO gear	0.03mm to 0.050mm [0.0012 in 0.0035 in]	
Clearance Between Bushing and Shaft			0.015 mm to 0.050 mm [0.0006 in to 0.002 in]	Replacement Limit: 0.10 mm [0.0039 in]
End Play of Idler Gear			0.03 mm to 0.09 mm [0.0012 in to 0.0035 in]	Replacement Limit: 0.20 mm [0.0079 in]



Temporarily position the fuel injection pump assembly and measure the backlash of the gears.



Measure the backlash of all the gears with a dial indicator.



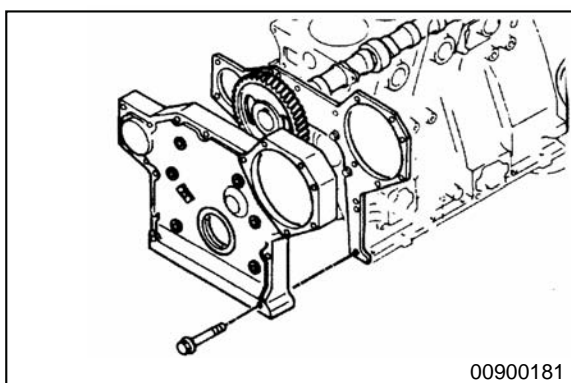
Gear Housing Cover



NOTE: A noise damper is installed on some engines. The noise damper **must** be installed prior to installing the front oil seal.

Install the front oil seal using tool, Part No. 3824498.

Fill 40 to 60 percent of the space in the seal lip with grease.



CAUTION

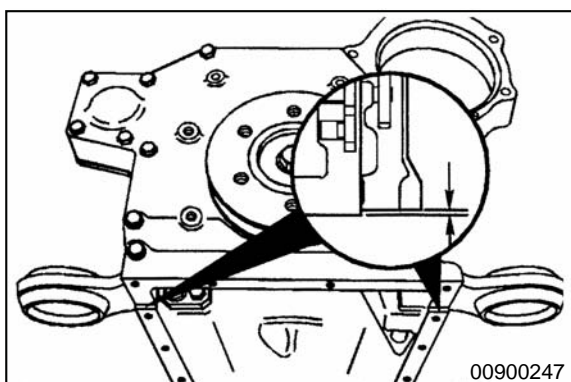


Do not apply excessive force to the seal lip surface when aligning and installing the gear housing cover. Damage to the engine will occur if the seal is damaged.

NOTE: Apply gasket sealant, Part No. 3823494, to the gear housing cover mounting surface.

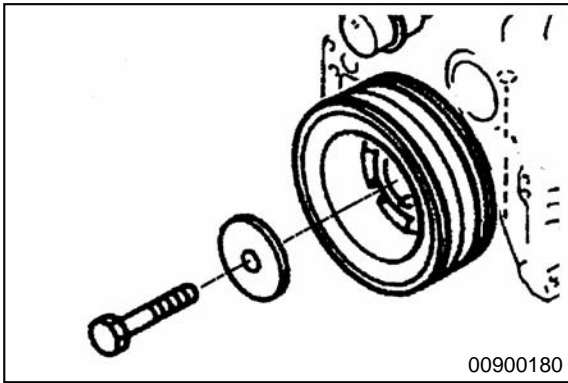
Install the gear housing cover and 17 capscrews. Tighten the capscrews.

Torque Value: 19 N•m [14 ft-lb]



Measure the distance in height between the cylinder block and the gear housing cover.

Maximum Height Difference: 0.15 mm [0.0059 in]

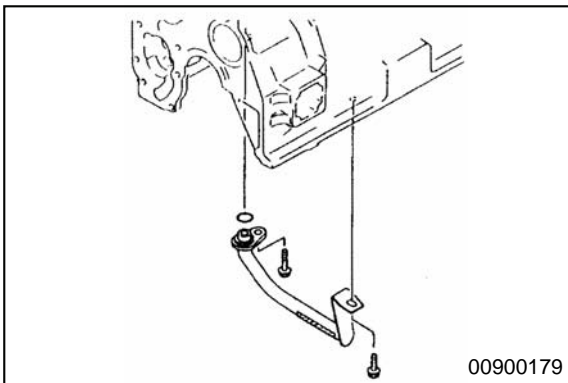


Crankshaft Pulley

Align the crankshaft pulley with the crankshaft key.
Install the crankshaft pulley, mounting plate, and cap screw.

Tighten the cap screw.

Torque Value: 93 N•m [69 ft-lb]

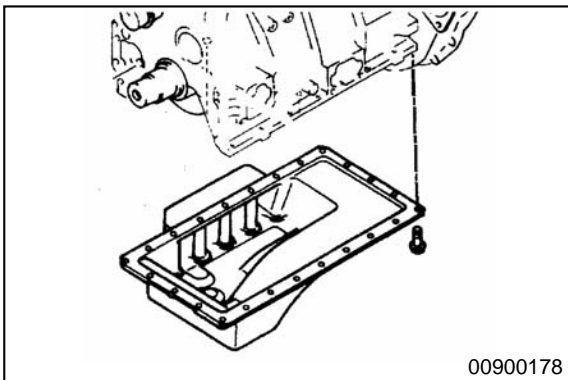


Lubricating Oil Suction Tube

Install a new o-ring, oil suction tube, and two cap screws.

Tighten the cap screws.

Torque Value: 19 N•m [14 ft-lb]



Lubricating Oil Pan

NOTE: Apply a 1-mm [0.039-in] bead of gasket sealant, Part No. 3823494, to the mounting surface of the lubricating oil pan.

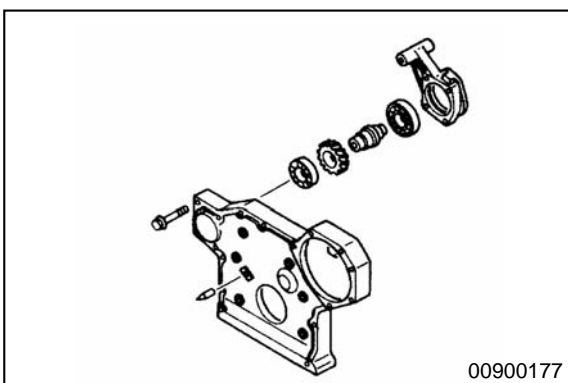
Install a new gasket, lubricating oil pan, and 24 cap screws.

Tighten the cap screws.

Torque Value: 32 N•m [24 ft-lb]

If the oil drain plug was removed, install the drain plug.

Torque Value: 51 N•m [38 ft-lb]



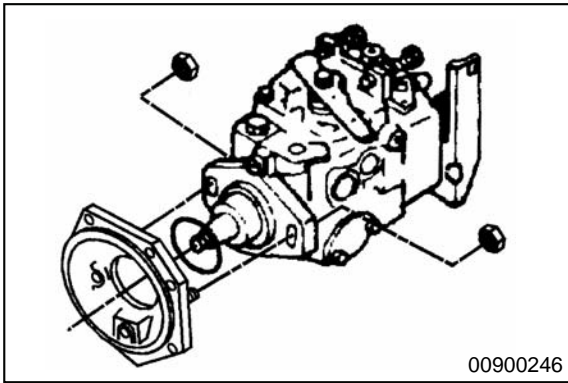
PTO Shaft (if applicable)

Align the gear of the PTO shaft with the surface teeth of the camshaft gear.

Install the o-ring, flange, and two cap screws.

Tighten the cap screws.

Torque Value: 19 N•m [14 ft-lb]



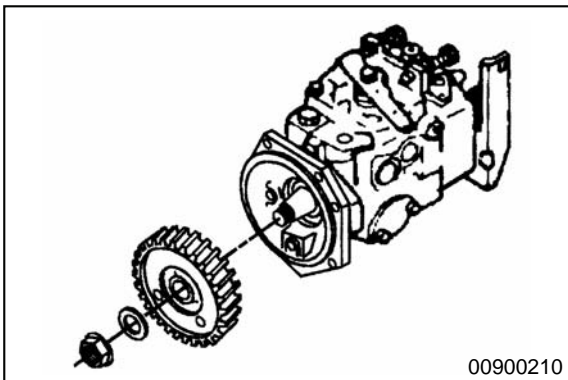
Fuel Injection Pump

⚠ CAUTION

Do not allow dirt or dust to enter the oil and fuel inlet and outlet ports. Severe engine damage will occur if contaminants are allowed to enter the engine.

Install new o-ring, fuel injection pump, and two mounting nuts on the adapter plate.
Tighten the nuts.

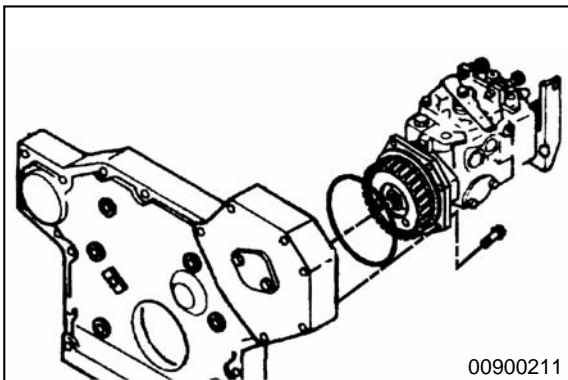
Torque Value: 31 N•m [23 ft-lb]



Install the fuel injection pump gear, washer, and nut on the fuel injection pump.

Tighten the nut.

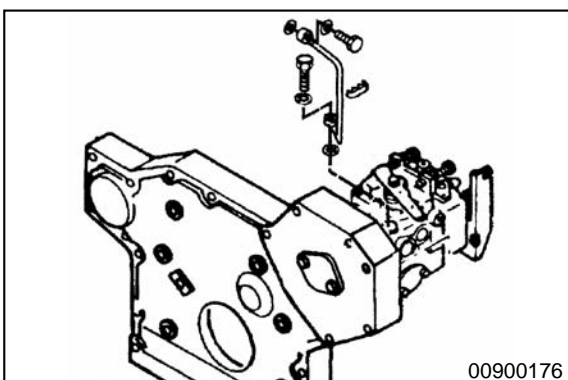
Torque Value: 70 N•m [52 ft-lb]



NOTE: Align the fuel injection pump gear match mark "C" with the idler gear match mark "C".
Install new o-ring, adapter plate, fuel injection pump assembly, and mounting capscrews to the gear housing.

Tighten the mounting capscrews.

Torque Value: 19 N•m [14 ft-lb]



Install the mounting capscrew on the fuel injection pump support bracket.

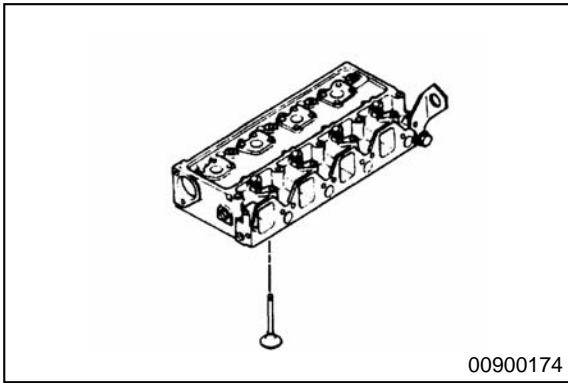
Tighten the capscrew.

Torque Value: 19 N•m [14 ft-lb]

NOTE: The fuel supply tube has a 12-mm and 14-mm banjo fitting. The 12-mm banjo fitting connects to the fuel injection pump. The 14-mm banjo fitting connects to the fuel filter head, which is installed later in the assembly process.

Install the fuel supply tube to the fuel injection pump.

Torque Value: 20 N•m [15 ft-lb]

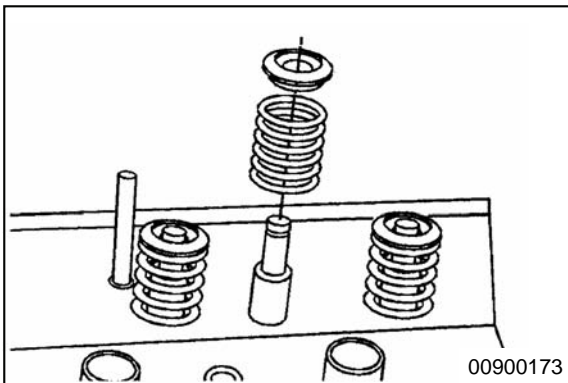


Cylinder Head Assembly

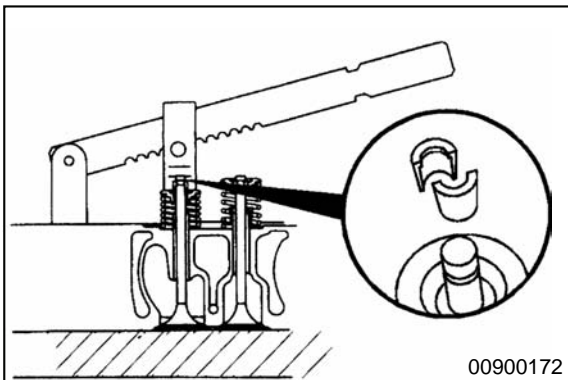


NOTE: Coat the stems of the intake and exhaust valves and the inside of the valve guides with engine oil.

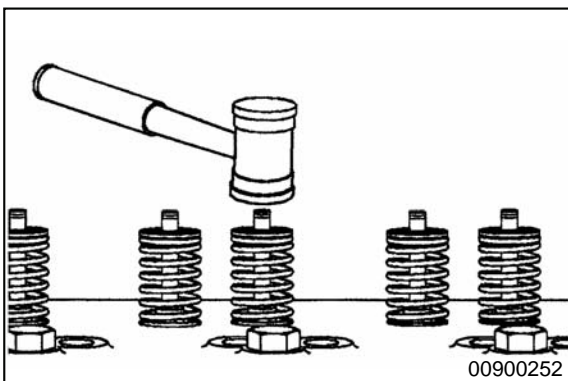
Install the valves.



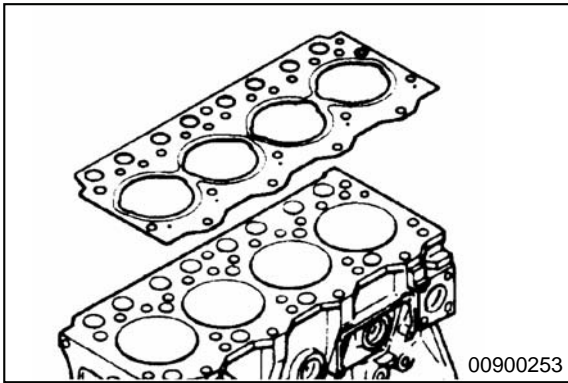
Install the valve spring and spring seat on the valve stem.



Install the valve cotter into the valve stem groove while compressing the valve spring with spring pusher, Part No. 3398179.



After releasing the valve spring, tap the top of the valve stem with a plastic hammer to make certain the cotter is completely fitted.

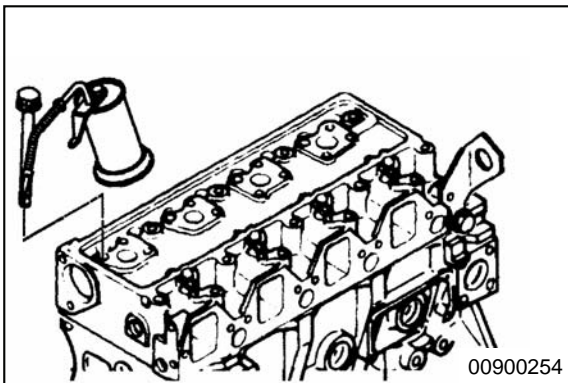


⚠ CAUTION



Remove all carbon and dirt from the contact surfaces of the cylinder block and the cylinder head. Remove all burrs and damage, and clean out all the dirt from inside the cylinder block. Failure to follow these steps will result in severe engine damage.

Install a new cylinder head gasket with the TOP mark facing up.



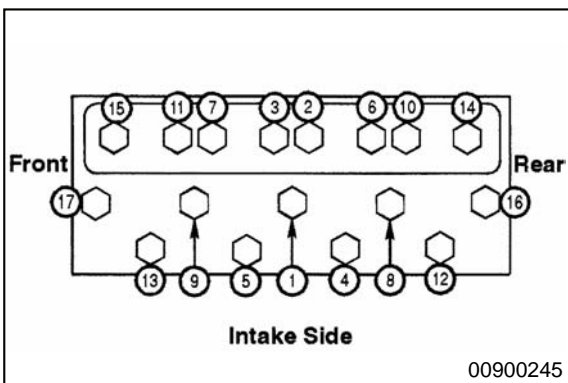
⚠ WARNING



This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.

NOTE: Coat the capscrew threads with antifriction compound, Part No. 3824879.

Install the cylinder head using four head capscrews as guides.



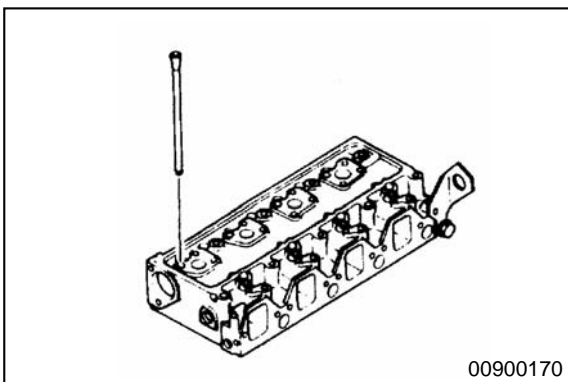
Install the capscrews. Tighten the capscrews in the sequence shown.



