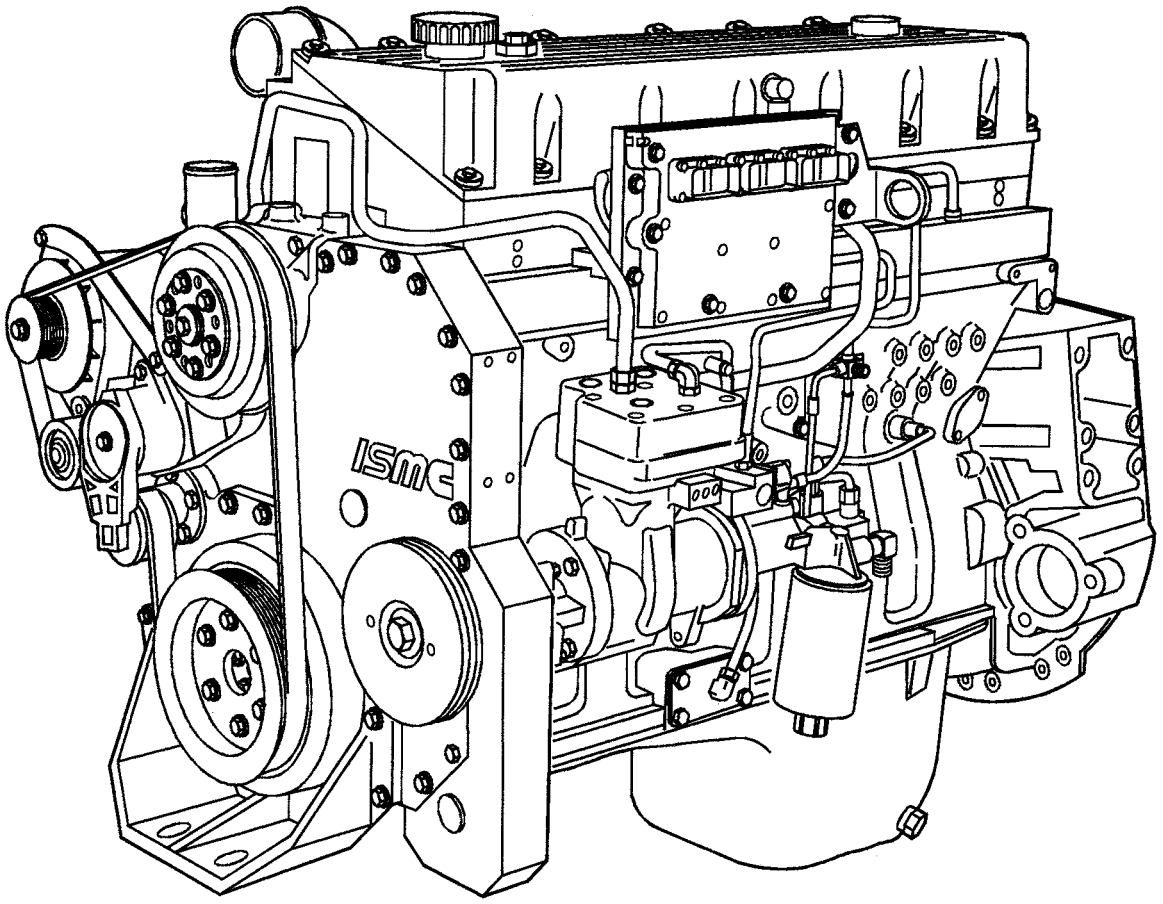
Troubleshooting and Repair Manual
ISM/QSM11 Series Engines



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Foreword

This manual provides instructions for troubleshooting and repairing this engine in the chassis. Component and assembly rebuild procedures are provided in the engine shop manual. Refer to Section i - Introduction for instructions on how to use this manual.

Read and follow all safety instructions. Refer to the WARNING in the General Safety Instructions in Section i - Introduction.

The manual is organized to guide a service technician through the logical steps of identifying and correcting problems related to the engine. This manual does not cover vehicle or equipment problems. Consult the vehicle or equipment manufacturer for repair procedures.

A series of specific service manuals (for example: Shop, Specifications, and Alternative Repair) are available and can be ordered by filling out and mailing the Literature Order Form located in Section L - Service Literature.

The repair procedures used in this manual are recommended by Cummins Engine Co., Inc. Some service procedures require the use of special service tools. Use the correct tools as described.

Cummins Engine Company, Inc. encourages the user of this manual to report errors, omissions, and recommendations for improvement. Please use the postage paid, pre-addressed Literature Survey Form in the back of this manual for communicating your comments.

The specifications and rebuild information in this manual are based on the information in effect at the time of printing. Cummins Engine Company, Inc. reserves the right to make any changes at any time without obligation. If differences are found between your engine and the information in this manual, contact a Cummins Authorized Repair Location or call 1-800-DIESELS (1-800-343-7357) toll free in the U.S. and Canada.

The latest technology and the highest quality components are used to manufacture Cummins engines. When replacement parts are needed, we recommend using only genuine Cummins or ReCon® exchange parts. These parts can be identified by the following trademarks:

Table of Contents

	Section
Introduction	i
Engine Identification	E
Troubleshooting Symptoms	TS
Complete Engine – Group 00	0
Cylinder Block – Group 01	1
Cylinder Head – Group 02	2
Rocker Levers – Group 03	3
Cam Followers/Tappets – Group 04	4
Fuel System – Group 05	5
Injectors and Fuel Lines – Group 06	6
Lubricating Oil System – Group 07	7
Cooling System – Group 08	8
Drive Units – Group 09	9
Air Intake System – Group 10	10
Exhaust System – Group 11	11
Compressed Air System – Group 12	12
Electrical Equipment – Group 13	13
Engine Testing – Group 14	14
Mounting Adaptations – Group 16	16
Miscellaneous Hardware – Group 17	17
Vehicle Braking – Group 20	20
Service Literature	L
Component Manufacturers	M
Specifications	V
Index	X

Section i - Introduction

Section Contents

Page

About the Manual i-1

Acronyms and Abbreviations i-7

General Cleaning Instructions i-6
Glass or Plastic Bead Cleaning i-6
Solvent and Acid Cleaning i-6
Steam Cleaning i-6

General Repair Instructions i-5
Welding on a Vehicle with an Electronic Controlled Fuel System i-5

General Safety Instructions i-4
Important Safety Notice i-4

How to Use the Manual i-1

Illustrations i-3

Symbols i-2

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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 manual is divided into sections. Each section is equivalent to a group used in Cummins film card 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 contents pages or the index at the back of the manual to locate specific topics when not using the troubleshooting trees.