Torque Value:

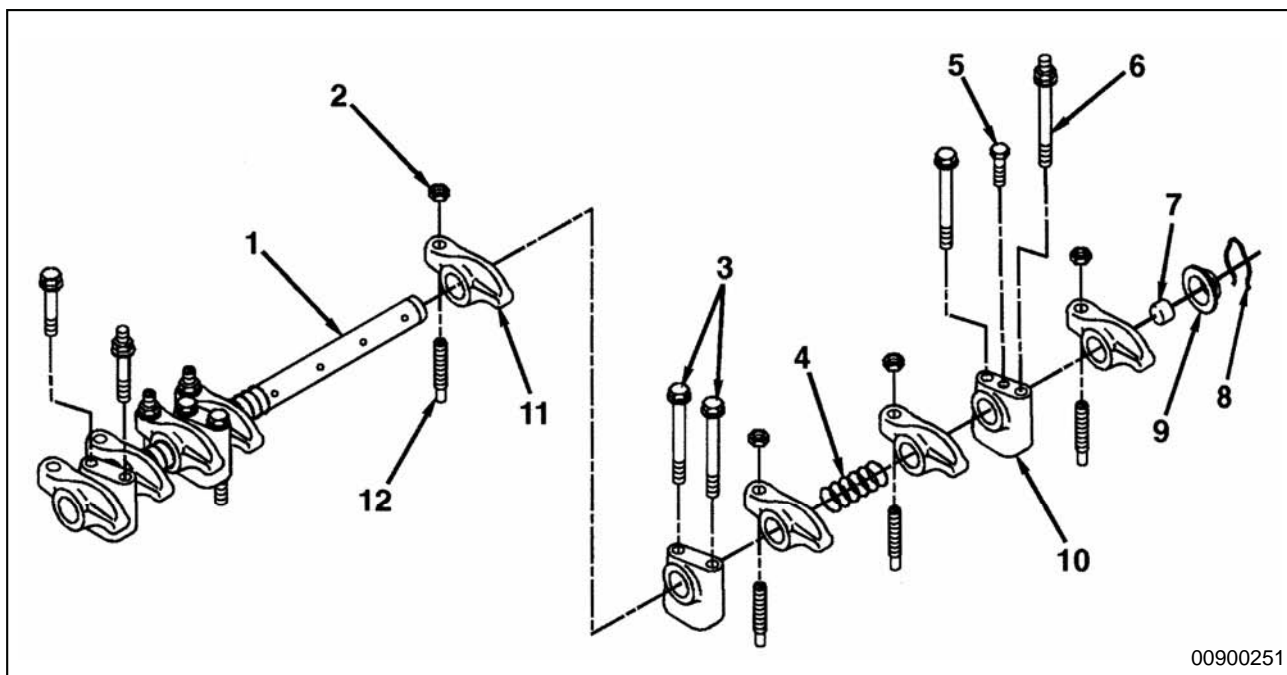
Cylinder Head Capscrews	Step 1	69 N•m	[51 ft-lb]
	2	108 N•m	[80 ft-lb]
	3	Rotate 90 degrees	

NOTE: The cylinder head capscrews can be reused five times. Make a punch mark on the capscrew head each time the capscrew is used. If there are already five marks on the capscrew head, the capscrew **must** be replaced.



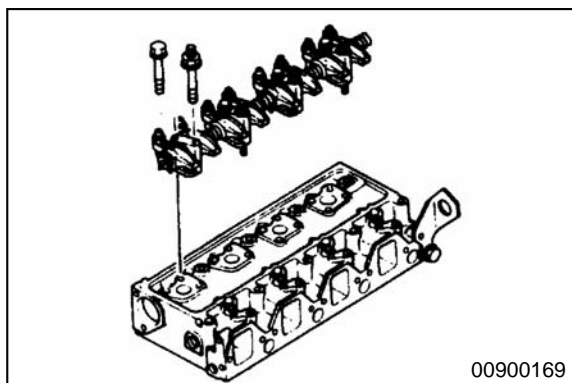
Push Rods

NOTE: If there is no abnormality in the pushrods, install them in the same position that they were removed from during disassembly.



Rocker Arm Assembly

- | | |
|--------------------------------|--|
| 1. Rocker Shaft | 7. Cup Plug |
| 2. Adjusting Screw Lock Nut | 8. Snap Ring |
| 3. Pedestal Mounting Capscrews | 9. Thrust Washer (only used on some engines) |
| 4. Separating Spring | 10. Rocker Lever Pedestal |
| 5. Rocker Shaft Indexing Screw | 11. Rocker Lever |
| 6. Pedestal Mounting Stud | 12. Adjusting Screw. |

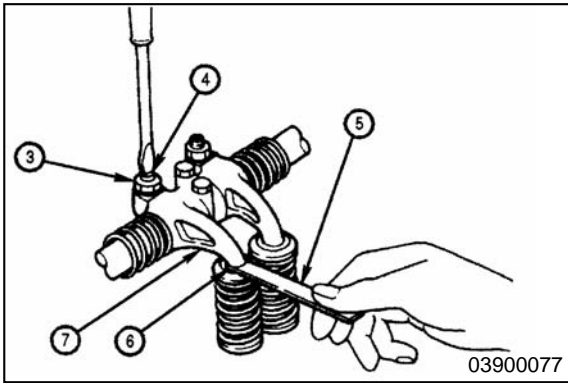


Rocker Arm Assembly

NOTE: Check that the ball of the adjustment screw is fitted properly into the socket of the pushrod before tightening the capscrews. If the valve spring tension pushes against the rocker arm, loosen the locknut, and turn the adjustment screw back to prevent strain on the pushrod.

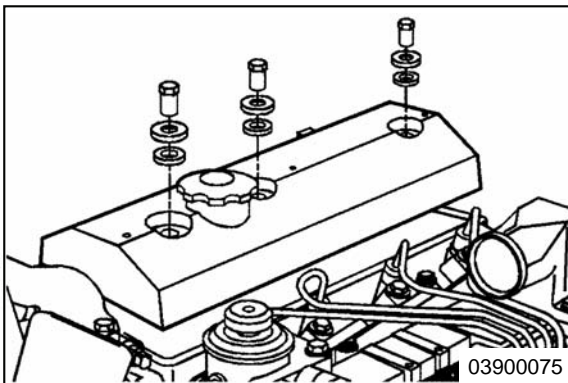
Install the rocker arm assembly and eight capscrews. Tighten the capscrews.

Torque Value: 25 N•m [18 ft-lb]



Adjusting Valve Clearance

Adjust the valve clearance. Refer to Section 14.



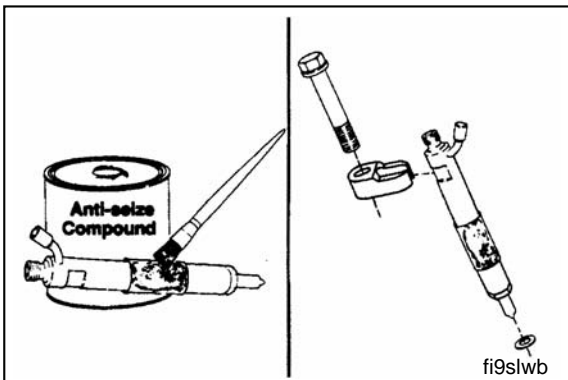
Rocker Lever Cover

Install the o-ring into the rocker lever cover.

Install the rocker lever cover, three capscrews, and isolator assemblies.

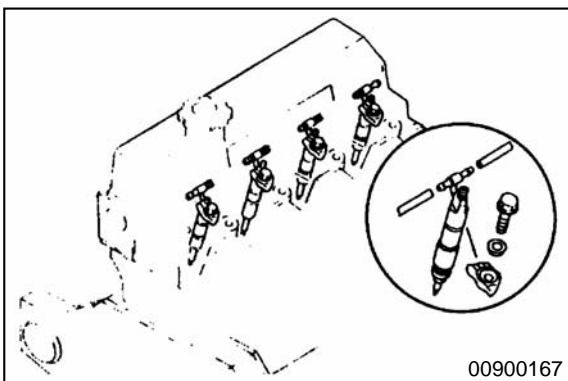
Tighten the capscrews.

Torque Value: 9 N•m [7 ft-lb]



Injector

Coat the injectors with anti-seize compound, Part No. 3824879, before installation.



CAUTION

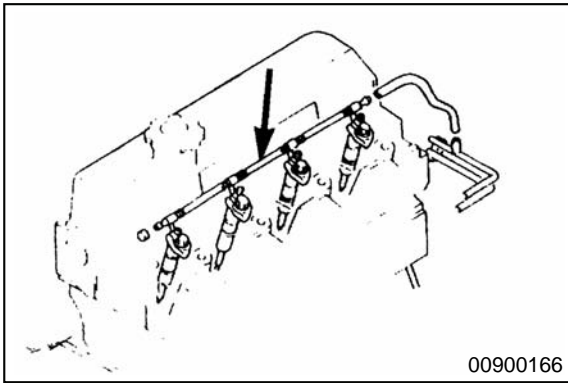
Be careful not to damage the tip of the injector when installing.

NOTE: When installing the injector, clean around the injector, and do **not** allow dust or dirt to enter the engine.

NOTE: If there is no abnormality in the injector, install it in the same position during assembly.

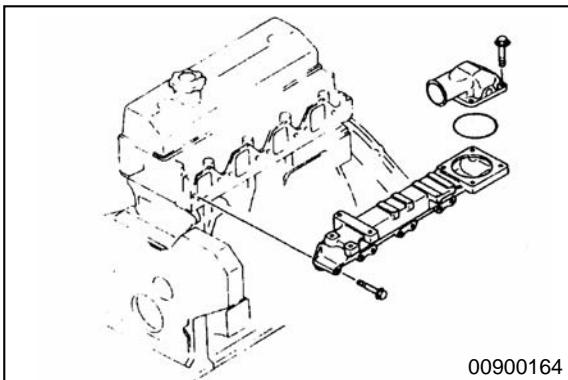
Install the injector, washer, and mounting capscrew. Tighten the capscrew.

Torque Value: 44 N•m [33 ft-lb]



Spill Tube

Install the spill tube.



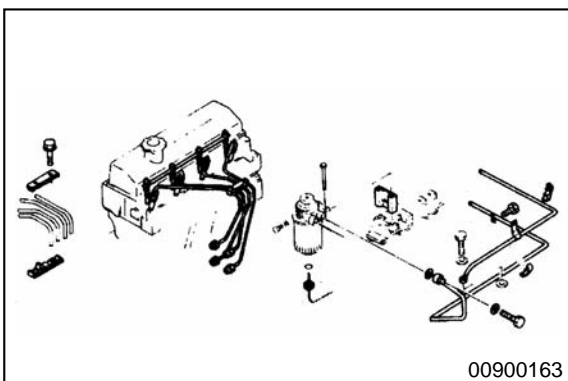
Intake Manifold

NOTE: Apply a 1-mm [0.039-in] bead of gasket sealant, Part No. 3823494, to the mounting surface of the intake manifold.

Install the air inlet connection, intake manifold, and seven capscrews.

Tighten the capscrews.

Torque Value: 40 N•m [30 ft-lb]



Fuel Injection Tubing

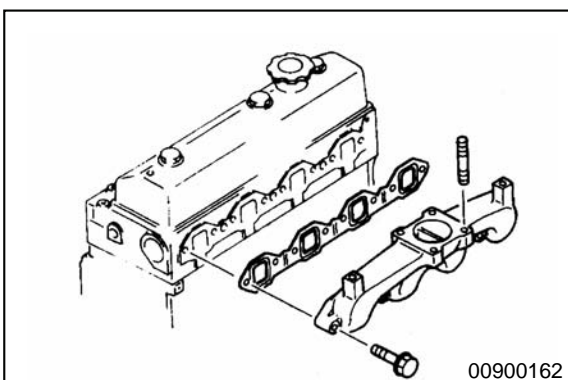
NOTE: Before installing the fuel injection tubing, blow compressed air through it to clean it.

Position the fuel injection tubing, and loosely install the sleeve nuts on the fuel injection pump and the cylinder head.

Tighten the clamp.

Tighten the banjo fittings

Torque Value: 20 N•m [15 ft-lb]

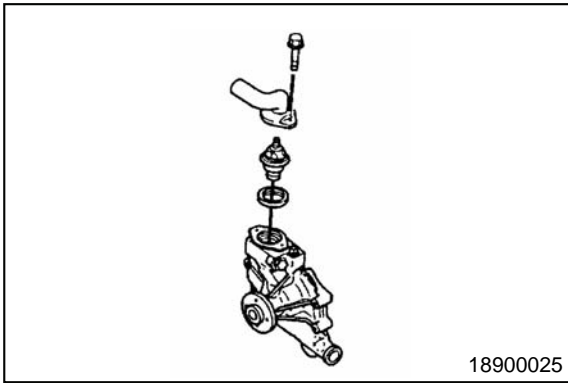


Exhaust Manifold

Install a new gasket, the exhaust manifold, and the eight capscrews.

Tighten the capscrews.

Torque Value: 66 N•m [49 ft-lb]



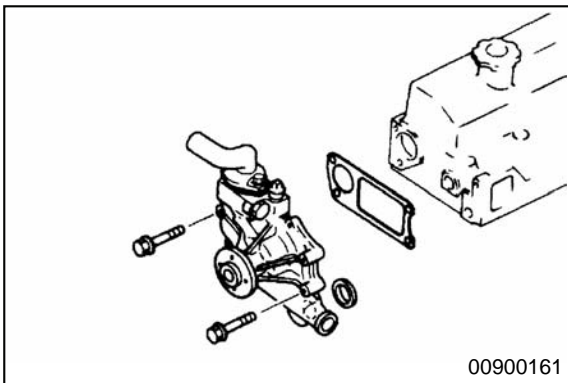
Thermostat



Install seal, thermostat, thermostat housing, and two mounting capscrews.

Tighten the capscrews.

Torque Value: 19 N•m [14 ft-lb]



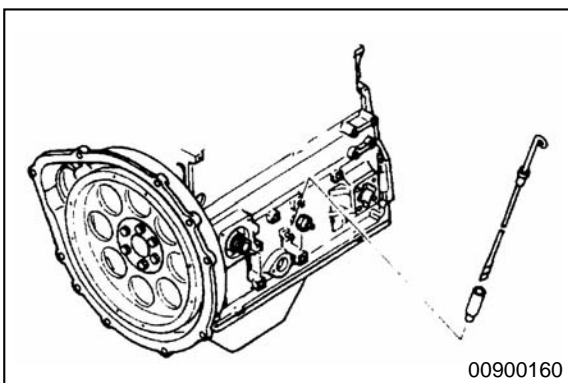
Water Pump



Install the o-ring, gasket, water pump, and mounting capscrews.

Tighten the capscrews.

Torque Value: 19 N•m [14 ft-lb]



Dipstick



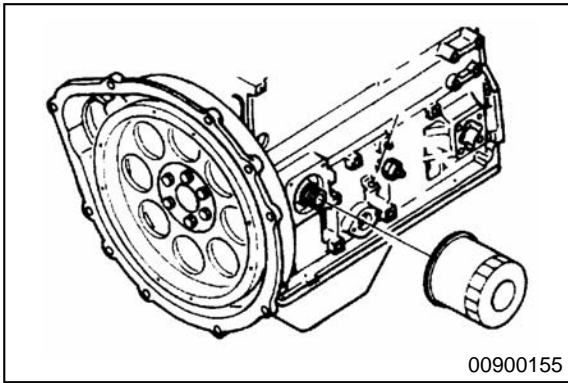
NOTE: Apply Loctite™ sealant, Part No. 3375068, or equivalent, to the outside of the dipstick tube.

⚠ CAUTION

Excessive sealant can run back into the engine and cause damage to other components.

Install the dipstick guide.

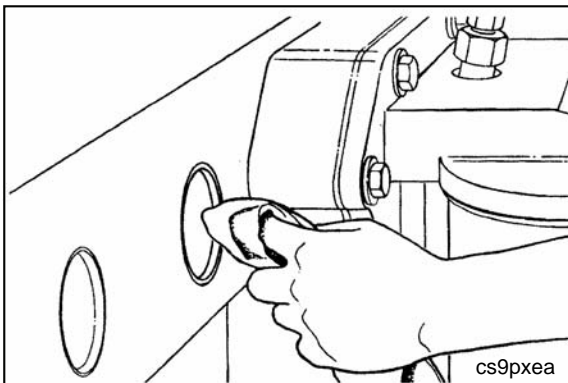
Install the dipstick.



Lubricating Oil Filter

Install the lubricating oil filter.

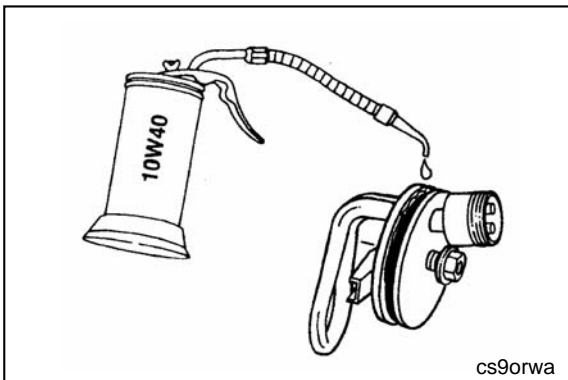
NOTE: Some engines will have an oil filter cooler mounted between the oil filter and the engine block.



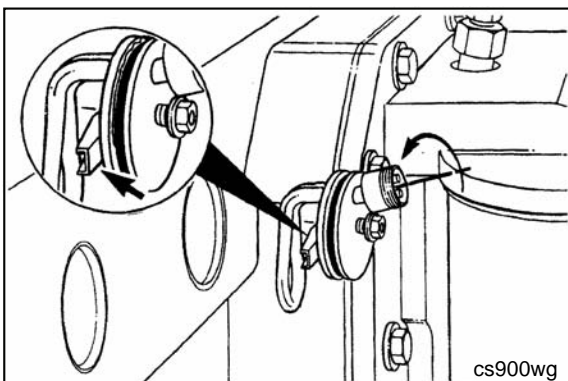
Block Water Heater



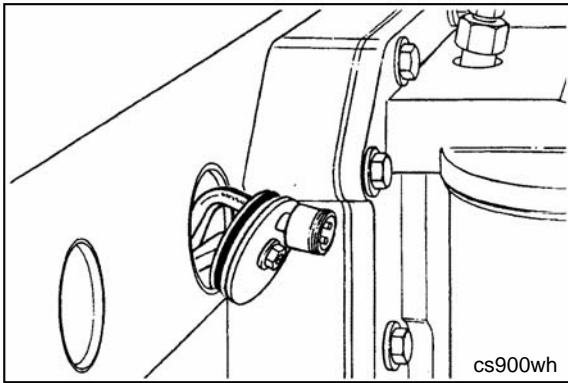
Clean the core plug hole thoroughly. Make sure there are **not** burrs or sharp edges that might cut the o-ring.



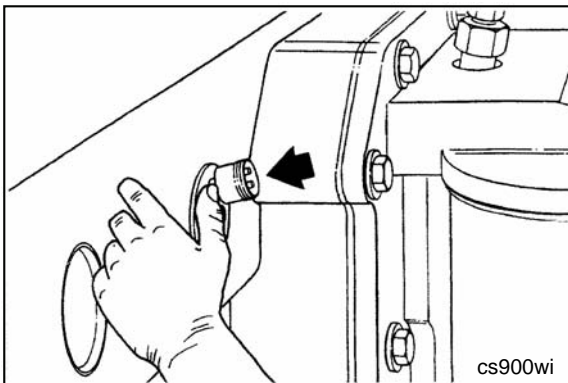
Lubricate the new heater o-ring with clean engine oil.



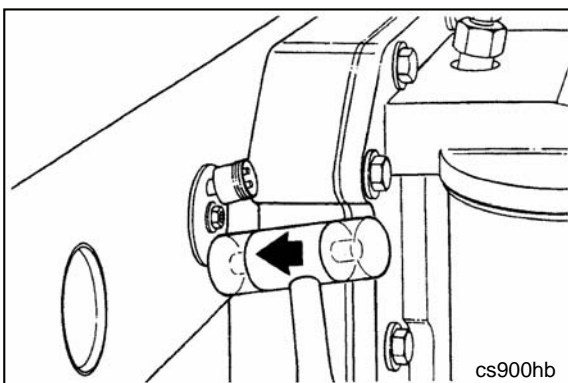
The locking channel (T-Bar) should be threaded out to the end of the bolt. If so equipped, do **not** remove the retaining wire used to position the channel (T-Bar).



Hook the element and one leg of the channel (T-Bar) into the hole as illustrated.



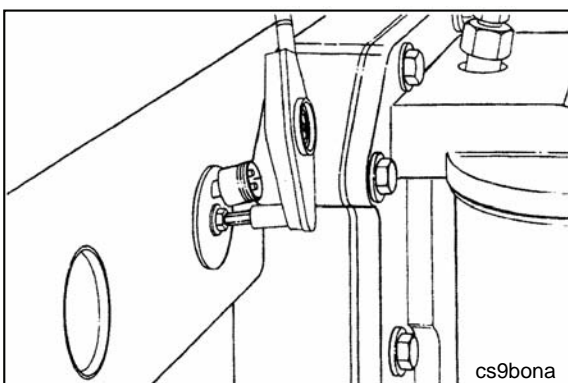
Hook the other leg of the channel in the hole and push the heater into the hole as far as possible by hand.



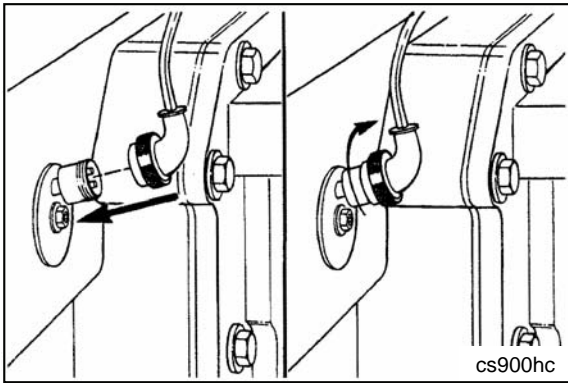
⚠ CAUTION

Do not pull the heater into location with the locking bolt as the channel (T-Bar) can bend or cause the threads to strip.

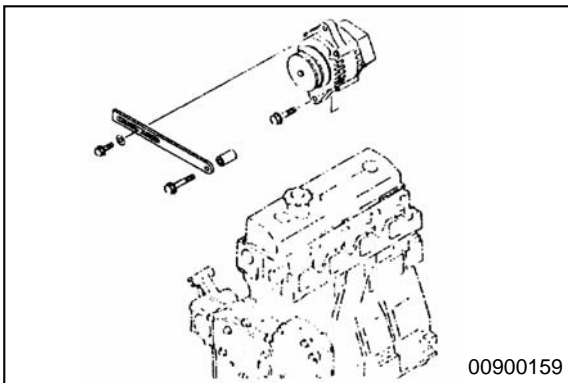
If necessary, use a plastic hammer to tap the heater in until the shoulder contacts the block.



Tighten the locking bolt.
Torque Value: 2.0 N•m [18 in-lb]
Do **not** over-tighten the locking bolt.

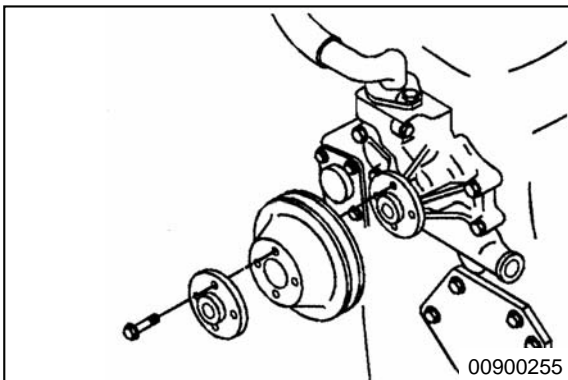


Insert the power cord into the socket being careful to align the pins with the sockets of the power cord. Tighten the retaining nut by hand.
Do **not** apply power until the cooling system is filled, and run the engine long enough for the thermostats to open and ensure all the air has escaped.



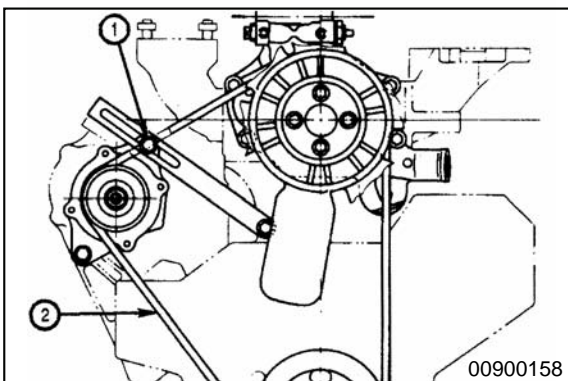
Alternator

Install the alternator and capscrew.
Install the spacer, mounting capscrew, and adjustment plate.
Loosely install the washer and adjustment capscrew.

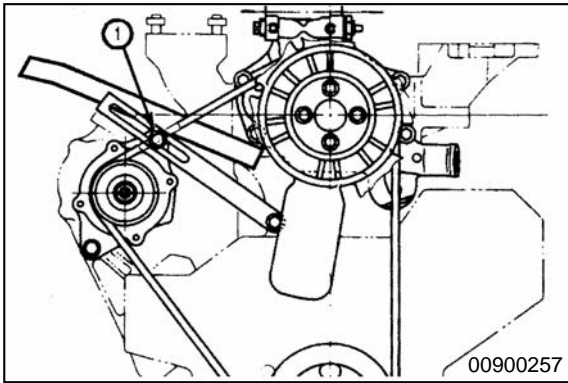


Fan Pulley

Install the fan pulley.



Position the fan belt (2) into the fan pulley groove, and loosely tighten the adjustment capscrew (1).



⚠ WARNING

Be careful not to injure your fingers or damage the alternator when adjusting the belt tension.

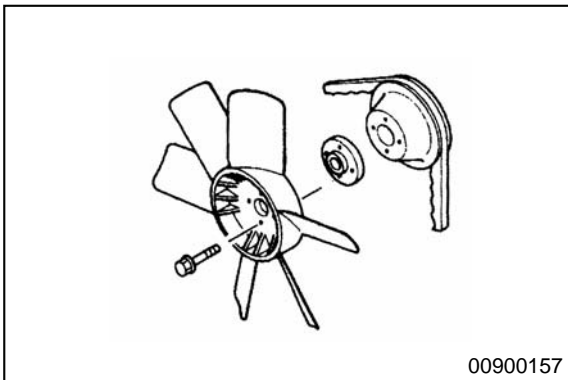
Insert a bar or pipe between the alternator and the cylinder block. Raise the alternator to adjust the fan tension.

NOTE: The belt **must** deflect 7 mm to 10 mm [0.28 in to 0.39 in] when pushed with finger-pressure of 6 kg [13 lb] at a point midway between the fan pulley and the crankshaft pulley.

Tighten the adjustment cap screw (1).

Torque Value:

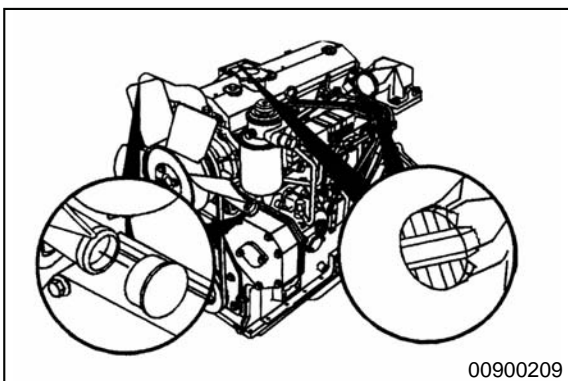
Mounting		
Capscrew	31 N•m	[23 ft-lb]
Adjustment		
Capscrew	31 N•m	[23 ft-lb]



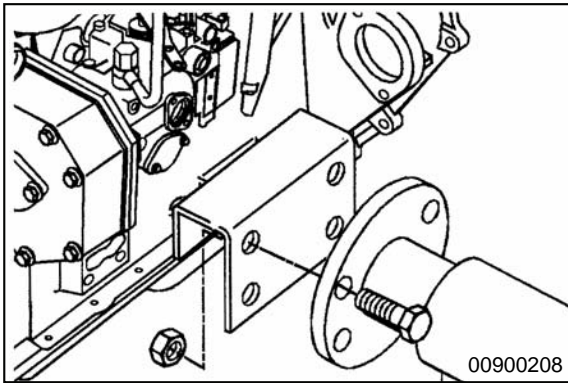
Fan

Install the spacer, fan, four capscrews. Tighten the capscrews.

Torque Value: 31 N•m [23 ft-lb]



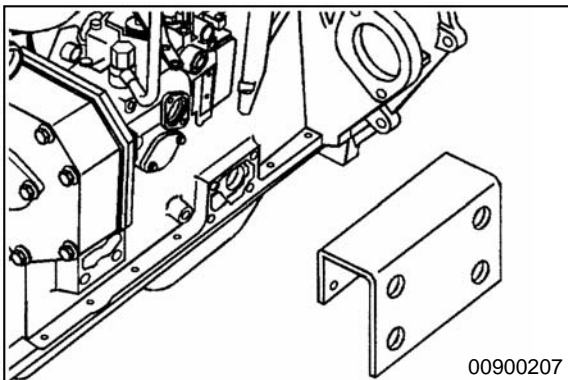
Remove the covers on all the engine openings that were installed to prevent dirt and debris from entering the engine.



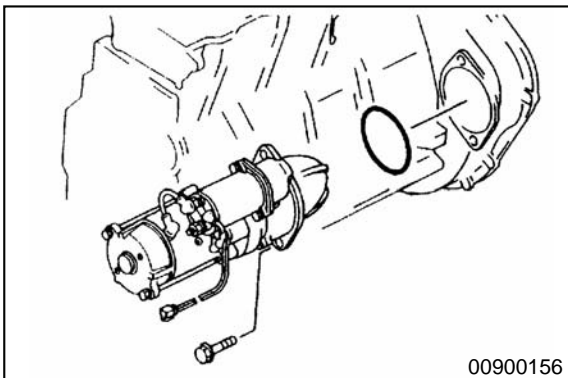
⚠ WARNING

This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component. The engine lifting equipment must be designed to lift the engine without causing personal injury.

Engine Weight (approx.) 330 kg [660 lb]
Remove the engine from the stand.



Remove the bracket, Part No. 3163625, from the engine.

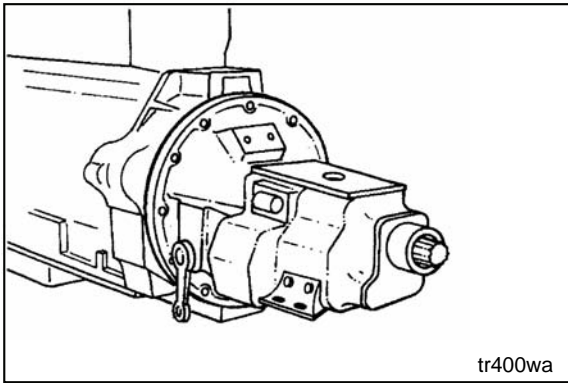


Install the starting motor.

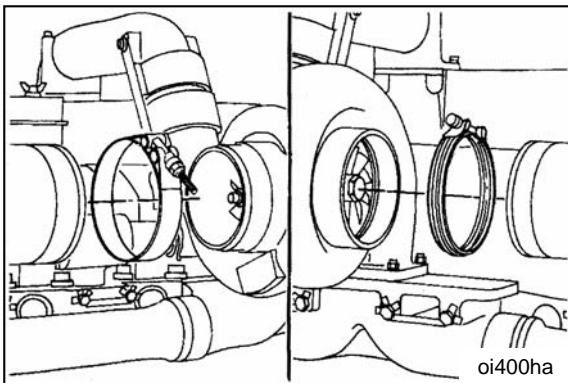
NOTE: The o-ring is used **only** on wet flywheel housings.



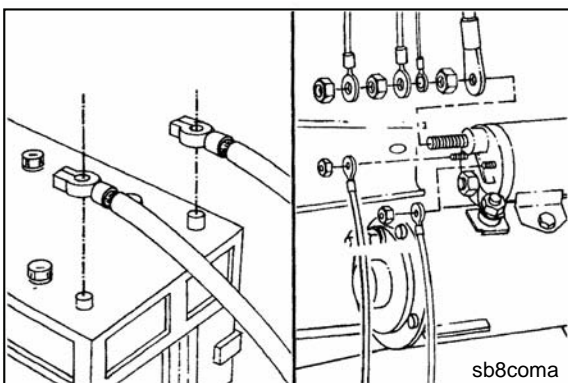
Install all the chassis components that were removed during removal of the engine from the equipment.



Connect the drive units to the flywheel housing and flywheel.



Connect the intake and exhaust system pipes.

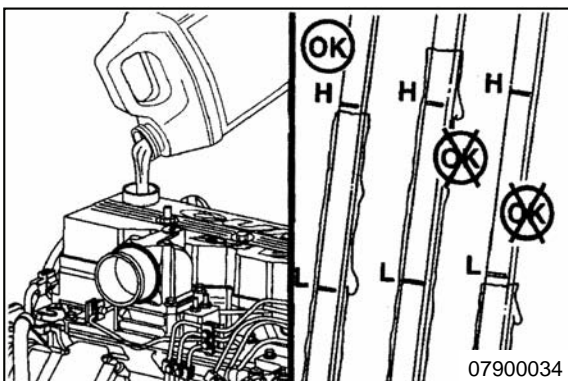


Connect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires, and hydraulic lines.

⚠ WARNING

Always connect the negative (-) cable last.

Connect the battery cables.

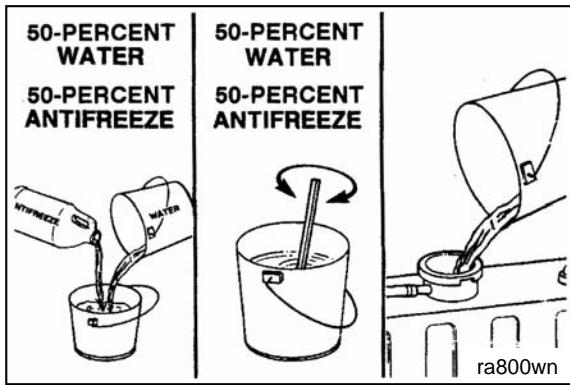


⚠ WARNING

Some state and federal agencies in the United States of America have determined that used oil is carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. Always use the proper procedures to dispose of the oil.

Fill the engine with lubricating oil.

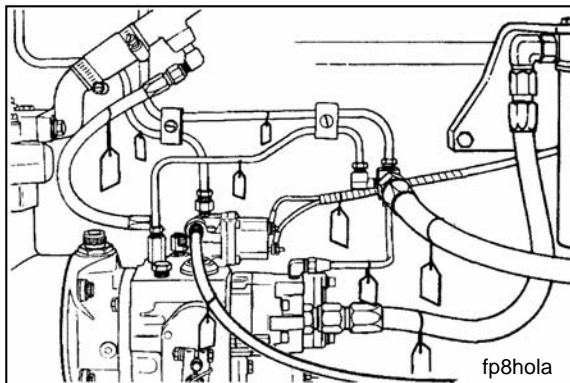
Engine Oil 6.5 liters [1.7 u.s.gal]



⚠ WARNING

Coolant is toxic. Keep away from children and animals. Save for reuse or dispose of in accordance with local regulations.

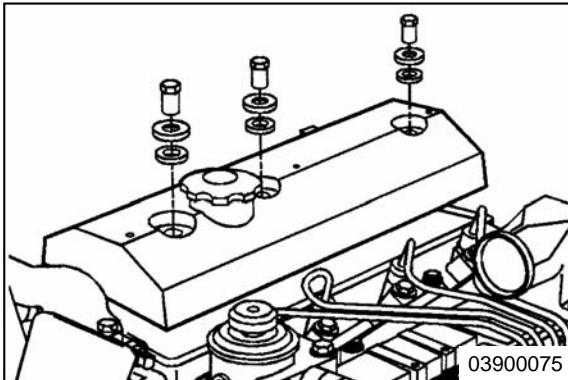
Fill the engine with engine coolant.



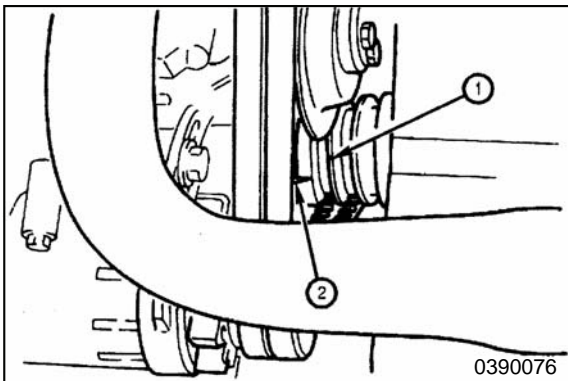
NOTE: Remove all tags that were put on all hoses, lines, linkage, and electrical connections as they were removed to identify location during the removal process.

Rocker Levers

Adjusting Valve Clearance



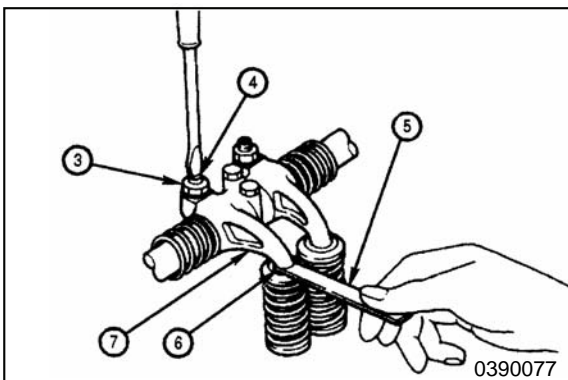
Remove the cylinder head cover.



Rotate the crankshaft in the normal direction. While watching the movement of the intake valve of No. 4 cylinder, bring the No.1 cylinder into compression top dead center position. Align the TOP engraved mark on the crankshaft pulley (1) with pointer (2).

NOTE:

- The engraved mark on the crankshaft pulley will read "1.4 TOP."
- The No. 4 intake valve will start to open when the No. 1 cylinder comes near compression top dead center.

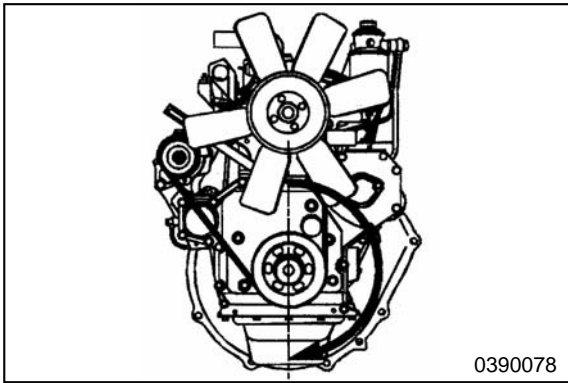


Loosen the lock nut (3) on the adjustment screw (4). Insert the feeler gauge (5) between the valve stem (6) and the rocker arm (7).