This manual covers all base engine repair procedures and some fuel system repair procedures. Repair procedures and fault code diagnosis for the electronic fuel system is covered in the Fuel System Troubleshooting and Repair Manual listed in section L .

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

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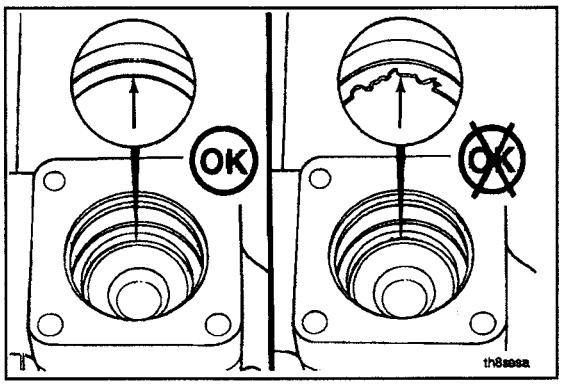
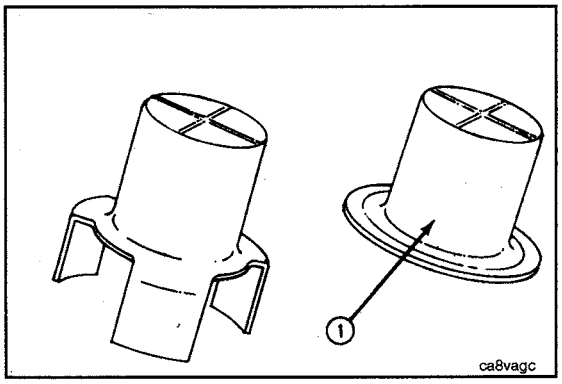
Illustrations

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.



General Safety Instructions

Important Safety Notice

⚠ WARNING ⚠

Improper practices or carelessness can cause burns, cuts, mutilation, asphyxiation or other bodily injury or death.

Read and understand all of the safety precautions and warnings before performing any repair. This list contains the general safety precautions that **must** be followed to provide personal safety. Special safety precautions are included in the procedures when they apply.

- Make sure the work area surrounding the product is dry, well lit, ventilated, free from clutter, loose tools, parts, ignition sources and hazardous substances. Be aware of hazardous conditions that can exist.
- **Always** wear protective glasses and protective shoes when working.
- Rotating parts can cause cuts, mutilation or strangulation.
- Do **not** wear loose-fitting or torn clothing. Remove all jewelry when working.
- Disconnect the battery (negative [-] cable first) and discharge any capacitors before beginning any repair work. Disconnect the air starting motor if equipped to prevent accidental engine starting. Put a "Do **Not** Operate" tag in the operator's compartment or on the controls.
- Use ONLY the proper engine barring techniques for manually rotating the engine. Do **not** attempt to rotate the crankshaft by pulling or prying on the fan. This practice can cause serious personal injury, property damage, or damage to the fan blade(s) causing premature fan failure.
- If an engine has been operating and the coolant is hot, allow the engine to cool before you slowly loosen the filler cap and relieve the pressure from the cooling system.
- Do **not** work on anything that is supported ONLY by lifting jacks or a hoist. **Always** use blocks or proper stands to support the product before performing any service work.
- Relieve all pressure in the air, oil, fuel and the cooling systems before any lines, fittings, or related items are removed or disconnected. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do **not** check for pressure leaks with your hand. High pressure oil or fuel can cause personal injury.
- To prevent suffocation and frostbite, wear protective clothing and ONLY disconnect fuel and liquid refrigerant (freon) lines in a well ventilated area. To protect the environment, liquid refrigerant systems **must** be properly emptied and filled using equipment that prevents the release of refrigerant gas (fluorocarbons) into the atmosphere. Federal law requires capturing and recycling refrigerant.
- To avoid personal injury, use a hoist or get assistance when lifting components that weigh 23 kg [50 lb] or more. Make sure all lifting devices such as chains, hooks, or slings are in good condition and are of the correct capacity. Make sure hooks are positioned correctly. **Always** use a spreader bar when necessary. The lifting hooks **must not** be side-loaded.
- Corrosion inhibitor, a component of SCA and lubricating oil, contains alkali. Do **not** get the substance in your eyes. Avoid prolonged or repeated contact with skin. Do **not** swallow internally. In case of contact, immediately wash skin with soap and water. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. IMMEDIATELY CALL A PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.
- Naptha and Methyl Ethyl Ketone (MEK) are flammable materials and **must** be used with caution. Follow the manufacturer's instructions to provide complete safety when using these materials. KEEP OUT OF REACH OF CHILDREN.
- To avoid burns, be alert for hot parts on products that have just been turned off, and hot fluids in lines, tubes, and compartments.
- **Always** use tools that are in good condition. Make sure you understand how to use them before performing any service work. Use ONLY genuine Cummins or Cummins ReCon® replacement parts.
- **Always** use the same fastener part number (or equivalent) when replacing fasteners. Do **not** use a fastener of lesser quality if replacements are necessary.
- Do **not** perform any repair when fatigued or after consuming alcohol or drugs that can impair your functioning.
- Some state and federal agencies in the United States of America have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

General Repair Instructions

This engine incorporates the latest technology at the time it was manufactured; yet, it is designed to be repaired using normal repair practices performed to quality standards.

- **Cummins Engine Company, Inc. does not recommend or authorize any modifications or repairs to engines or components except for those detailed in Cummins Service Information. In particular, unauthorized repair to safety-related components can cause personal injury or death. Below is a partial listing of components classified as safety-related:**

Air Compressor
Air Controls
Air Shutoff Assemblies
Balance Weights
Cooling Fan
Fan Hub Assembly
Fan Mounting Bracket(s)
Fan Mounting Capscrews
Fan Hub Spindle
Flywheel
Flywheel Crankshaft Adapter
Flywheel Mounting Capscrews
Fuel Shutoff Assemblies
Fuel Supply Tubes
Lifting Brackets
Throttle Controls
Turbocharger Compressor Casing
Turbocharger Oil Drain Line(s)
Turbocharger Oil Supply Line(s)
Turbocharger Turbine Casing
Vibration Damper Mounting Capscrews

- **Follow all safety instructions noted in the procedures**
  - — Follow the manufacturer's recommendations for cleaning solvents and other substances used during the repair of the engine. Some solvents and used engine oil have been identified by government agencies as toxic or carcinogenic. Avoid excessive breathing, ingestion and contact with such substances. **Always** use good safety practices with tools and equipment.
- **Provide a clean environment and follow the cleaning instructions specified in the procedures**
  - — The engine and its components **must** be kept clean during any repair. Contamination of the engine or components will cause premature wear.
- **Perform the inspections specified in the procedures**
- **Replace all components or assemblies which are damaged or worn beyond the specifications**
- **Use genuine Cummins new or ReCon® service parts and assemblies**
  - — The assembly instructions have been written to use again as many components and assemblies as possible. When it is necessary to replace a component or assembly, the procedure is based on the use of new Cummins or Cummins ReCon® components. All of the repair services described in this manual are available from all Cummins Distributors and most Dealer locations.
- **Follow the specified disassembly and assembly procedures to avoid damage to the components**

Complete rebuild instructions are available in the shop manual which can be ordered or purchased from a Cummins Authorized Repair Location. Refer to Section L — Service Literature for ordering instructions.

Welding on a Vehicle with an Electronic Controlled Fuel System

⚠ CAUTION ⚠

Disconnect both the positive (+) and negative (-) battery cables from the battery before welding on the vehicle. Attach the welder ground cable no more than 0.61 meters [2 feet] from the part being welded. Do not connect the ground cable of the welder to the ECM cooling plate or ECM. Welding on the engine or engine mounted components is not recommended.

General Cleaning Instructions

Solvent and Acid Cleaning

Several solvent and acid-type cleaners can be used to clean the engine parts. Experience has shown that the best results can be obtained using a cleaner that can be heated to 90 to 95 degrees Celsius [180 to 200 degrees Fahrenheit]. A cleaning tank that provides a constant mixing and filtering of the cleaning solution will give the best results. **Cummins Engine Company, Inc. does not recommend any specific cleaners. Always** follow the cleaner manufacturer's instructions.

Remove all the gasket material, o-rings, and the deposits of sludge, carbon, etc., with a wire brush or scraper before putting the parts in a cleaning tank. Be careful **not** to damage any gasket surfaces. When possible, steam clean the parts before putting them in the cleaning tank.

⚠ WARNING ⚠

Acid is extremely dangerous and can cause personal injury and damage the machinery. Always provide a tank of strong soda water as a neutralizing agent.

Rinse all of the parts in hot water after cleaning. Dry completely with compressed air. Blow the rinse water from all of the capscrew holes and the oil drillings.

If the parts are **not** to be used immediately after cleaning, dip them in a suitable rustproofing compound. The rustproofing compound **must** be removed from the parts before installation on the engine.

Steam Cleaning

Steam cleaning can be used to remove all types of dirt that can contaminate the cleaning tank. It is a good way to clean the oil drillings.

⚠ WARNING ⚠

Wear protective clothing to prevent personal injury from the high pressure and extreme heat.

Do **not** steam clean the following parts:

1. Electrical Components
2. Wiring
3. Injectors
4. Fuel Pump
5. Belts and Hoses
6. Bearings
7. Electronic Control Module (ECM)
8. ECM Connectors

Glass or Plastic Bead Cleaning

Glass or plastic bead cleaning can be used on many engine components to remove carbon deposits. The cleaning process is controlled by the size of the glass or plastic beads, the operating pressure, and the cleaning time.

△ CAUTION △

Do not use glass or plastic bead cleaning on aluminum piston skirts. Do not use glass bead cleaning on aluminum ring grooves. Small particles of glass or plastic will embed in the aluminum and result in premature wear. Valves, turbocharger shafts, etc., can also be damaged. Follow the cleaning directions listed in the procedures.

NOTE: Plastic bead blasting media, Part No. 3822735, can be used to clean aluminum ring grooves. Do **not** use any bead blasting media on pin bores or aluminum skirts.

Follow the equipment manufacturer's cleaning instructions. The following guidelines can be used to adapt to manufacturer's instructions:

1. Bead size:
   a. Use U.S. size No. 16-20 for piston cleaning with plastic bead media, Part No. 3822735.
   b. Use U.S. size No. 70 for piston domes with glass media.
   c. Use U.S. size No. 60 for general purpose cleaning with glass media.
2. Operating Pressure:
   a. Glass: Use 620 kPa [90 psi] for general purpose cleaning.
   b. Plastic: Use 270 kPa [40 psi] for piston cleaning.
3. Steam clean or wash the parts with solvent to remove all of the foreign material and glass or plastic beads after cleaning. Rinse with hot water. Dry with compressed air.
4. Do **not** contaminate the wash tanks with glass or plastic beads.

Acronyms and Abbreviations

AFC	Air Fuel Control
API	American Petroleum Institute
ASA	Air Signal Attenuator
ASTM	American Society of Testing and Materials
°C	Celsius
CARB	California Air Resources Board
C.I.D.	Cubic Inch Displacement
CNG	Compressed Natural Gas
CPL	Control Parts List
cSt	Centistokes
ECM	Electronic Control Module
ECS	Emission Control System
EPA	Environmental Protection Agency
EPS	Engine Position Sensor
°F	Fahrenheit
GVW	Gross Vehicle Weight
Hg	Mercury
hp	Horsepower
H_2O	Water
ICM	Ignition Control Module
km/l	Kilometers per Liter
kPa	Kilopascal
LNG	Liquid Natural Gas
LTA	Low Temperature Aftercooling
MIP	Mixer Inlet Pressure
MPa	Megapascal
mph	Miles Per Hour
mpq	Miles Per Quart
N•m	Newton-meter
NG	Natural Gas
OEM	Original Equipment Manufacturer
ppm	Parts Per Million
psi	Pounds Per Square Inch
PTO	Power Takeoff
rpm	Revolutions Per Minute
SAE	Society of Automotive Engineers
SCA	Supplemental Coolant Additive
STC	Step Timing Control
VS	Variable Speed
VSS	Vehicle Speed Sensor

NOTES

Section E - Engine Identification

Section Contents

Page

Engine Diagrams E-6
Engine Views E-6

Engine Identification E-1
Cummins Engine Nomenclature E-2
ECM Dataplate E-2
Engine Dataplate E-1

Specifications E-3
Air Intake System E-5
Batteries (Specific Gravity) E-5
Cooling System E-4
Electrical System E-5
Exhaust System E-5
Fuel System E-4
General Specifications E-3
Lubricating Oil System E-4