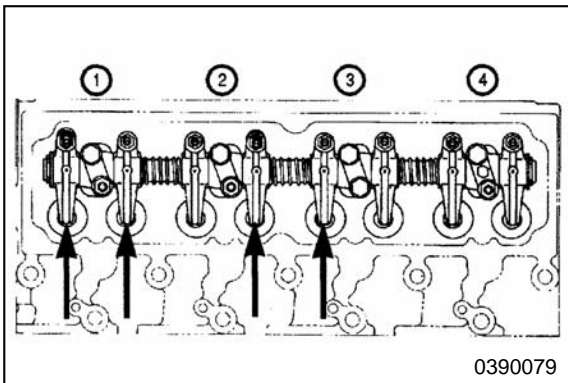


Adjust the clearance with the adjustment screw until slight drag is felt on the feeler gauge.

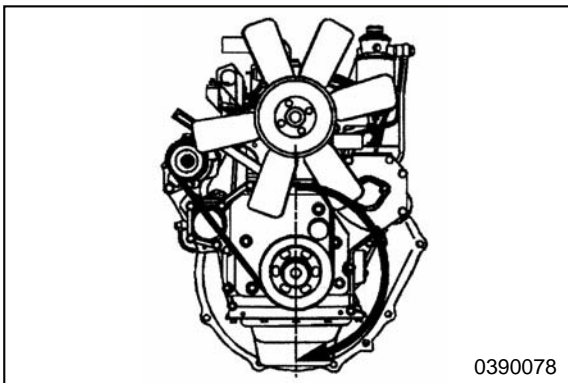
Valve Clearance (Engine Hot or Cold)	
Intake Valve	Exhaust Valve
0.35 mm	0.50 mm
0.014 in	0.020 in



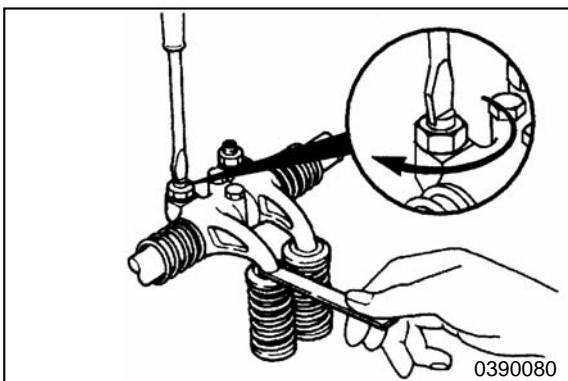
NOTE: Adjust intake and exhaust clearances in the following firing order by rotating the crankshaft 180 degrees in the normal direction: 1-2-4-3.



Adjust the valve clearances for **intake** valves No. 1 and No. 3.
Adjust the valve clearances for **exhaust** valves No. 1 and No. 2.



Rotate the crankshaft in the normal direction one revolution.
Adjust the valve clearances for **intake** valves No. 2 and No. 4.
Adjust the valve clearances for **exhaust** valves No. 3 and No. 4.



Tighten the locknut to secure the adjustment screw.



Locknut Torque Value		
N•m		ft-lb
39.2	MIN	28.9
49	MAX	36.1

Complete Engine

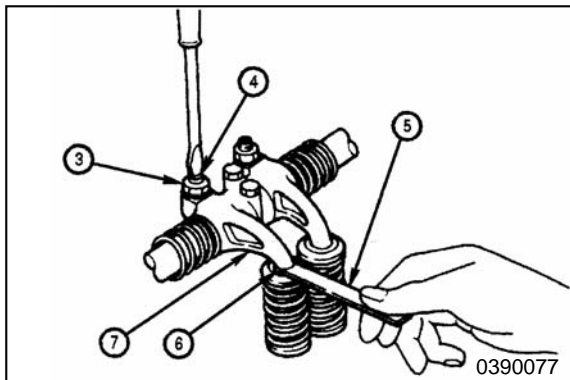
Measuring Compression Pressure

⚠ WARNING

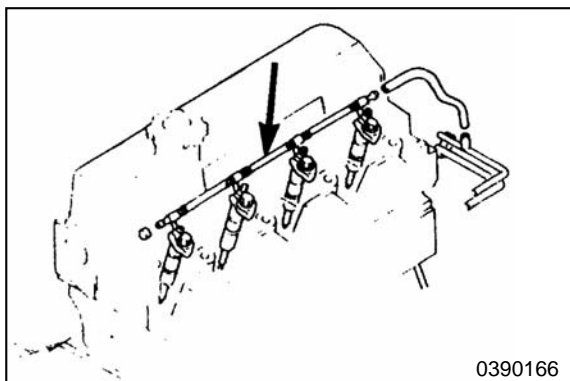
Exhaust manifold and muffler are hot. Do not touch the exhaust manifold or muffler or personal injury will occur.

⚠ WARNING

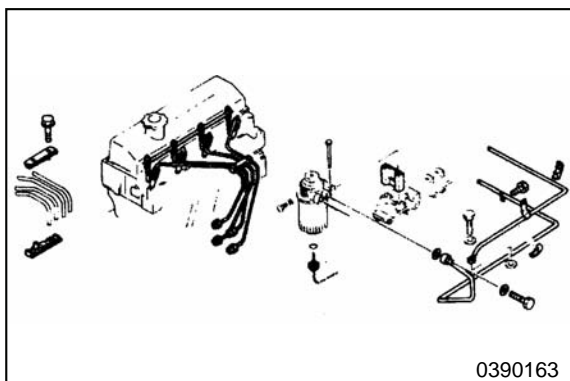
To avoid personal injury, keep hands, long hair, jewelry, and loose fitting or torn clothing away from fans and other moving parts.



Adjust the overhead. Refer to Adjusting Valve Clearance procedure.

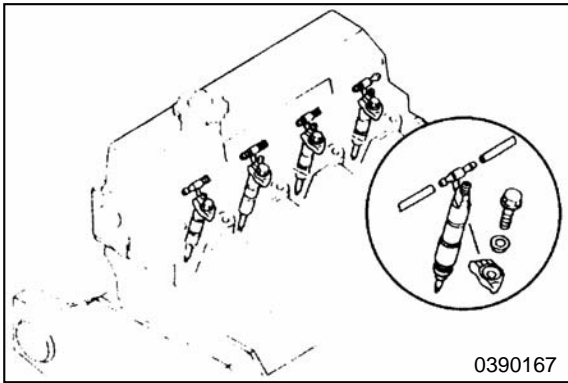


Remove the spill tube.



Disconnect the fuel injection tubing.

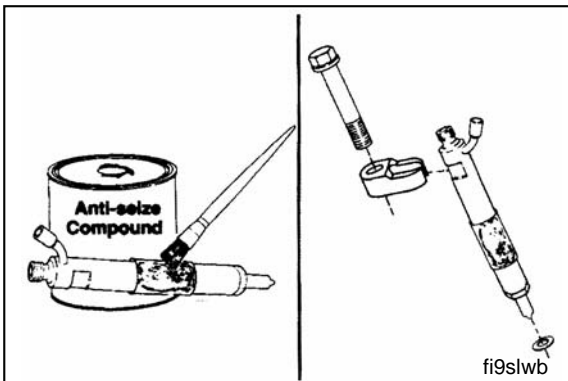
NOTE: Disconnect the fuel shut-off solenoid.



⚠ CAUTION

Do not allow dirt or foreign matter to get into the cylinder. Foreign objects in the cylinder can cause severe engine damage.

Remove the nozzle holder assembly for each cylinder.
Remove the injector.

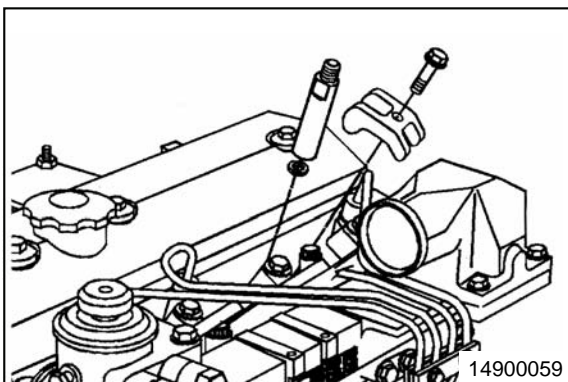


Lubricate the sealing lips of the sleeve with anti-seize compound. Assemble the injector, sealing sleeve, a new copper sealing washer, and the hold-down clamp.



Use only one washer.

NOTE: A light coat of clean 15W-40 engine oil between the washer and injector can help hold the washer in place during installation.

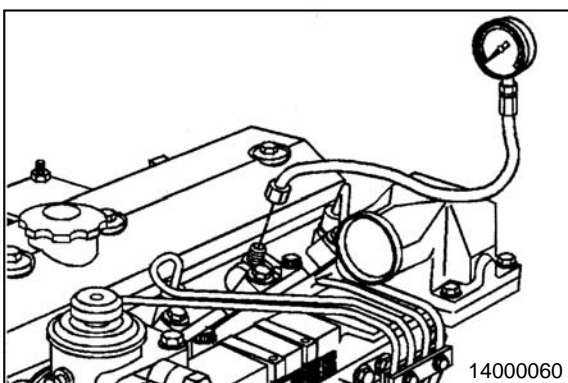


Install the adapter to the nozzle holder mounting section of the cylinder to be measured. Tighten the adapter.



Adapter Capscrews

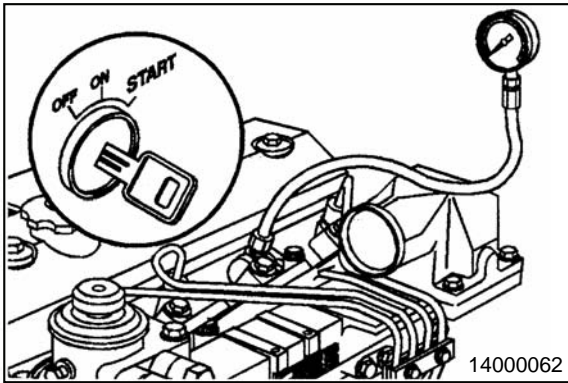
N•m		ft-lb
39	MIN	29
49	MAX	36



Connect the compression gauge to the adapter.



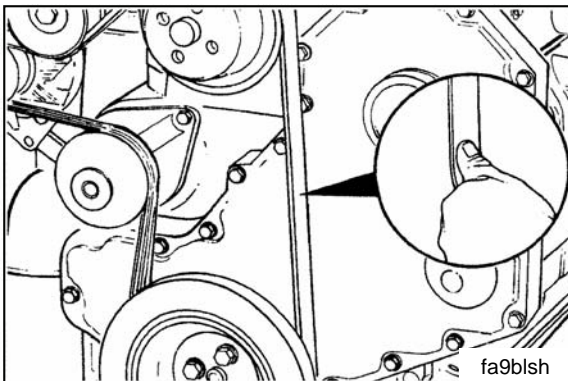
NOTE: Most compression leakage can be prevented by applying a small amount of oil to the mounting section of the adapter.



Crank the engine with the starting motor. Read the gauge when the pointer is stabilized.

Engine Compression		
kPa		psi
1965	MIN	285
2944	NOM	427

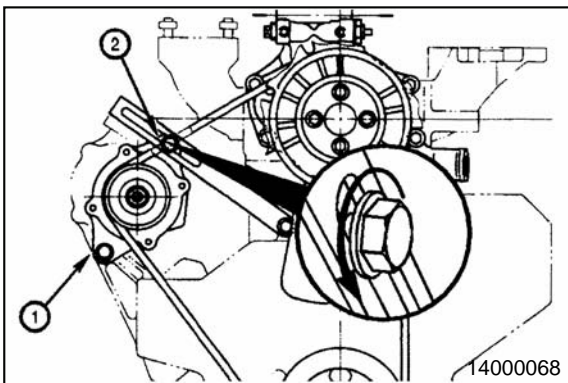
Testing and Adjusting the Fan Belt Tension



Testing the Fan Belt Tension

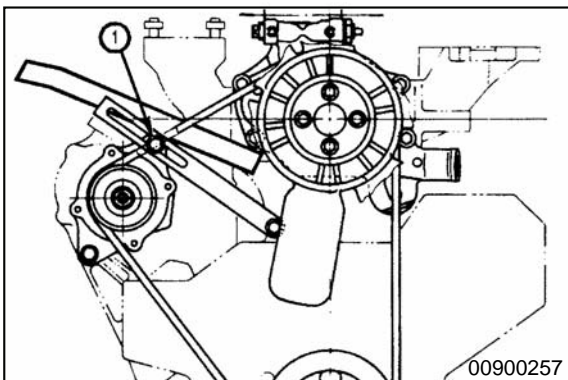
Check the amount the fan belt deflects when pushed with a force of 6 kg [13.2 lb] at a point midway between the fan pulley and the alternator pulley.

Fan Belt Deflection		
mm		in
7.0	MIN	0.28
10.0	MAX	0.39



Adjusting the Fan Belt Tension

Loosen the mounting cap screw of the alternator (1) and belt tension adjustment cap screw (2).



Using a bar, raise the alternator, and adjust the fan belt tension.



Tighten the adjustment cap screw and the mounting cap screw.

Torque Value:

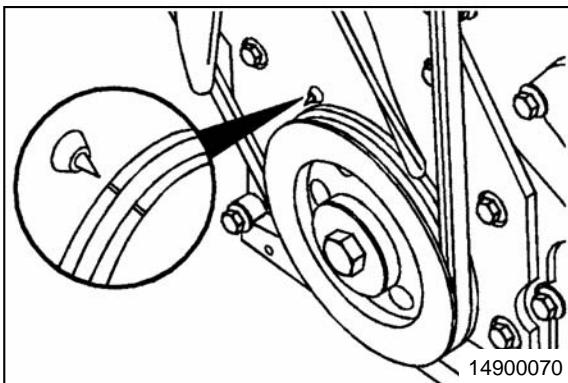
Adjustment Capscrew	31 N•m	[23 ft-lb]
Mounting Capscrew	66 N•m	[49 ft-lb]

Fuel System

Checking and Adjusting Fuel Injection Timing

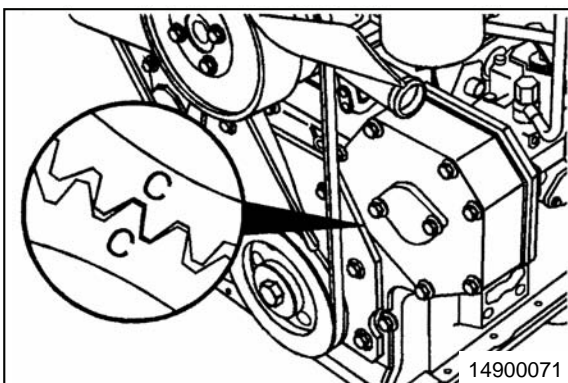
There are two methods for checking and adjusting the fuel injection timing of an injection pump.

- The "MATCH MARK ALIGNMENT" method, which is used when the injection pump is installed on the original engine and the pump is not being repaired.
- The "MEASURING DEVICE" method, which is used when a repaired or replaced injection pump is installed on the engine.



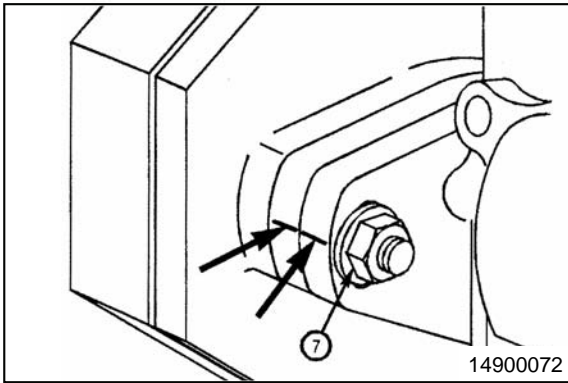
Checking and Adjusting with the Match Mark Alignment Method

NOTE: Set the No. 1 cylinder at compression top dead center (TDC) by aligning the pointer on the gear cover with the TDC line on the crankshaft pulley. Confirm that the mark "C" can be seen on the idler gear. If the mark "C" can not be seen, rotate the crankshaft one complete revolution and confirm that "C" can be seen.



NOTE: Align the match mark "C" on the injection pump gear with the match mark "C" on the idler gear during installation for correct alignment. Align the stamped line "a" on the injection pump with the stamped line "b" on the timing gear case during installation for correct alignment.

Install the injection pump.



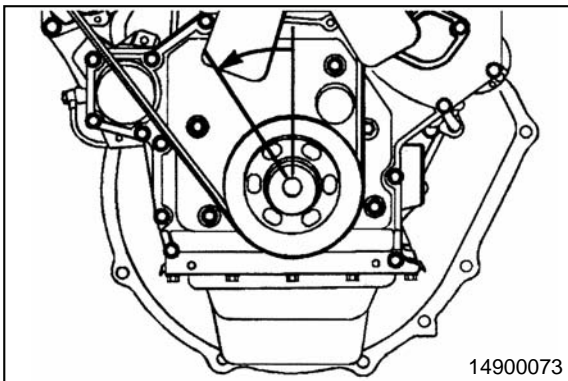
If the stamp lines are out of alignment, loosen nut (7). Align the stamp lines by rotating the coupling. Tighten the nut.



Torque Value: 31 N•m [23 ft-lb]



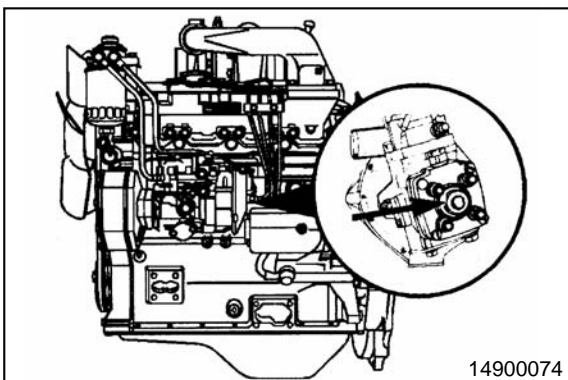
14900072



Checking and Adjusting with the Measuring Device Method

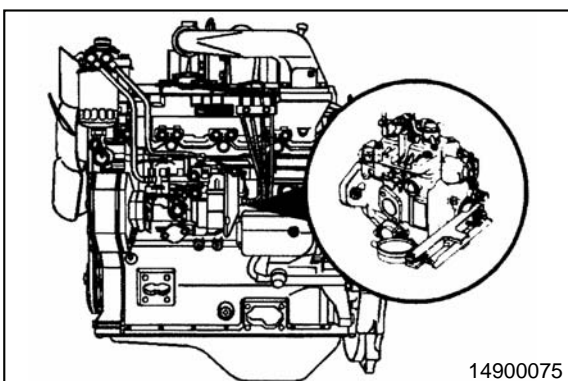
NOTE: Set the No. 1 cylinder at compression top dead center (TDC) by aligning the pointer on the gear cover with the TDC line on the crankshaft pulley.