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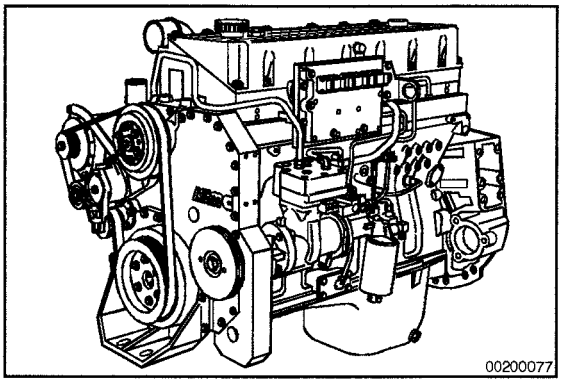
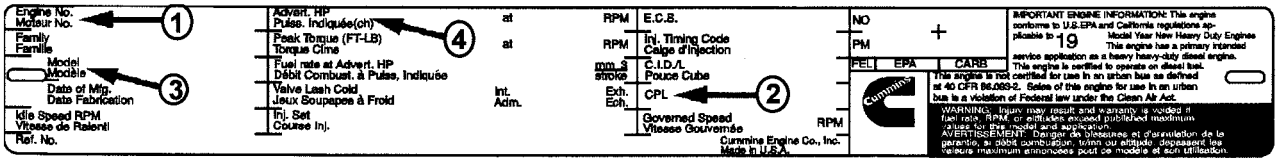
Engine Identification

Engine Dataplate

The engine dataplate shows facts about your engine. The Engine Serial Number and CPL provide information for ordering parts and service needs. The engine dataplate **must not** be changed unless approved by Cummins Engine Company, Inc.

The dataplate is located on the fuel pump side of the engine on the rocker housing. Have the following engine data available when communicating with a Cummins Authorized Repair Location. The following information on the dataplate is **mandatory** when sourcing service parts.





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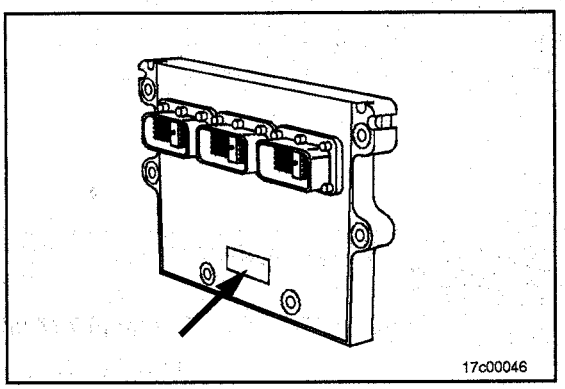
1. Engine serial number
2. CPL
3. Model
4. Horsepower and rpm rating.

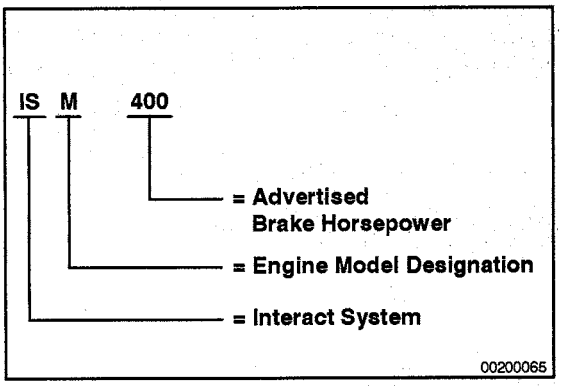


ECM Dataplate

The ECM dataplate is located on the front of the ECM.

The abbreviations on the dataplate are explained as follows:

- P/N = part number
- S/N = serial number
- D/C = date code.



Cummins Engine Nomenclature

The Cummins engine nomenclature provides the data as illustrated in the graphics.

Specifications

General Specifications

Horsepower (refer to engine dataplate)

Engine Speed @ Maximum Output:
Governed Speed (rpm)
Automotive 1800
Vocational/Transit Bus 2100
Marine 2300

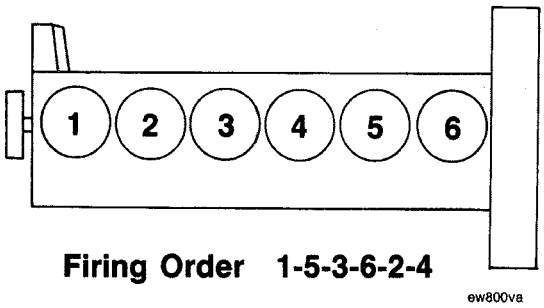
Bore and Stroke ..... 125 mm [4.921 in] x 147 mm [5.787 in]

Displacement ..... 10.8 liters [661 C.I.D.]

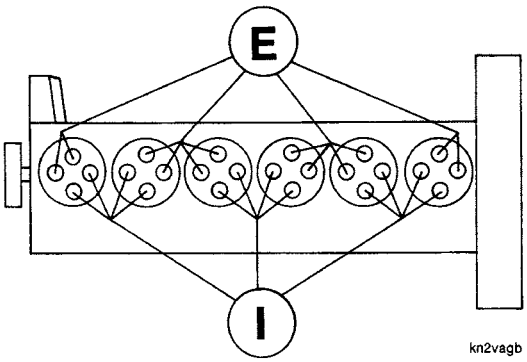
Firing Order 1-5-3-6-2-4

Engine Weight (with standard accessories):
Dry Weight ..... 940 kg [2070 lb]
Wet Weight ..... 996 kg [2193 lb]

Crankshaft Rotation (viewed from the front of the engine) ..... **Clockwise**



Cylinder Location and Firing Order



Intake and Exhaust Valve Locations

Fuel System

For performance and fuel rate values, refer to the engine data sheet or the fuel pump code for the particular model involved.