14900073



Remove the distributor head bolt and copper washer from the injection pump. Discard the copper washer.

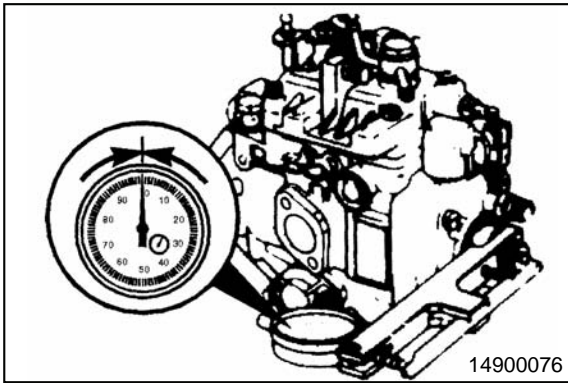
14900074



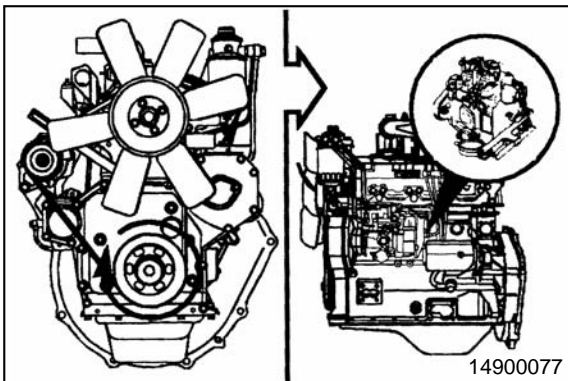
Install the dial gauge, Part No. 3377259, into the distributor head.

NOTE: Check that the stylus end of the dial gauge contacts the plunger head.

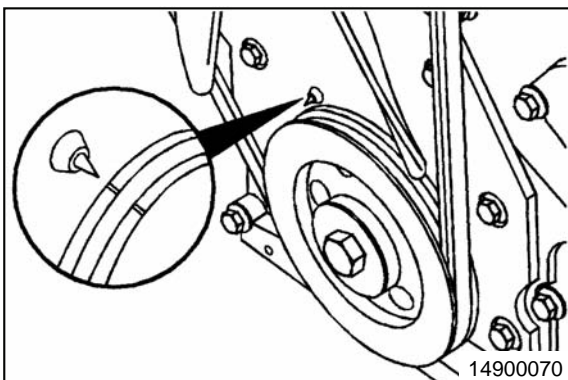
14900075



Rotate the crankshaft opposite normal engine rotation (**counterclockwise**) slightly, until the dial gauge does **not** move any longer.
Set the dial gauge pointer to 0.



Rotate the crankshaft in the normal direction until the dial gauge reads 1.0 ± 0.3 mm [0.04 ± 0.01 in].

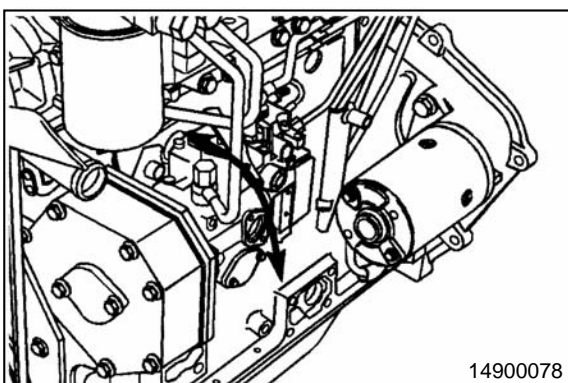


Look at the pointer on the crankshaft. It should point to the timing mark in degrees as stamped on the dataplate. The timing marks on the crank pulley range from 6 to 14 degrees in two degree increments.

NOTE: Check the values on the data plate. Values may change as new ratings are developed.

NOTE: The gauge reading ± 0.03 mm [0.001 in] is equivalent to ± 0.5 degrees fuel injection timing.

NOTE: The crankshaft **must** be rotated in the normal direction (**clockwise** looking from the front of the engine) without stopping.

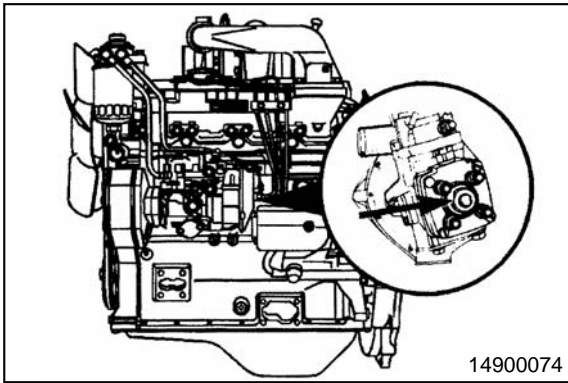


If the dial readings are **not** within the standard value, loosen nut. Adjust the fuel injection timing to within standard value by rotating the injection pump body. Tighten the nut.



Torque Value: 31 N•m [23 ft-lb]





Remove the dial gauge.

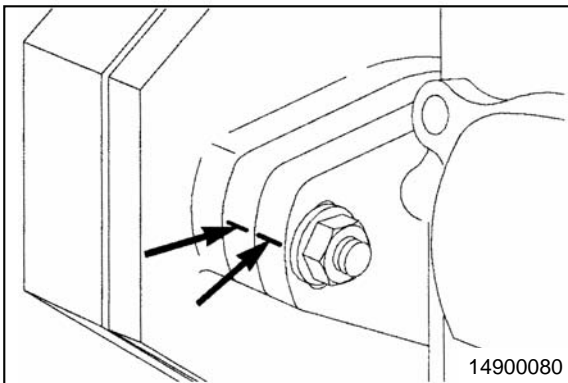


Install the distributor head bolt and new copper washer into the injection pump.

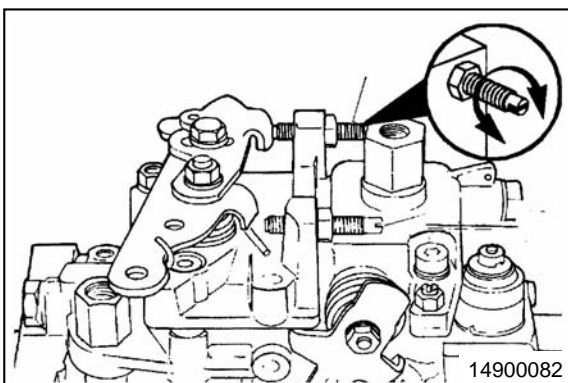


Tighten the bolt.

Torque Value: 17 N•m [13 ft-lb]



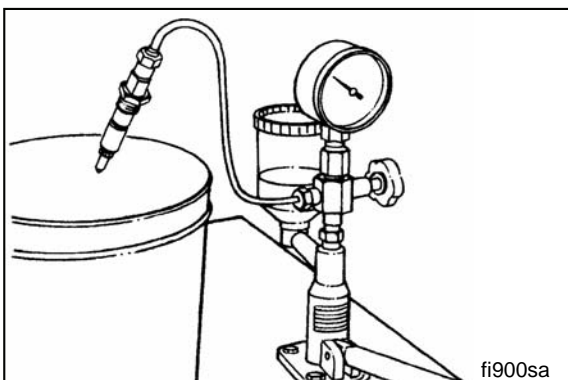
Stamp a match mark on the injection pump and the timing gear case.



Adjusting the Idle



Move the governor control lever to the desired idling speed by using the idling adjustment screw.



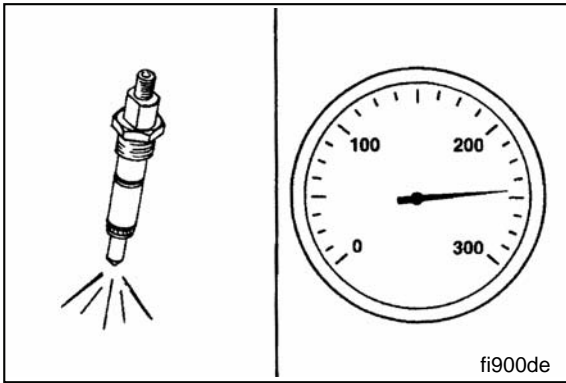
Injector

Testing

WARNING

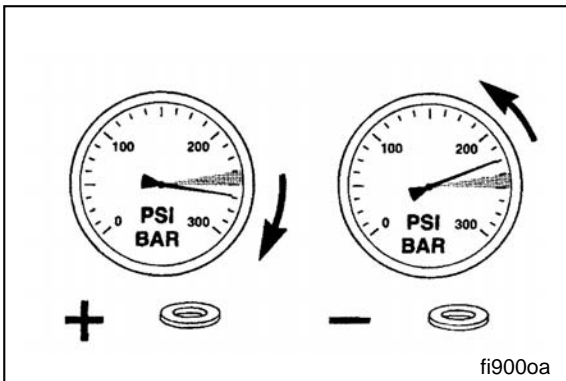
Keep your body clear of test spray. Fluid can be injected into the bloodstream causing blood poisoning and possible death.

NOTE: All nozzles **must** be tested for opening pressure, chatter and spray pattern.



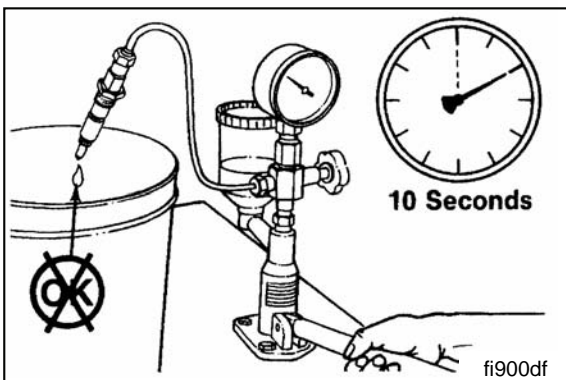
Check the opening pressure.

- Open valve.
- Operate lever at one stroke per second.
- Read pressure indicated when spray begins.



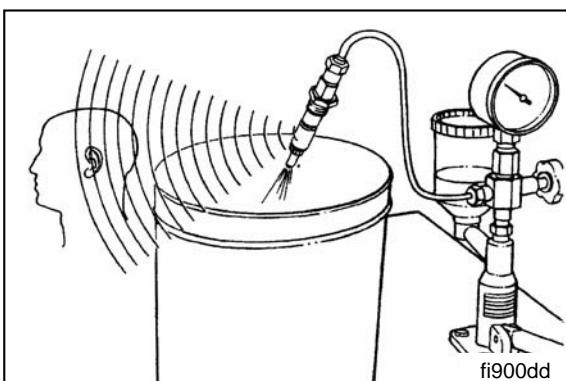
If the opening pressure is out of specification, disassemble the injector and change the shims in order to change the opening pressure.

NOTE: .01 mm [0.0039 in] shim thickness equals 41 bar [595 psi].



Leakage Test

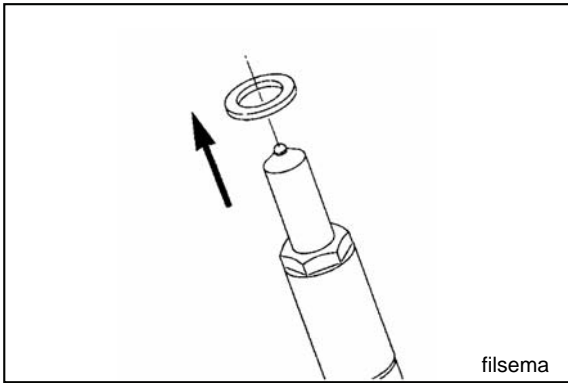
- Open the valve.
- Operate the lever to hold pressure 20 bar [290 psi] below opening pressure.
- No drops should fall from the tip within 10 seconds.



Chatter Test

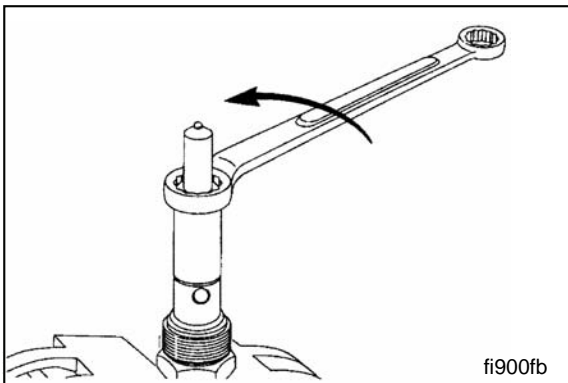
The chatter test indicates the ability of the needle valve to move freely and correctly atomize the fuel. An audible sound should be heard as the valve rapidly opens and closes. A well optimized spray pattern should be seen.

Used nozzles should **not** be evaluated for chatter at lower speeds. A used nozzle can generally be used if it passes the leakage test.

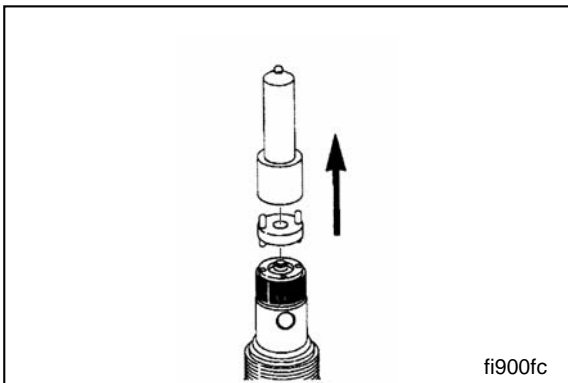


Disassembly

Remove the copper sealing washer and discard.

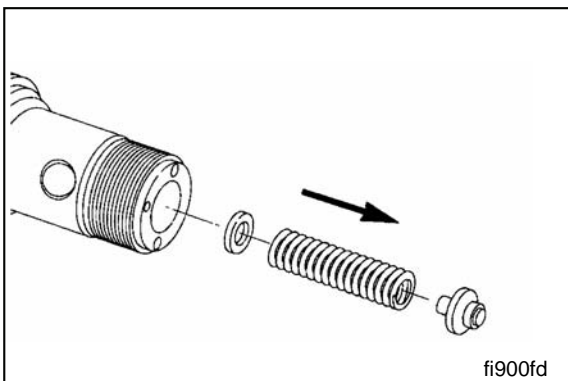


Clamp the nozzle holder in a soft jawed vise and remove the nozzle nut.

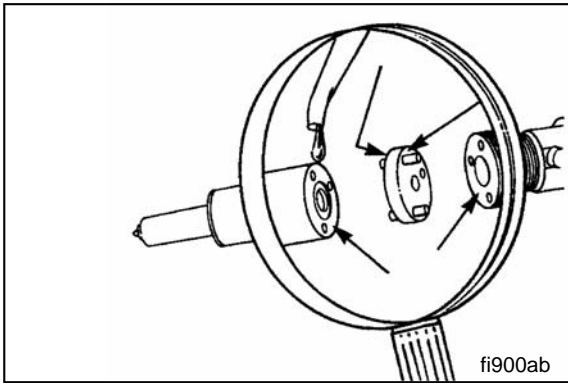


Remove the nozzle needle valve and intermediate plate.

NOTE: To avoid damage, place the injector nozzle and needle valve in a suitable bath of clean test oil.

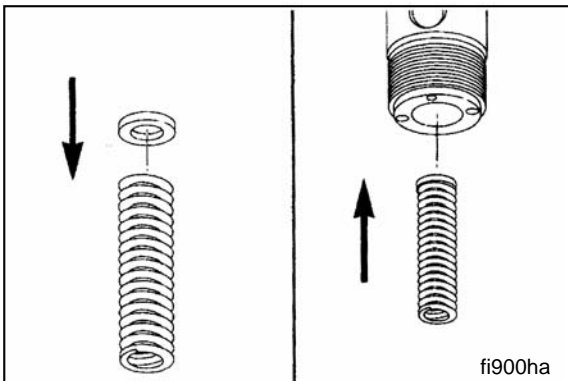


Remove the nozzle holder from the vise; then remove the pressure spindle, pressure spring, and shims.



Assembly

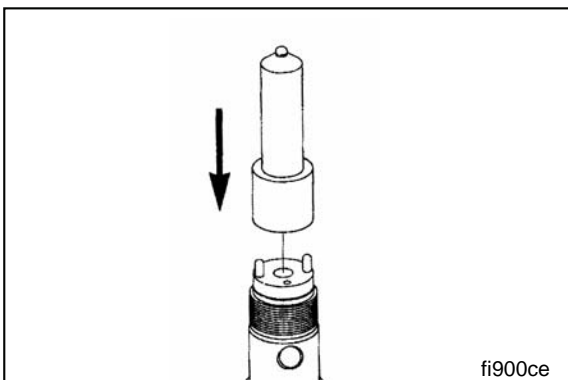
NOTE: Make sure all mating surfaces and pressure faces are clean and lubricated with fuel oil before assembly.



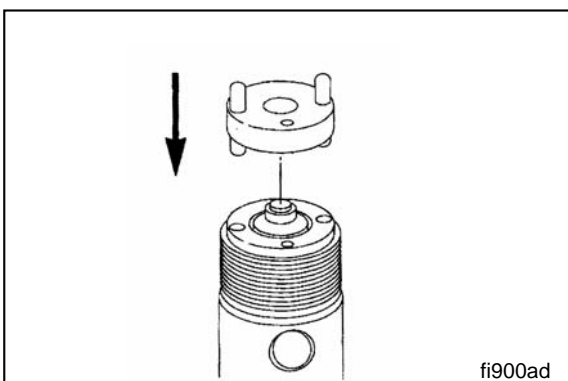
WARNING

Install the same thickness of shims that were removed in disassembly. Use the pressure spring to make sure the shims are installed flat.

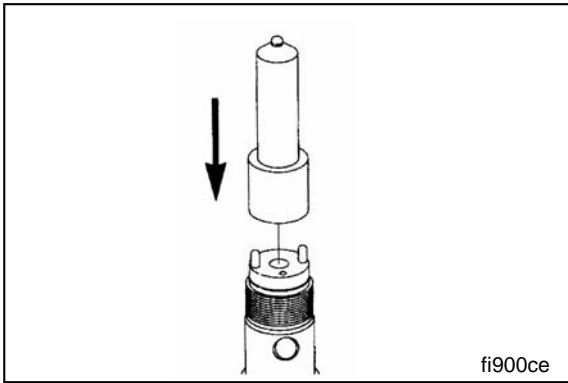
Install the shims.