Engine Idle Speed ..... 600 to 800 rpm

Fuel Inlet Maximum Restriction:
- Clean Fuel Filter ..... 152 mm Hg [6 in Hg]
- Dirty Fuel Filter ..... 254 mm Hg [10 in Hg]

Fuel Drain Line Maximum Restriction ..... 89 mm Hg [3.5 in Hg]

Minimum Fuel Pressure:
- During Cranking ..... 172 kPa [25 psi]
- 1200 rpm ..... 827 kPa [120 psi]
- Governed rpm ..... 1034 to 1241 kPa [150 to 180 psi]

Fuel Inlet Maximum Temperature ..... 71°C [160°F]

Engine Minimum Cranking Speed ..... 150 rpm

Shutoff Valve Solenoid Coil Resistance
- 12 VDC ..... 7.0 to 8.0 ohms

Lubricating Oil System

Oil Pressure:
- Low Idle (minimum allowable) ..... 70 kPa [10 psi]
- At 1200 rpm or Torque Peak (minimum allowable) ..... 207 kPa [30 psi]

Oil Capacity of Standard Engine:
- Combination Filter:
  - LF9000 ..... 3.0 liters [0.8 gal]
  - LF9001 ..... 2.6 liters [0.7 gal]
- Oil Pan (high-low) ..... 34 to 26.5 liters [9 to 7 gal]
  - Transit Bus Oil Pan (high-low) ..... 34 to 30.3 liters [9 to 8 gal]

Cooling System

Coolant Capacity (engine **only**) ..... 9.5 liters [10 qt]

Standard Modulating Thermostat Range ..... 82 to 93°C [180 to 200°F]

Cylinder Block Coolant Pressure (pressure cap removed):
- Minimum
  - Closed Thermostat - 1800 rpm - No Load ..... 138 kPa [20 psi]
- Maximum
  - Closed Thermostat ..... 275 kPa [40 psi]

Maximum Allowable Operating Coolant Temperature ..... 100°C [212°F]

Minimum Recommended Operating Coolant Temperature ..... 70°C [160°F]

Minimum Recommended Pressure Cap ..... 48 kPa [7 psi]

Maximum Allowable Coolant Flow to Accessories (liters/minute [gpm]) ..... 75.7 Liters [20 gal]

Coolant Sensing Fan Control:
- On ..... 96°C [205°F]
- Off ..... 91°C [195°F]

Air Intake System

Maximum Intake Restriction:
- Clean Air Filter Element ..... 254 mm H_2O [10 in H_2O]
- Dirty Air Filter Element ..... 635 mm H_2O [25 in H_2O]

Maximum Temperature Rise Between Ambient Air and Engine Inlet Air:
- (ambient above 0° [32°F]) ..... 17°C [30°F]

Maximum Allowable Pressure Drop From Turbocharger to Intake Manifold ..... 152 mm Hg [6 in Hg]

Maximum Allowable Pressure Drop Across Charge Air Cooler ..... 152 mm Hg [6 in Hg]

Exhaust System

Maximum Back Pressure From Piping and Silencer (combined):
- Without Catalyst
  - Hg ..... 76 mm [3 in]
  - H_2O ..... 1016 mm [40 in]
- With Catalyst
  - Hg ..... 152 mm [6 in]
  - H_2O ..... 2082 mm [82 in]

Exhaust Pipe Size (normally acceptable inside diameter) ..... 127 mm [5 in]

Electrical System

Minimum recommended battery capacity:

System Voltage	Ambient Temperature -18°C [0°F]		Ambient Temperature 0°C [32°F]	
	Cold Cranking Amperes	Reserve Capacity [1] Amperes	Cold Cranking Amperes	Reserve Capacity [1] Amperes
12 VDC	1800	640	1280	480
24 VDC [2]	900	320	640	240

1. The number of plates within a given battery size determines reserve capacity. Reserve capacity determines the length of time during that sustained cranking can occur.
2. Cold Cranking Amperes ratings are based on two 12-VDC batteries in series.

A minimum of 6.5 VDC at the power connector is required to power up the ECM.

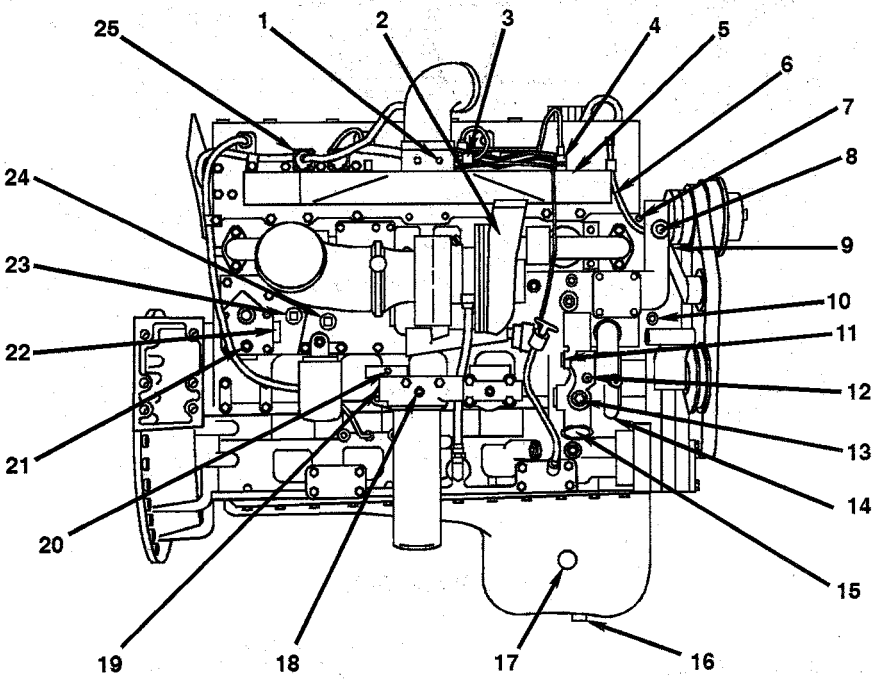
Batteries (Specific Gravity)

Specific Gravity at 27°C [80°F]	State of Charge
1.260 to 1.280	100%
1.230 to 1.250	75%
1.200 to 1.220	50%
1.170 to 1.190	25%
1.110 to 1.130	Discharged

Engine Diagrams

Engine Views

The following illustrations contain information about engine components, filter locations, drain points, and access locations for instrumentation and engine controls. The information and configuration of components shown in these drawings are of a general nature. Some component locations will vary depending on applications and installations.