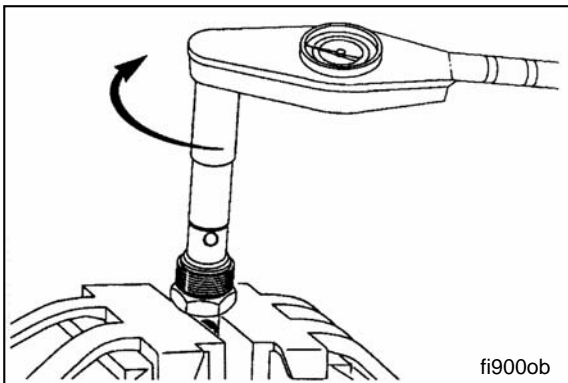
Clamp the nozzle holder in a soft jawed vise and install the spindle.



Install the intermediate plate.



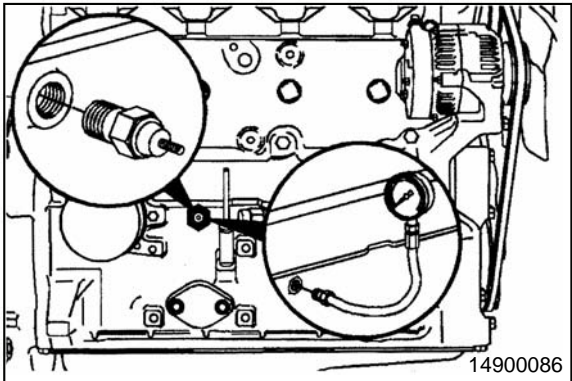
Install the needle valve and nozzle assembly.



Install the nozzle nut.

Lubricating System

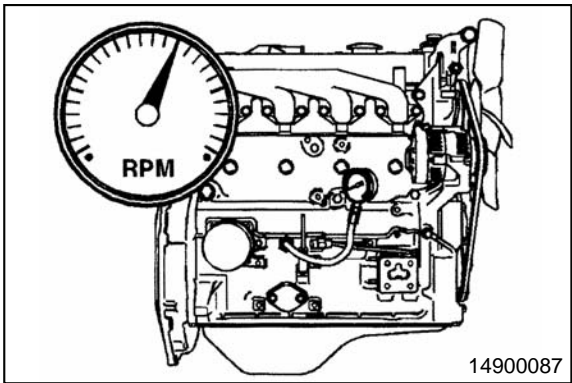
Measuring Oil Pressure



⚠ WARNING

When measuring the oil pressure, be careful not to get caught in rotating parts. always remove or install plug or oil pressure gauges with the engine stopped.

Remove the oil pressure sensor, and install the pressure gauge.



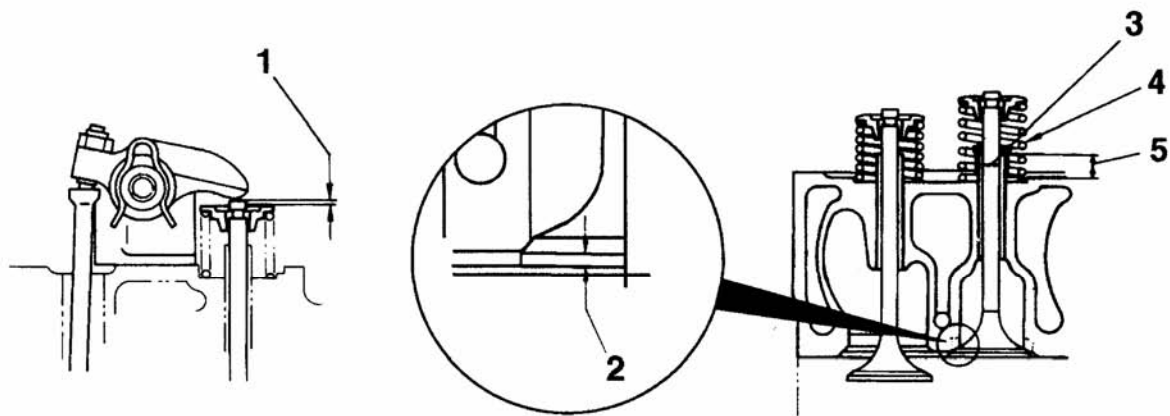
NOTE: Measure the oil pressure while the engine is warm (oil temperature minimum: 82° C [180° F]).

Start the engine, and measure the oil pressure.

Lubricating Oil Pressure		
kPa		ft-lb
210	MIN	30
700	MAX	102

Specifications

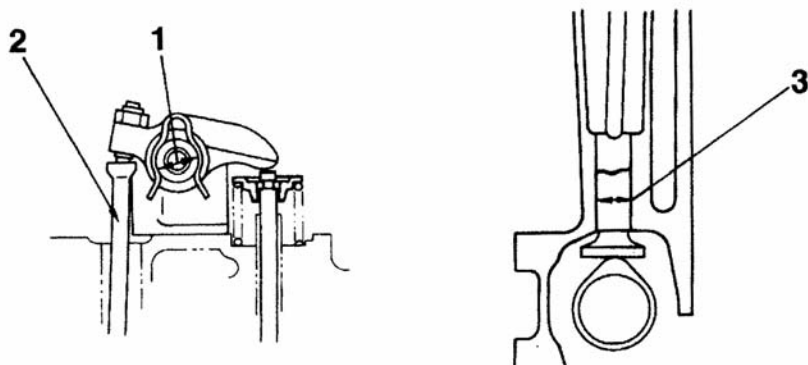
Valves, Valve Guides, and Springs



18900014

Ref	Inspection Item		Standard	Remarks
VALVES				
3	Stem Diameter	Intake	Nominal: 8 mm [0.3130 in]	Tolerance: -0.035 mm [-0.0014 in] -0.050 mm [-0.0020 in]
		Exhaust		Tolerance: -0.050 mm [-0.0020 in] -0.065 mm [-0.0026 in]
	Clearance Between Guide and Stem	Intake	0.035 to 0.065 mm [0.0014 to 0.0026 in]	Clearance Limit: 0.20 mm [0.0079 in]
		Exhaust	0.050 to 0.080 mm [0.0020 to 0.0031 in]	
2	Head Thickness	Intake	1.40 to 1.60 mm [0.0551 to 0.0630 in]	Repair Limit: 1.00 mm [0.039 in]
		Exhaust		
1	Valve Clearance (at Cold and Warm)	Intake	0.35 mm [0.0138 in]	Tolerance: ±0.02 mm [±0.0008 in]
		Exhaust	0.50 mm [0.0197 in]	
VALVE GUIDE				
5	Protrusion Above Cylinder Head Surface	Intake	14.5 mm [0.571 in]	Tolerance: ±0.2 mm [±0.0079 in]
		Exhaust		
VALVE SPRING				
4	Free-Length		49.2 mm [1.94 in]	Repair Limit: 48.5 mm [1.90 in]
	Installed Length		40.5 mm [1.59 in]	—
	Installed Load		18.5 ±0.9 kg [40.8±2.0 lb]	Repair Limit: 16.5 kg [36.4 lb]
	Squareness		—	Repair Limit: 1.85

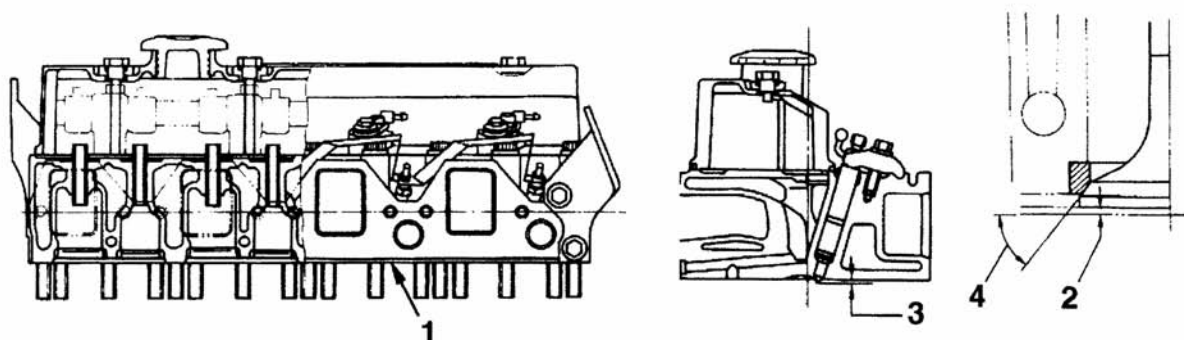
Rocker Arm Shaft, Push Rod and Tappets



18900016

Ref	Inspection Item	Standard	Remarks
VALVE ROCKER ARM SHAFT			
1	Diameter of Shaft	19 mm [0.75 in]	Tolerance: -0.020 mm [-0.0008 in]
	Diameter of Rocker Arm Shaft Hole	Nominal: 19 mm [0.75 in]	Tolerance: 0.030 mm [0.0012 in] 0.010 mm [0.0004 in]
	Clearance Between Rocker Arm and Shaft	0.010 to 0.050 mm [0.0004 to 0.0020 in]	Clearance Limit: 0.12 mm [0.0047 in]
	Bend of Shaft	—	Repair Limit: 0.20 mm [0.0079 in]
PUSH ROD			
2	Bend of Push Rod	—	Repair Limit: 0.30 mm [0.012 in]
TAPPET			
3	Clearance Between Tappet and Tappet Hole	0.012 to 0.048 mm [0.0005 to 0.0020 in]	Clearance Limit: 0.12 mm [0.0047 in]

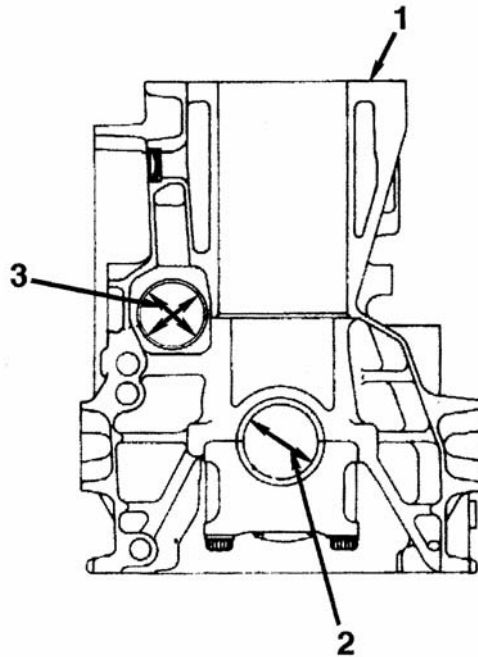
Cylinder Head



18900011

Ref	Inspection Item		Standard	Remarks	
CYLINDER HEAD					
1	Surface Flatness (Warpage Limit)		0.00 to 0.05 mm [0.00 to 0.002 in]	Repair Limit: 0.30 mm [0.012 in]	
2	Valve Seat	Intake	1.00 ±0.100 mm [0.039 ±0.004 in]	Repair Limit: 2.00 mm [0.079 in]	
		Exhaust	0.90 ±0.100 mm [0.035 ±0.004 in]	Repair Limit: 1.90 mm [0.075 in]	
3	Nozzle (Protrusion)		3.12 ±0.28 mm [0.123 ±0.011 in]	Tolerance: 2.700 to 3.500 mm [0.106 to 0.138 in]	
4	Valve Seat	Angle	45°	Tolerance: ±0°15'	Repair Limit: Judge condition of contact surface by vacuum test.

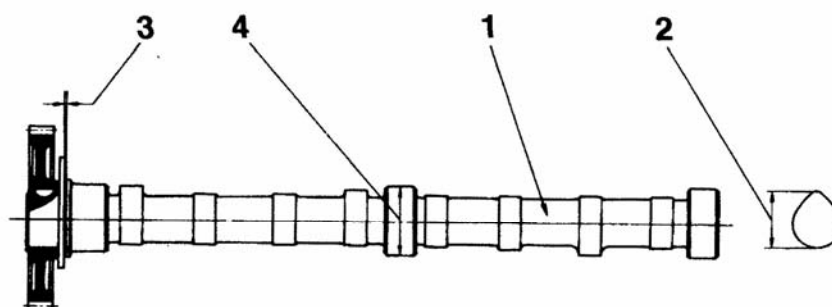
Cylinder Block



18900012

Ref	Inspection Item		Standard	Remarks
CYLINDER BLOCK				
1	Surface Flatness (Warpage Limit)		0.00 to 0.08 mm [0.00 to 0.003 in]	Repair Limit: 0.15 mm [0.006 in]
2	Inner Diameter of Main Bearing	STD	70.000 mm [2.756 in]	Repair Limit: 70.200 mm [2.764 in]
		U/S 0.25	69.750 mm [2.746 in]	Repair Limit: 69.950 mm [2.754 in]
		U/S 0.50	69.500 mm [2.736 in]	Repair Limit: 69.700 mm [2.744 in]
		U/S 0.75	69.250 mm [2.726 in]	Repair Limit: 69.450 mm [2.734 in]
		U/S 1.00	69.000 mm [2.717 in]	Repair Limit: 69.200 mm [2.724 in]
3	Inner Diameter of Cam Bushing		50.500 mm [1.988 in]	Repair Limit: 50.600 mm [1.992 in]

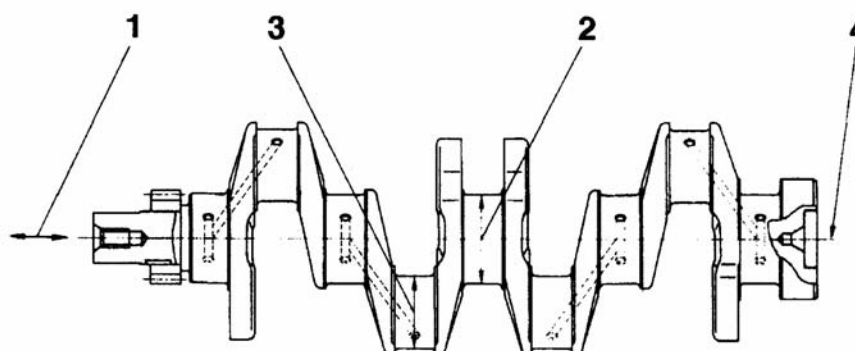
Camshaft and Camshaft Bushing



18900015

Ref	Inspection Item		Standard	Remarks
CAMSHAFT				
			Naturally Aspirated	Naturally Aspirated
1	Bend of Shaft		—	0.03 mm [0.0012 in]
2	Cam Height	Intake	42.69 mm [1.681 in]	Repair Limit: 42.20 mm [1.661 in]
		Exhaust	43.04 mm [1.694 in]	Repair Limit: 42.50 mm [1.673 in]
3	Thrust Clearance		0.150 to 0.350 mm [0.0059 to 0.0138 in]	Repair Limit: 0.50 mm [0.0197 in]
CAMSHAFT BUSHING				
4	Clearance to Cam	No. 1 No. 2 No. 3	0.040 to 0.140 mm [0.0016 to 0.0055 in]	Repair Limit: 0.25 mm [0.0098 in]

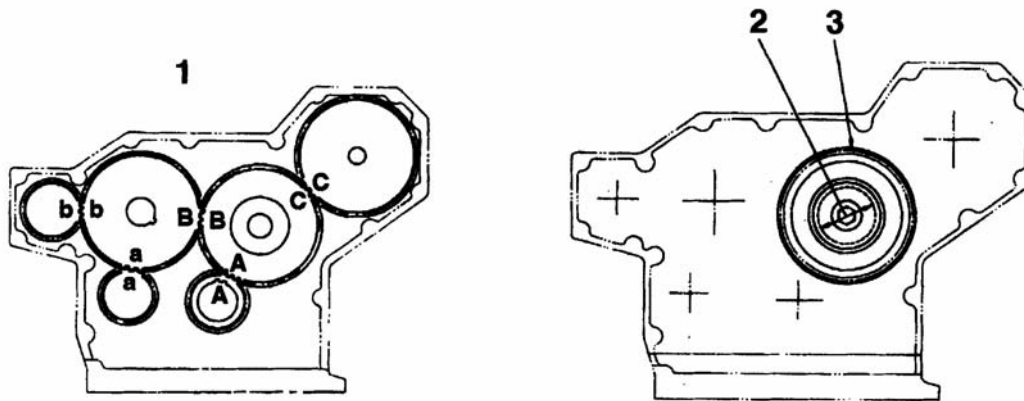
Crankshaft



18900019

Ref	Inspection Item		Standard	Remarks
CRANKSHAFT				
1	Thrust Clearance		0.131 to 0.351 mm [0.0052 to 0.0138 in]	Repair Limit: 0.40 mm [0.016 in]
2	Main Journal	STD	70.000 mm [2.756 in]	Repair Limit: 69.86 mm [2.750 in]
		U/S 0.25	69.75 mm [2.746 in]	Repair Limit: 69.61 mm [2.741 in]
		U/S 0.50	69.50 mm [2.736 in]	Repair Limit: 69.36 mm [2.731 in]
		U/S 0.75	69.25 mm [2.726 in]	Repair Limit: 69.11 mm [2.721 in]
		U/S 1.00	69.00 mm [2.717 in]	Repair Limit: 68.86 mm [2.711 in]
	Roundness		—	Repair Limit: 0.020 mm [0.0008 in]
	Clearance		0.043 to 0.103 mm [0.0017 to 0.0041 in]	Clearance Limit: 0.25 mm [0.0098 in]
3	Crank Pin Journal	STD	57.000 mm [2.244 in]	Repair Limit: 56.91 mm [2.241 in]
		U/S 0.25	56.750 mm [2.234 in]	Repair Limit: 56.66 mm [2.231 in]
		U/S 0.50	56.500 mm [2.224 in]	Repair Limit: 56.41 mm [2.221 in]
		U/S 0.75	56.250 mm [2.215 in]	Repair Limit: 56.16 mm [2.211 in]
		U/S 1.00	56.000 mm [2.205 in]	Repair Limit: 55.91 mm [2.201 in]
	Roundness		—	Repair Limit: 0.020 mm [0.0008 in]
	Clearance of Crank Pin Journal		0.029 to 0.089 mm [0.0011 to 0.0035 in]	Clearance Limit: 0.22 mm [0.0087 in]
4	Bend of Crankshaft		—	Repair Limit: 0.09 mm [0.0035 in]