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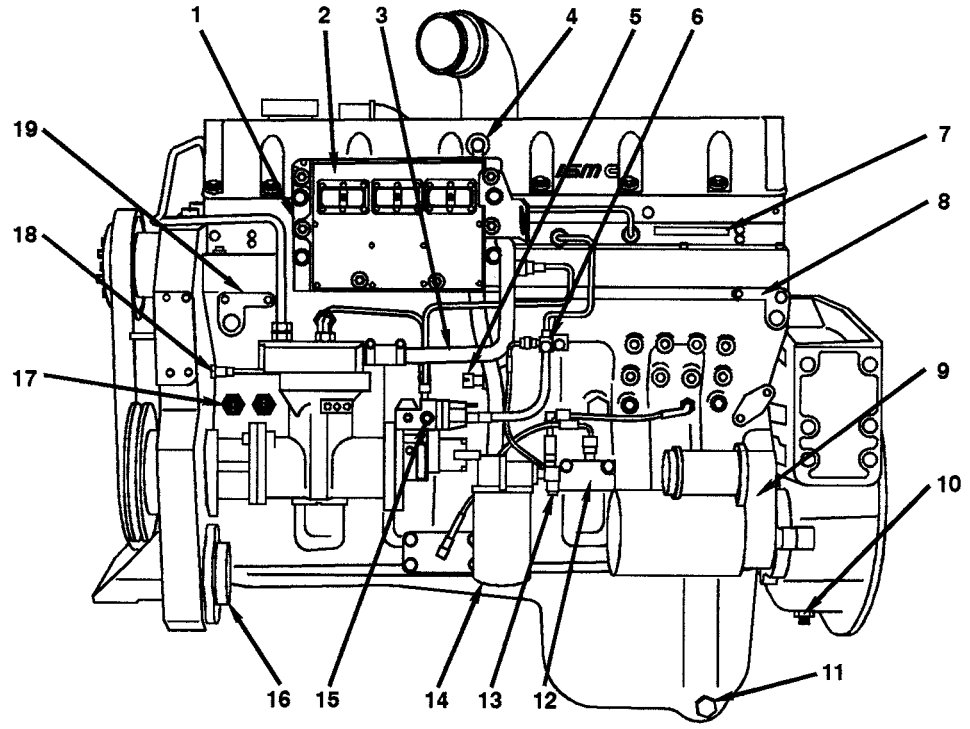
Exhaust Side

1. Ether Hookup
2. Before Charge Air Cooler
3. Boost Temperature Sensor
4. Intake Manifold Pressure Sensor
5. After Charge Air Cooler
6. Shutter Stat
7. Engine Vent Coolant
8. Shutter Stat
9. Fan Sensor
10. Coolant Temperature Sensor
11. Heater Return
12. Coolant Inlet Pressure
13. Makeup line from Radiator
14. Water Pump Pressure
15. Coolant Inlet
16. Oil Drain
17. Oil Pan Sump Heater
18. Filter Out Pressure
19. Engine Brake Oil Supply
20. Filter Inlet Pressure
21. Block Coolant Pressure
22. Coolant Heater
23. Heater Supply
24. Coolant Temperature Pickup
25. Wastegate Controller



Fuel Pump Side

1. ECM Cooling Plate
2. Electronic Control Module (ECM)
3. Compressor Air Discharge
4. Blowby Measurement
5. Ambient Air Pressure Sensor
6. Fuel Return to Tank
7. Engine Data Tag
8. Engine Serial Number
9. Starter
10. Flywheel Ring Gear Sensor
11. Side Oil Drain
12. Centinel™ (optional)
13. Fuel Inlet to Pump
14. Fuel Filter
15. Rail Pressure
16. Power Steering Pump Mounting Location
17. Oil Pressure and Temperature Sensor
18. Engine Position Sensor
19. Freon Compressor Mounting Location.

NOTES

Section TS - Troubleshooting Symptoms

Section Contents

Page

Troubleshooting Procedures and Techniques TS-2
Air Compressor Air Pressure Rises Slowly TS-3
Air Compressor Cycles Frequently TS-5
Air Compressor Noise is Excessive TS-7
Air Compressor Pumping Excess Lubricating Oil into the Air System TS-8
Air Compressor Will Not Maintain Adequate Air Pressure (Not Pumping Continuously) TS-10
Air Compressor Will Not Pump Air TS-11
Air Compressor Will Not Stop Pumping TS-12
Alternator Not Charging or Insufficient Charging TS-13
Alternator Overcharging TS-15
Communication Error – Electronic Service Tool or Control Device TS-16
Connecting Rod Bearing Noise TS-113
Coolant in the Lubricating Oil TS-26
Coolant Loss – External TS-18
Coolant Loss – Internal TS-19
Coolant Temperature Above Normal – Gradual Overheat TS-20
Coolant Temperature is Above Normal – Sudden Overheat TS-23
Coolant Temperature is Below Normal TS-24
Crankcase Gases (Blowby) Excessive TS-27
Cranking Fuel Pressure is Low TS-28
Driveability — General Information TS-114
Driveability/Low Power — Customer Complaint Form TS-115
Driveability/Low Power/Excessive Fuel Consumption — Checklist TS-116
Engine Acceleration or Response Poor TS-29
Engine Brake Does Not Operate TS-34
Engine Brake — One or More Cylinders Braking with Power Switch Off TS-38
Engine Brake – Low Retarding Power or Slow to Activate TS-36
Engine Decelerates Slowly TS-39
Engine Difficult to Start or Will Not Start (Exhaust Smoke) TS-40
Engine Difficult to Start or Will Not Start (No Exhaust Smoke) TS-43
Engine Noise Diagnostic Procedures — General Information TS-113
Engine Noise Excessive TS-47
Engine Noise Excessive — Combustion Knocks TS-50
Engine Noise Excessive — Connecting Rod TS-51
Engine Noise Excessive — Main Bearing TS-52
Engine Noise Excessive — Piston TS-53
Engine Noise Excessive — Turbocharger TS-54
Engine Power Output Low TS-55
Engine Runs Rough at Idle TS-61
Engine Runs Rough or Misfires TS-64
Engine Shuts Off Unexpectedly or Dies During Deceleration TS-67
Engine Speed Surges at Low or High Idle TS-69
Engine Speed Surges Under Load or in Operating Range TS-71
Engine Starts But Will Not Keep Running TS-74
Engine Vibration Excessive TS-76
Engine Will Not Crank or Cranks Slowly (Air Starter) TS-78
Engine Will Not Crank or Cranks Slowly (Electric Starter) TS-80
Engine Will Not Shut Off TS-82
Fuel Consumption Excessive TS-83
Fuel Consumption — Customer Complaint Form TS-118
Fuel Consumption — General Information TS-117
Fuel in Coolant TS-86
Fuel in the Lubricating Oil TS-87
Intake Manifold Air Temperature Above Specification TS-88
Intake Manifold Pressure (Boost) is Below Normal TS-90
Low Idle Adjust Switch Does Not Work TS-92
Lubricating Oil Consumption Excessive TS-93
Lubricating Oil Contaminated TS-95
Lubricating Oil Degradation (Centinel) TS-96
Lubricating Oil Pressure High TS-97
Lubricating Oil Pressure Low TS-98
Lubricating Oil Sludge in the Crankcase Excessive TS-101
Lubricating Oil Temperature Above Specification TS-102