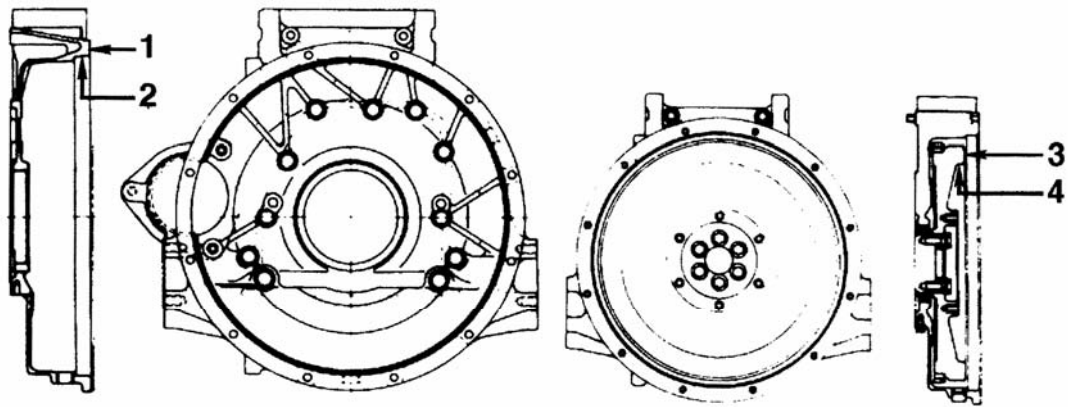
Timing Gear



18900018

Ref	Inspection Item			Standard	Remarks
TIMING GEAR					
				Naturally Aspirated	Replacement Limit: 0.40 mm [0.0157 in]
1	Bend of Shaft	A	Crankshaft gear and idler gear	0.08 mm to 0.19 mm [0.0031 in to 0.007 in]	
		B	Camshaft gear and idler gear	0.08 mm to 0.19 mm [0.0031 in to 0.007 in]	
		C	Injection pump gear and idler gear	0.07 mm to 0.29 mm [0.003 in to 0.011 in]	
		a	Camshaft gear and oil pump gear	0.07 mm to 0.29 mm [0.003 in to 0.011 in]	
		b	Camshaft gear and PTO gear	0.15 mm to 0.30 mm [0.006 in to 0.012 in]	
2	Clearance Between Bushing and Shaft			0.015 mm to 0.050 mm [0.0006 in to 0.002 in]	Replacement Limit: 0.10 mm [0.0039 in]
3	End Play of Idler Gear			0.03 mm to 0.09 mm [0.0012 in to 0.0035 in]	Replacement Limit: 0.20 mm [0.0079 in]

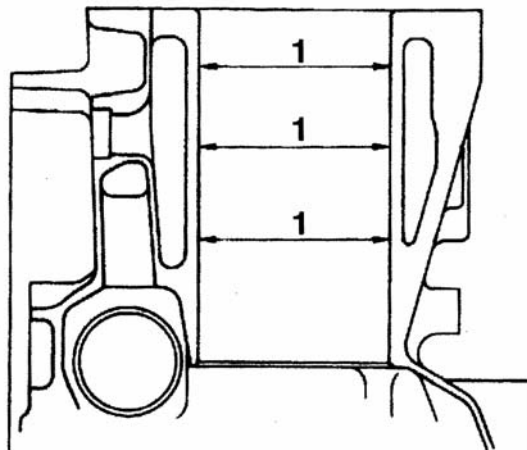
Flywheel



18900013

Ref	Inspection Item	Standard	Remarks
FLYWHEEL			
1	Face Runout of Flywheel Housing	—	Repair Limit: 0.30 mm [0.012 in]
2	Radial Runout of Flywheel Housing	—	Repair Limit: 0.35 mm [0.014 in]
3	Face Runout of Flywheel	—	Repair Limit: 0.15 mm [0.0059 in]
4	Radial Runout of Flywheel	—	Repair Limit: 0.20 mm [0.079 in]

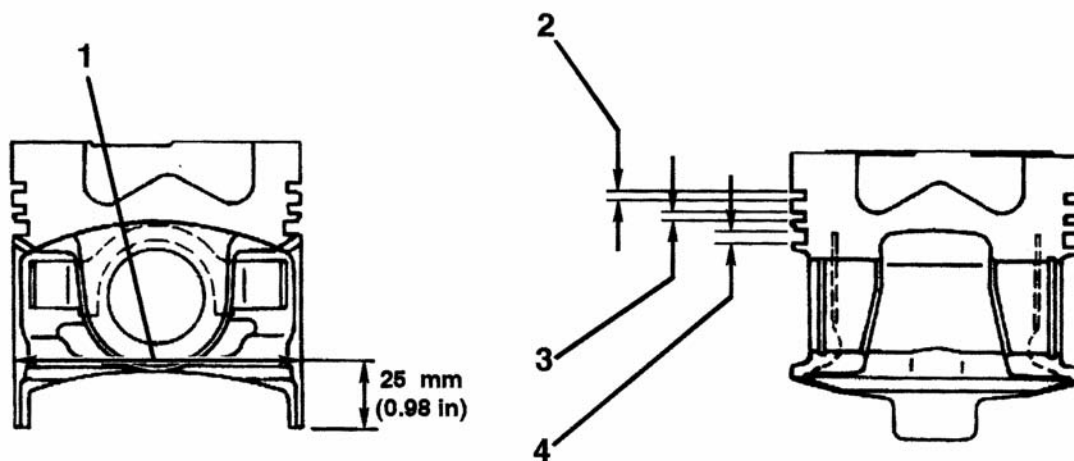
Cylinder



18900020

Ref	Inspection Item		Standard		Remarks
CYLINDER					
1	Bore	STD	ID: 95.00 mm [3.740 in]	Tolerance: 0.022 mm [0.0008 in]	Repair Limit: ID: 95.15 mm [3.746 in]
	Roundness of Cylinder		—		Repair Limit: 0.02 mm [0.0008 in]
	Cylindricity of Cylinder		—		

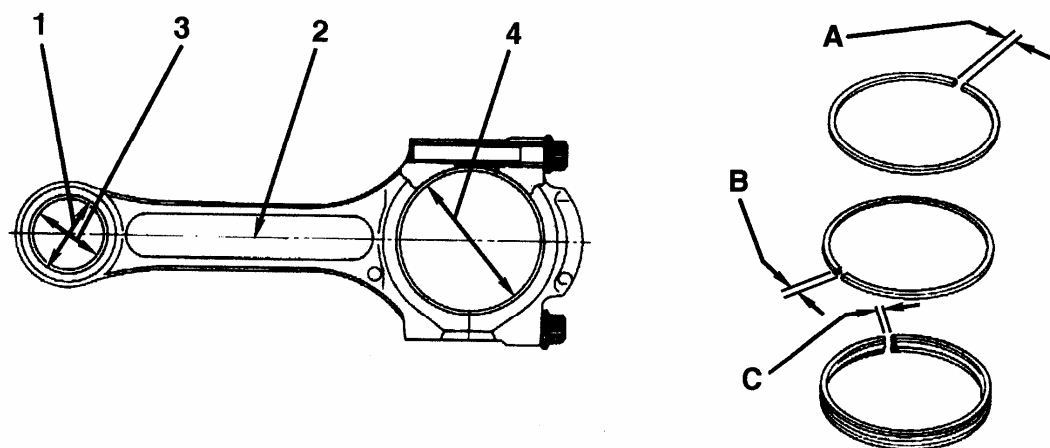
Piston



18900020

Ref	Inspection Item		Standard		Remarks
PISTON					
1	Diameter	STD	ID: 95.00 mm [3.740 in]		Repair Limit: ID: 94.85 mm [3.734 in]
2	Clearance Between Piston Ring Groove and Piston Ring	Top	0.06 to 0.10 mm [0.0024 to 0.0039 in]	2.0 mm [0.079 in]*	Repair Limit: 0.15 mm [0.0059 in]
3		Second	0.03 to 0.07 mm [0.0012 to 0.0028 in]	2.0 mm [0.079 in]*	Repair Limit: 0.20 mm [0.0079 in]
4		Oil		4.0 mm [0.158 in]*	Repair Limit: 0.15 mm [0.0059 in]
*Width of Groove (Nominal)					

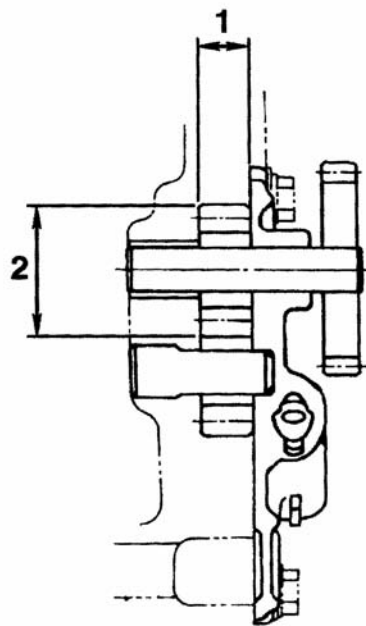
Connecting Rod, Piston Ring and Piston Pin



18900022

Ref	Inspection Item		Standard		Remarks
PISTON PIN					
1	Outer Diameter		Nominal OD: 30.00 mm [1.181 in]		—
	Clearance		0.004 to 0.018 mm [0.0002 to 0.0007 in]		Clearance Limit: 0.05 mm [0.002 in]
PISTON RING					
A	Piston Ring Gap	Top	0.30 to 0.45 mm [0.012 to 0.018 in]		Clearance Limit: 2.00 mm [0.079 in]
B		Second	0.30 to 0.45 mm [0.012 to 0.018 in]		Clearance Limit: 2.00 mm [0.079 in]
C		Oil	0.25 to 0.45 mm [0.0098 to 0.018 in]		Clearance Limit: 1.50 mm [0.059 in]
CONNECTING ROD					
2	Bend (B)/Torsion (T)		Maximum: 0.20/0.30 mm [0.0078/0.0118 in]		Repair Limit: 0.25/0.35 mm [0.0098/0.0138 in]
3	Inner Diameter of Bushing Hole		33.00 mm [1.299 in]		Tolerance: 0.025 mm [0.001 in]
CONNECTING ROD BUSHING					
1	Clearance Between Bushing and Piston Ring (Small End)		0.020 to 0.039 mm [0.0008 to 0.0015 in]	Nominal OD: 30.00 mm [1.18 in]	Clearance Limit: 0.100 mm [0.0039 in]
CONNECTING ROD BEARING					
4	Inner Diameter	STD	57.00 mm [2.244 in]		Repair Limit: 57.20 mm [2.252 in]

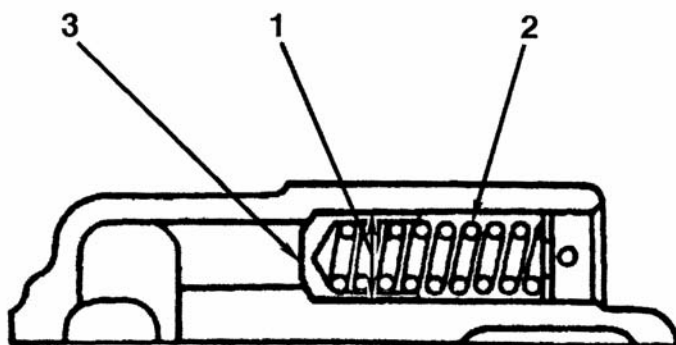
Oil Pump



18900017

Ref	Inspection Item		Standard	Remarks
1	Clearance of Pump Gear	Axial	0.030 to 0.085 mm [0.0012 to 0.0033 in]	Clearance Limit: 0.10 mm [0.0039 in]
2		Radial	0.045 to 0.090 mm [0.0018 to 0.0035 in]	Clearance Limit: 0.13 mm [0.0051 in]

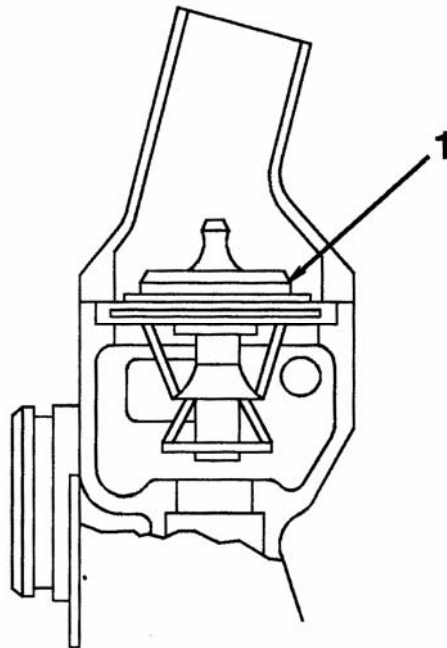
Regulator Valve



18900023

Ref	Inspection Item	Standard					Remarks
1	Clearance Between Valve and Body	Standard Size	Tolerance		Standard Clearance	Clearance Limit	
			Shaft	Hole			
		11 mm [0.43 in]	-0.050mm -0.077mm	0.020 mm -0.020mm	0.030 to 0.097 mm		
			[0.002 in] [0.003 in]	[0.0008 in] [0.0008 in]	[0.001 to 0.004 in]		
		Standard			Repair Limit		Replace
		Free- Length	Installed Length	Installed Load	Free- Length	Installed Load	
2	Regulator Valve Sprng Naturally Aspirated	33.1 mm [1.30 in]	27.8 mm [1.09 in]	2.44 kg [5.38 lb]	—	2.30 kg [5.07 lb]	
3	Regulator Valve Set Pressure	Standard: 5.0 ±0.5 kg/cm					Repair or Replace Spring

Thermostat



18900024

Ref	Inspection Item	Standard		Remarks
THERMOSTAT				
1	Thermostat	Cracking Temperature: 82° C ±2° C [180° F ±2° F] Fully Open Temperature: 95° C [203° F] Fully Open Lift: Minimum: 8 mm [0.315 in] (when immersed in a hot water bath at 95° C [203° F] for 4 to 5 minutes)	(Fully Open: Shall open fully when immersed in hot water bath at a temperature between 77° C [171° F] and 95° C [203° F] for 4 to 5 minutes)	Replace

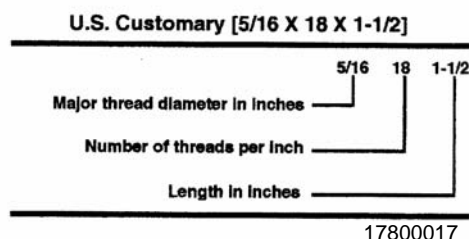
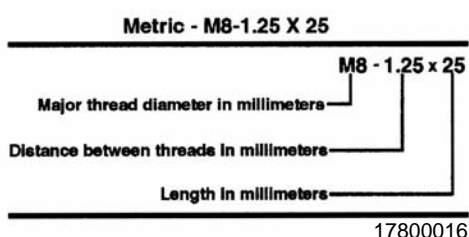
Capscrew Markings and Torque Values

⚠ CAUTION

When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using the wrong capscrews can result in engine damage.

Metric capscrews and nuts are identified by the grade number stamped on the head of the capscrew or on the surface of the nuts. U.S. Customary capscrews are identified by radial lines stamped on the head of the capscrew.

The following examples indicate how capscrews are identified:



NOTE:

1. **Always** use the torque values listed in the following tables when specific torque values are not available.
2. Do **not** use the torque values in place of those specified in other sections of this manual.
3. The torque values in the table are based on the use of lubricated threads.
4. When the ft-lb value is less than 10, convert the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.

Capscrew Markings and Torque Values - Metric

Commercial Steel Class

8.8

10.9




12.9

Capscrew Head Markings



Body Size	Torque				Torque				Torque			
	Cast Iron		Aluminum		Cast Iron		Aluminum		Cast Iron		Aluminum	
Diameter	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
6	9	5	7	4	13	10	7	4	14	9	7	4
7	14	9	11	7	18	14	11	7	23	18	11	7
8	23	17	18	14	33	25	18	14	40	49	18	14
10	45	33	30	25	65	50	30	25	70	50	30	25
12	80	60	55	40	115	85	55	40	125	95	55	40
14	125	90	90	65	180	133	90	65	195	145	90	65
16	195	140	140	100	280	200	140	100	290	210	140	100
18	280	200	180	135	390	285	180	135	400	290	180	135
20	400	290	-	-	550	400	-	-	-	-	-	-

Capscrew Markings and Torque Values - U.S. Customary

SAE Grade Number	5	8
Capscrew Head Markings These are all SAE Grade 5 (3 line)		
	Capscrew Torque - Grade 5 Capscrew	Capscrew Torque - Grade 8 Capscrew

Capscrew Body Size	Cast Iron		Aluminum		Cast Iron		Aluminum	
	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1/4 - 20	9	7	8	6	15	11	8	6
- 28	12	9	9	7	18	13	9	7
5/16 - 18	20	15	16	12	30	22	16	12
- 24	23	17	19	14	33	24	19	14
3/8 - 16	40	30	25	20	55	40	25	20
- 24	40	30	35	25	60	45	35	25
7/16 - 14	60	45	45	35	90	65	45	35
- 20	65	50	55	40	95	70	55	40
1/2 - 13	95	70	75	55	130	95	75	55
- 20	100	75	80	60	150	110	80	60
9/16 - 12	135	100	110	80	190	140	110	80
- 18	150	110	115	85	210	155	115	85
5/8 - 11	180	135	150	110	255	190	150	110
- 18	210	155	160	120	290	215	160	120
3/4 - 10	325	240	255	190	460	340	255	190
- 16	365	270	285	210	515	380	285	210
7/8 - 9	490	360	380	280	745	550	380	280
- 14	530	390	420	310	825	610	420	310
1 - 8	720	530	570	420	1100	820	570	420
- 14	800	590	650	480	1200	890	650	480

Fraction, Decimal, Millimeter Conversions

Fraction	inch	mm	Fraction	inch	mm
1/64	0.0156	0.397	33/64	0.5156	13.097
1/32	0.0313	0.794	17/32	0.5313	13.494
3/64	0.0469	1.191	35/64	0.5469	13.891
1/16	0.0625	1.588	9/16	0.5625	14.288
5/64	0.0781	1.984	37/64	0.5781	14.684
3/32	0.0938	2.381	19/32	0.5938	15.081
7/64	0.1094	2.778	39/64	0.6094	15.478
1/8	0.1250	3.175	5/8	0.6250	15.875
9/64	0.1406	3.572	41/64	0.6406	16.272
5/32	0.1563	3.969	21/32	0.6563	16.669
11/64	0.1719	4.366	43/64	0.6719	17.066
3/16	0.1875	4.763	11/16	0.6875	17.463
13/64	0.2031	5.159	45/64	0.7031	17.859
7/32	0.2188	5.556	23/32	0.7188	18.256
15/64	0.2344	5.953	47/64	0.7344	18.653
1/4	0.2500	6.350	3/4	0.7500	19.050
17/64	0.2656	6.747	49/64	0.7656	19.447
9/32	0.2813	7.144	25/32	0.7813	19.844
19/64	0.2969	7.541	51/64	0.7969	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.3281	8.334	53/64	0.8281	21.034
11/32	0.3438	8.731	27/32	0.8438	21.431
23/64	0.3594	9.128	55/64	0.8594	21.828
3/8	0.3750	9.525	7/8	0.8750	22.225
25/64	0.3906	9.922	57/64	0.8906	22.622
13/32	0.4063	10.319	29/32	0.9063	23.019
27/64	0.4219	10.716	59/64	0.9219	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.4531	11.509	61/64	0.9531	24.209
15/32	0.4688	11.906	31/32	0.9688	24.606
31/64	0.4844	12.303	63/64	0.9844	25.003
1/2	0.5000	12.700	1	1.0000	25.400

Conversion Factor: 1 inch = 25.4 mm

Newton-Meter to Foot-Pound Conversion Chart

N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1	8.850756 in-lb	55	41	155	114
5	44 in-lb	60	44	160	118
6	53 in-lb	65	48	165	122
7	62 in-lb	70	52	170	125
8	71 in-lb	75	55	175	129
9	80 in-lb	80	59	180	133
10	89 in-lb	85	63	185	136
1	0.737562 ft-lb	90	66	190	140
12	9	95	70	195	144
14	10	100	74	200	148
15	11	105	77	205	151
16	12	110	81	210	155
18	13	115	85	215	159
20	15	120	89	220	162
25	18	125	92	225	165
30	22	130	96	230	170
35	26	135	100	235	173
40	30	140	103	240	177
45	33	145	107	245	180
50	37	150	111	250	184
NOTE: To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.					