Page

Lubricating or Transmission Oil in the Coolant TS-103
Main Bearing Noise TS-113
Oil Consumption TS-119
Oil Pan Level Incorrect – High (Centinel) TS-105
Oil Pan Level Incorrect – Low (Centinel) TS-104
Operating Fuel Pressure is Low TS-106
Piston Noise TS-113
Response Test TS-122
Smoke, Black — Excessive TS-107
Smoke, White — Excessive TS-110
Turbocharger Leaks Engine Oil or Fuel TS-112

Troubleshooting Symptoms Charts TS-1

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.

⚠ WARNING ⚠

Troubleshooting presents the risk of equipment damage, personal injury or death. Troubleshooting must be performed by trained experienced technicians.

Troubleshooting 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

Air Compressor Air Pressure Rises Slowly

This is symptom tree T004.

Cause	Correction
Air intake system restriction to air compressor is excessive	Replace the air compressor air cleaner (if installed). Check the air intake piping. Check engine air intake restriction if the air compressor inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031.
OK ▼	
Air system leaks	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, and valves. Refer to Procedure 012-019 and the OEM service manuals.
OK ▼	
Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Refer to Procedure 012-017.
OK ▼	
Carbon buildup is excessive in the air discharge line, check valve, or cylinder head	Check for carbon buildup. Replace the air compressor discharge line if necessary. Refer to Procedure 012-003. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedures 010-040 and 010-049.
OK ▼	
E-type system is **not** plumbed correctly (Holset™ only)	Install an Econ valve, check valve, and system hoses. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin No. 3666121.
OK ▼	
Air system component is malfunctioning	Check the operation of check valves, alcohol evaporators, air dryers, and other OEM-installed air system components. Refer to the manufacturer's instructions.
OK ▼	
Unloader valve is malfunctioning	Check the unloader valve and unloader body seal. Refer to Procedure 012-013.
OK ▼	

(Continued)

Air Compressor Air Pressure Rises Slowly (Continued)

Cause	Correction
Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to Procedure(s) 012-103, 012-104, or 012-106.
OK ↓	
Air installation issues	Refer to the Automotive and Bus Installation Recommendations - Air Compressor Systems, Bulletin No. 3884946.

Air Compressor Cycles Frequently

This is symptom tree T005.

Cause	Correction
Air system leaks	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, and valves. Refer to Procedure 012-019 and the OEM service manuals.
OK ⬇	
Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Refer to Procedure 012-017.
OK ⬇	
Air system component is malfunctioning	Check the operation of check valves, alcohol evaporators, air dryers, and other OEM-installed air system components. Refer to the manufacturer's instructions.
OK ⬇	
E-type system is **not** plumbed correctly (Holset™ only)	Install an Econ valve, check valve, and system hoses. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin No. 3666121.
OK ⬇	
Carbon buildup is excessive in the air discharge line, check valve, or cylinder head	Check for carbon buildup. Replace the air compressor discharge line if necessary. Refer to Procedure 012-003. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedures 010-040 and 010-049.
OK ⬇	
Air dryer desiccant cartridge needs replaced	Replace the desiccant cartridge on the Turbo/CR2000 air dryer (if equipped). Refer to the OEM service manual.
OK ⬇	
Air dryer outlet check valve is sticking	Lubricate or replace the air dryer outlet check valve assembly. Refer to the manufacturer's instructions.
OK ⬇	

(Continued)

Air Compressor Cycles Frequently (Continued)

Cause	Correction
Air installation issues	Refer to the Automotive and Bus Installation Recommendations - Air Compressor Systems, Bulletin No. 3884946.
OK ↓	
Air compressor **not** designed for application	Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to Section G in the Master Repair Manual, Holset® Air Compressors, Bulletin No. 3666121.

Air Compressor Noise is Excessive

This is symptom tree T006.

Cause	Correction
Carbon buildup is excessive in the air discharge line, check valve, or cylinder head	Check for carbon buildup. Replace the air compressor discharge line if necessary. Refer to Procedure 012-003. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedures 010-040 and 010-049.
OK ↓	
Air compressor is sending air pulses into the air tanks	Install a ping tank between the air dryer and the wet tank. Refer to the manufacturer's instructions.
OK ↓	
Accessory drive is worn (axial end play is out of specification)	Check the accessory drive axial end play. Inspect the shaft for wear. Refer to Procedure 009-001.
OK ↓	
Air compressor timing is **not** correct	Check the air compressor timing. Refer to Procedure 012-014.
OK ↓	
Air compressor drive gear or engine gear train is worn or damaged	Inspect the accessory drive gears and gear train. Refer to Procedure 009-001, 001-036, 001-039, and 001-040.
OK ↓	
Ice buildup in the air system components	For all models, check for ice in low spots of the air discharge line, dryer inlet, and elbow fittings. On Holset™ models also check the Econ valve (if equipped).
OK ↓	
Pin bore wear is excessive	Check for pin bore wear. Refer to Procedure 012-010.
OK ↓	
Air compressor is excessively worn or internally damaged	Replace or rebuild the air compressor. Refer to 012-014.

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree T007.

Cause	Correction
Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to Section 2 in the correct Operation and Maintenance Manual.
OK ▼	
Air intake system restriction to air compressor is excessive	Replace the air compressor air cleaner (if installed). Check the air intake piping. Check engine air intake restriction if the air compressor inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031.
OK ▼	
Contaminants are building up in the system reservoirs	Drain the reservoirs daily. Refer to the Operation and Maintenance Manual.
OK ▼	
E-type system is **not** plumbed correctly (Holset™ only)	Install an Econ valve, check valve, and system hoses. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin No. 3666121.
OK ▼	
Air dryer desiccant cartridge needs replaced	Replace the desiccant cartridge on the Turbo/CR2000 air dryer (if equipped). Refer to the OEM service manual.
OK ▼	
Carbon buildup is excessive in the air discharge line, check valve, or cylinder head	Check for carbon buildup. Replace the air compressor discharge line if necessary. Refer to Procedure 012-003. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedures 010-040 and 010-049.
OK ▼	
Engine angularity during operation exceeds specification	Refer to the Engine Specification data sheet.
OK ▼	
Air compressor pumping too high air pressure	Check the air governor for correct operation. Refer to Procedure 012–017.
OK ▼	