Pipe Plug Torque Values

Size		Torque		Torque	
Thread	Actual Thread O.D.	In Aluminum Components		In Cast Iron or Steel Components	
in	in	N•m	ft-lb	N•m	ft-lb
1/16	0.32	5	45 in-lb	15	10
1/8	0.41	15	10	20	15
1/4	0.54	20	15	25	20
3/8	0.68	25	20	35	25
1/2	0.85	35	25	55	40
3/4	1.05	45	35	75	55
1	1.32	60	45	95	70
1-1/4	1.66	75	55	115	85
1-1/2	1.90	85	65	135	100

Tap-Drill Chart - U.S. Customary and Metric

NOTE ON SELECTING TAP-DRILL SIZE: The tap drill size shown on this card give the theoretical tap drill size for approximately 60% and 75% of full thread depth. Generally, it is recommended that drill sizes be selected in the 60% range as these sizes will provide about 90% of the potential holding power. Drill sizes in the 75% range are recommended for shallow hole tapping (less than 1 1/2 times the hole diameter) in soft metals and mild steel.

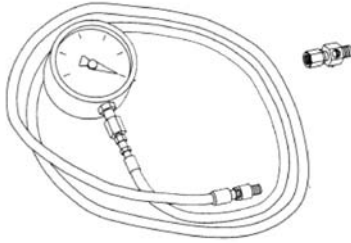
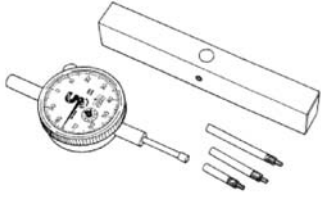
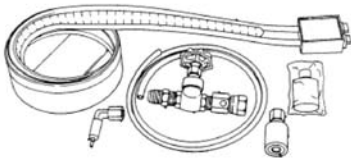

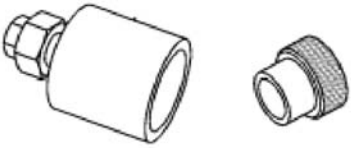
Tap Size		Drill Size	Tap Size		Drill Size	Tap Size		Drill Size	Tap Size		Drill Size
60%	75%		60%	75%		60%	75%		60%	75%	
		48		12-24	4.40mm			7.50mm			13.25mm
		1.95mm			16			19/64		5/8-11	17/32
		5/64			4.50mm			7.60mm		M15x1.5	13.50mm
	3-48	47			15			N			13.75mm
	M2.5x.45	2.00mm		M5.5x.9	4.60mm		M9x1.25	7.70mm		M16x2	35/64
		2.05mm	12-24	12-28	14			7.75mm			14.00mm
		46			13			7.80mm		M16x1.5	14.25mm
		45			4.70mm			7.90mm		5/8-18	9/16
3-48	3058	2.10mm	M6.5x.9		4.75mm		3/8-16	5/16		M16x2	14.50mm
M2.5x.45	M2.6x.46	2.15mm	12-28		3/16		M9x1	8.00mm		5/8-18	37/64
3-56	4-36	44			12			O			14.75mm
		2.20mm			4.80mm		M9x1.25	8.10mm		M16x1.5	15.00mm
M2.6x.45		2.25mm			11			8.20mm			19.32
4-36	4-40	43			4.90mm			P			15.25mm
		2.30mm			10			8.25mm			39/64
		2.35mm			9		3/8-16	8.30mm		M17x1.5	15.50mm
4-40	4-48	42		M6x1	5.00mm			21/64		M18x2.5	15.75mm
		3/32			8			8.40mm			5/8
	M3x.6	2.40mm		1/4-20	5.10mm		3/8-24	Q		M18x2.5	16.00mm
4-48		41			7		M10x1.5	8.50mm		M18x2	16.25mm
		2.45mm			13/64			8.60mm			41/64
		40			6			R		3/4-10	16.50mm
M3x.6	M3x.5	2.50mm		M6x1	5.20mm		3/8-24	8.70mm		M18x1.5	16.75mm
		39			5		1/8-27NPT	11/32		M19x2.5	21/32
	5-40	38		M6x.75	5.25mm			M10x1.25			17.00mm
M3x.6		2.60mm			5.30mm		M10x1.5	8.80mm			43/64
5-40	5-44	37		1/4-20	5.40mm			S			17.25mm
		2.70mm		M6x.75	3		M10x1.25	8.90mm		3/4-16	11/16
5-44	6-32	36			5.50mm			9.00mm		M20x2.5	17.50mm
		2.75mm			7/32			T			17.75mm
		7/64			2			9.10mm		M20x2	45/64
		35		1/4-28	5.60mm			23/64		M20x2.5	18.00mm
		2.80mm			2			9.20mm			18.25mm
		34			5.70mm		M10x1	9.30mm			23/32
6-32	6-40	33			5.75mm			U		M20x1.5	18.50mm
	M3.5x6	2.90mm			1			9.40mm			47/64
		32			5.80mm			9.50mm		M20x1.5	18.75mm
M3.5x6		3.00mm			5.90mm		M11x1.5	3/8			19.00mm
6-40		31			A			V			3/4
		3.10mm			15/64			9.60mm			19.25mm
		1/8			6.00mm			9.70mm		7/8-9	49/64
		3.20mm			B		M11x1.5	9.75mm		M22x2.5	19.50mm
		3.25mm			6.10mm		7/16-14	9.80mm			25/32
	M4x.75	30			C			W		7/8-9	19.75mm
		3.30mm			6.20mm			9.90mm		M22x2.5	20.00mm
M4x.75		3.40mm			D			25/64		M22x2	51/64
M4x.7	8-32	29		M7x.75	6.25mm		7/16-20	10.00mm		7/8-14	20.25mm
		3.50mm			6.30mm			X		M22x1.5	20.50mm
8-32	8-36	28			E			10.20mm			13/16
		9/64			1/4			Y		M22x1.5	20.75mm
		3.60mm			6.40mm			13/32			21.00mm
8-36		27			6.50mm			Z		M24x3	53/64
		3.70mm			F			10.50mm			21/25mm
		26		5/16-18	6.60mm		M12x1.75	1/2-13			27/32
		3.75mm			G			27/64		M24x3	21.50mm
	M4.5x.75	25			6.70mm		M12x1.5	10.75mm			21.75mm
	10-24	3.80mm			17/64		M12x1.25	11.00mm			55/64
		24			6.75mm		1/2-13	7/16			22.00mm
		3.90mm			H		1/4-18NPT			M24x2	7/8
M4.5x.75		23			6.80mm			11.25mm			22.25mm
		5/32			6.90mm			11.50mm		M24x2	22.50mm
		22			I			11.75mm		1"-8	57/64
10-24		4.00mm		5.16-24	7.00mm			11.50mm		M24x1.5	22.75mm
	M5x1	21			J			29/64			23.00mm
	10-32	20		M8x1.25	7.10mm			15/32		M25x2	29/32
		4.10mm			K		1/2-20	12.00mm		1"-12	23.25mm
M5x1	M5x.9	4.20mm		5/16-24	9/32		9/16-12	12.25mm		1"-14	59/64
10-32	M5x.8	19			7.20mm		M14x2	12.50mm		M25x1.5	23.50mm
M5x.9		4.25mm			7.25mm			31/64			23.75mm
M6x.8		4.30mm			7.30mm		M14x1.5	12.75mm			15/16
		18			L		9/16-18	1/2			
		11/64			7.40mm			13.00mm			
		17			M			33/64			

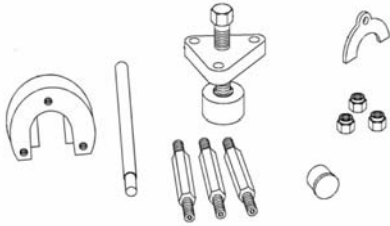
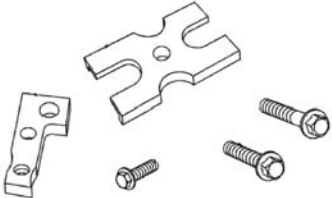
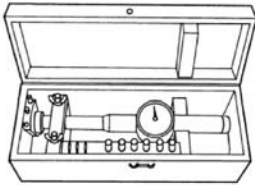

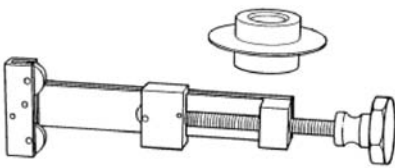
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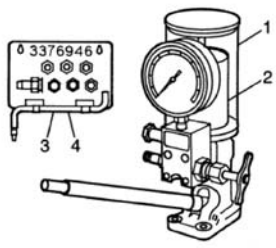
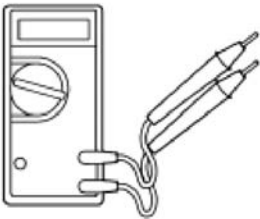

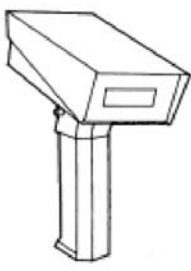
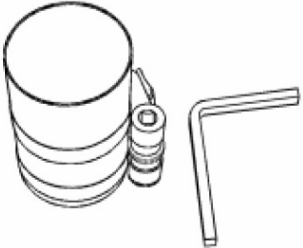
Weight and Measures - Conversion Factors

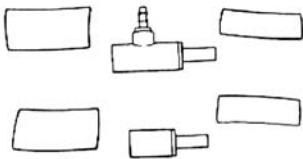


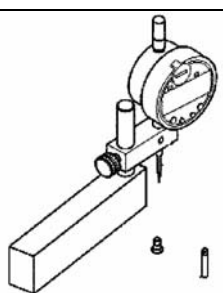
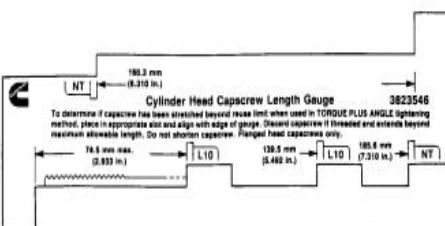
Quantity	U.S. Customary		Metric		From U.S. Customary To Metric Multiply By	From Metric To U.S. Customary Multiply By
	Unit Name	Abbreviation	Unit Name	Abbr.		
Area	sq. inch	in ²	sq. millimeters	mm ²	645.16	0.001550
			sq. centimeters	cm ²	6.452	0.155
	sq. foot	ft ²	sq. meter	m ²	0.0929	10.764
Fuel Consumption	pounds per horsepower hour	lb/hp-hr	grams per kilowatt hour	g/kW-hr	608.277	0.001645
Fuel Performance	miles per gallon	mpg	kilometers per liter	km/l	0.4251	2.352
	gallons per mile	gpm	liters per kilometer	l/km	2.352	0.4251
Force	pounds force	lbf	Newton	N	4.4482	0.224809
Length	inch	in	millimeters	mm	25.40	0.039370
	foot	ft	millimeters	mm	304.801	0.00328
Power	horsepower	hp	kilowatt	kW	0.746	1.341
Pressure	pounds force per sq. inch	psi	kilopascal	kPa	6.8948	0.145037
	inches of mercury	in Hg	kilopascal	kPa	3.3769	0.29613
	inches of water	in H ₂ O	kilopascal	kPa	0.2488	4.019299
	inches of mercury	in Hg	millimeters of mercury	mm Hg	25.40	0.039370
	inches of water	in H ₂ O	Millimeters of water	mm H ₂ O	25.40	0.039370
	bars	bars	kilopascals	kPa	100.001	0.00999
	bars	bars	millimeters of mercury	mm Hg	750.06	0.001333
Temperature	fahrenheit	°F	centigrade	°C	(°F-32)÷1.8	(1.8x°C) +32
Torque	pound force per foot	ft-lb	Newton-meter	N•m	1.35582	0.737562
	pound force per inch	in-lb	Newton-meter	N•m	0.113	8.850756
Velocity	miles/hour	mph	kilometers/hour	kph	1.6093	0.6214
Volume: liquid displacement	gallon (U.S.)	gal.	liter	l	3.7853	0.264179
	gallon (Imp*)	gal.	liter	l	4.546	0.219976
	cubic inch	in ³	liter	l	0.01639	61.02545
	cubic inch	in ³	cubic centimeter	cm ³	16.387	0.06102
Weight (mass)	pounds (avoir.)	lb	kilograms	kg	0.4536	2.204623
Work	British Thermal Unit	BTU	joules	J	1054.5	0.000948
	British Thermal Unit	BTU	kilowatt-hour	kW-hr	0.000293	3414
	horsepower hours	hp-hr	kilowatt-hour	kW-hr	0.746	1.341

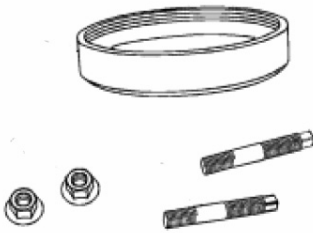

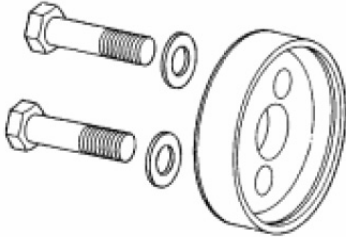
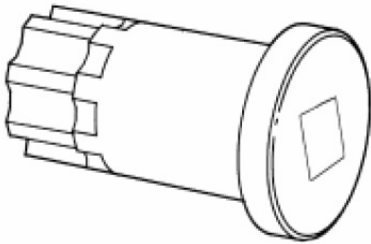
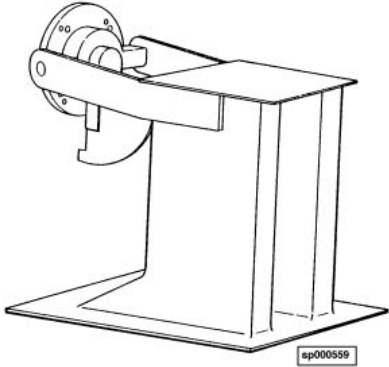
SPECIAL TOOLS

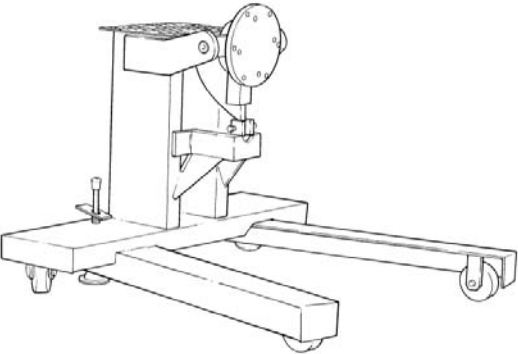
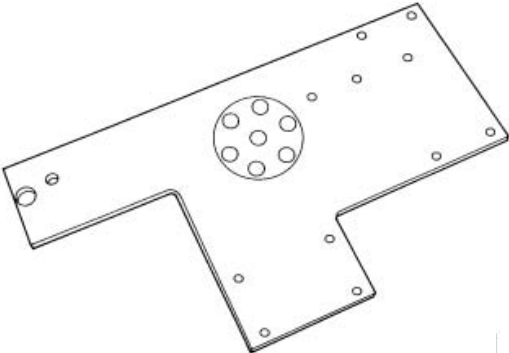
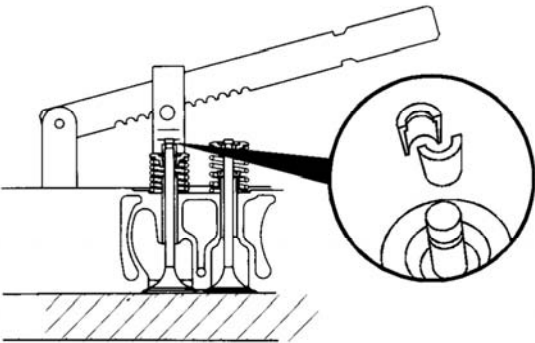
Style	Tool No.	Tool name
	ST 434	Vacuum Gauge
	ST 537	Dial Depth Gauge
	ST 1111-3	Seal Leakage Tester
	ST 1273	Pressure Gauge
	3162745	Injector/Connector Removal tool

Style	Tool No.	Tool name
	3163054	Camshaft Gear R&I Tool
	3163292	Valve spring compressor
	3375072	Dial Bore Gauge Kit
	3375432	Crack Detection Kit
	3376579	Tube(Filter) Cutter

Style	Tool No.	Tool name
 <p>Diagram of an injector nozzle tester. It features a pressure gauge (1) and a nozzle (2). A control unit with a scale from 0 to 33769460 and four ports (3, 4) is shown. A long nozzle is also depicted.</p>	3376946	Injector nozzle tester
 <p>Diagram of a digital multimeter with two test leads.</p>	3377161	Digital multimeter
 <p>Diagram of a fuel pump timing tool, which is a long, thin rod with a circular gauge at one end.</p>	3377259	Fuel Pump Timing tool
 <p>Diagram of a digital optical tachometer, consisting of a rectangular head and a vertical stand.</p>	3377462	Digital optical tachometer
 <p>Diagram of a piston ring compressor, showing a cylindrical component and a long, thin rod.</p>	3397773	Piston Ring Compressor

Style	Tool No.	Tool name
	3822476	Blow By tool, use with ST111-3
	3822666	Digital Thermometer (Dual Input)
	3823137	Piston ring expander
	3164438	Depth Gauge Assembly
 <p>Cylinder Head Capcrew Length Gauge 3823546</p> <p>To determine if capcrew has been stretched beyond reuse limit when used in TORQUE PLUS ANGLE tightening method, place in appropriate slot and align with edge of gauge. Discard capcrew if threaded end extends beyond maximum allowable length. Do not shorten capcrew. Flanged head capcrews only.</p> <p>18.8 mm (0.74 in.) 11.0 120.5 mm (4.74 in.) 185.6 mm (7.31 in.) NT</p>	3823956	Fuel Pump Mounting Kit

Style	Tool No.	Tool name
	3824078	Oil Seal/Sleeve Installation Tool (rear)
	3824498	Oil Seal Installation Tool
	3824500	Wear Sleeve Installation Tool
	3824591	Engine Barring Tool
	3375193	Engine Rebuild Stand

Style	Tool No.	Tool name
	3375194	Engine Rebuild Stand (Portable)
	3163625	Bracket
	3397890	Flange Puller