(Continued)

Air Compressor Pumping Excess Lubricating Oil into the Air System (Continued)

Cause	Correction
Crankcase pressure is excessive	Check for excessive blowby. Refer to Section 14. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.
OK ▼	
Lubricating oil pressure is above specification	Check the oil pressure. Refer to Procedure 007-028.
OK ▼	
Air compressor runs hot	If coolant temperature is above normal, refer to the Coolant Temperature Above Normal-Gradual Overheat symptom tree.
OK ▼	
Lubricating oil drain line is restricted	Remove the air compressor, and check the oil drain holes in the air compressor and the accessory drive. Refer to Procedure 012-014.
OK ▼	
Air compressor **not** designed for application	Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to Section G in the Master Repair Manual, Holset® Air Compressors, Bulletin No. 3666121.
OK ▼	
Air installation issues	Refer to the Automotive and Bus Installation Recommendations - Air Compressor Systems, Bulletin No. 3884946.
OK ▼	
Air compressor is excessively worn or internally damaged	Replace or rebuild the air compressor. Refer to Procedure 012-014. Replace the desiccant element on the Turbo/CR 2000 air dryer (if equipped). Refer to the manufacturer's instructions.

Air Compressor Will Not Maintain Adequate Air Pressure (Not Pumping Continuously)

This is symptom tree T008.

Cause	Correction
Air system leaks	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, and valves. Refer to Procedure 012-019 and the OEM service manuals.
OK ▼	
Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Refer to Procedure 012-017.
OK ▼	
Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to Procedure(s) 012-103, 012-104, or 012-106.
OK ▼	
Cover gasket is leaking internally (Holset™ SS models **only**)	Check the torque on the unloader screws. Refer to Procedure 012-013.
OK ▼	
Air installation issues	Refer to the Automotive and Bus Installation Recommendations - Air Compressor Systems, Bulletin No. 3884946.

Air Compressor Will Not Pump Air

This is symptom tree T009.

Cause	Correction
Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Refer to Procedure 012-017.
OK ▼	
Unloader valve is malfunctioning	Check the unloader valve and unloader body seal. Refer to Procedure 012-013.
OK ▼	
Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to Procedure(s) 012-103, 012-104, or 012-106.
OK ▼	
Cover gasket is ruptured (Holset™ SS models **only**)	Check the discharge line for blockage. Refer to Procedure 012-003. Check the cover gasket for flatness. Replace the cover gasket.
OK ▼	
Air compressor is excessively worn or internally damaged	Replace or rebuild the air compressor. Refer to Procedure 012-014.

Air Compressor Will Not Stop Pumping

This is symptom tree T010.

Cause	Correction
Air system leaks	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, and valves. Refer to Procedure 012-019 and the OEM service manuals.
OK ↓	
Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Refer to Procedure 012-017.
OK ↓	
Air governor signal line or actuator line is plugged	Inspect the signal line and actuator line. Refer to the manufacturer's instructions.
OK ↓	
Air system component is malfunctioning	Check the operation of check valves, alcohol evaporators, air dryers, and other OEM-installed air system components. Refer to the manufacturer's instructions.
OK ↓	
Unloader valve is malfunctioning	Check the unloader valve and unloader body seal. Refer to Procedure 012-013.
OK ↓	
Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to Procedure(s) 012-103, 012-104, or 012-106.

Alternator Not Charging or Insufficient Charging

This is symptom tree T013.

Cause	Correction
Vehicle gauge is malfunctioning	Check the vehicle gauge. Refer to the OEM service manual.
OK ↓	
Alternator belt is loose	Check the alternator belt tension. Adjust as necessary. Refer to Procedure 13–005.
OK ↓	
Alternator pulley is loose on the shaft	Tighten the pulley. Refer to manufacturer's instructions.
OK ↓	
Alternator drive pulley is loose on the water pump shaft	Make sure the drive pulley is tight on the shaft. Refer to Procedure 009-010.
OK ↓	
Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009.
OK ↓	
Batteries have failed	Check the condition of the batteries. Refer to Procedure 013-007. Replace the batteries if necessary. Refer to the OEM service manual.
OK ↓	
Alternator or voltage regulator is malfunctioning	Test the alternator output. Refer to Procedure 013-001. Replace the alternator or voltage regulator if necessary. Refer to the OEM service manual.
OK ↓	
Electrical system is "open" (blown fuses, broken wires, or loose connections)	Check the fuses, wires, and connections. Refer to the OEM service manual and the manufacturer's wiring diagrams.
OK ↓	
Alternator is overloaded or alternator capacity is below specification	Install an alternator with a higher capacity. Refer to Procedure 013-001 and the OEM service manual.
OK ↓	

(Continued)

Alternator Not Charging or Insufficient Charging (Continued)

Cause	Correction
Battery temperature is above specification	Position batteries away from heat sources. Refer to the OEM service manual.

Alternator Overcharging

This is symptom tree T014.

Cause	Correction
Voltage regulator is malfunctioning	Check the voltage regulator. Replace the voltage regulator if necessary. Refer to the OEM service manual.
OK ▼	
Battery cell is damaged (open circuit)	Check the condition of the batteries. Replace the batteries if necessary. Refer to the OEM service manual.

Communication Error – Electronic Service Tool or Control Device

This is symptom tree T016.

Cause	Correction
Keyswitch is in the OFF position	Turn on the keyswitch.
OK ⬇	
Datalink is locked up	Turn off the keyswitch and the electronic service tool and disconnect the battery cables for a least 5 minutes. Connect the battery cables and turn on the keyswitch and the electronic service tool to establish communication.
OK ⬇	
INLINE adapter (datalink adapter) is **not** connected to the battery voltage supply	Check the power light on the INLINE adapter. If the light is **not** illuminated, connect the battery voltage to the INLINE adapter. Refer to the appropriate INSITE™ user's manual.
OK ⬇	
Electronic service tool cartridge or software is **not** correct for the system	Verify that the electronic service tool cartridge or software is correct for this system.
OK ⬇	
Electronic control module (ECM) is **not** calibrated	Calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032.
OK ⬇	
Moisture in the wiring harness connectors	Dry the connectors with Cummins electronic cleaner, Part No. 3824510.
OK ⬇	
Keyswitch circuit is malfunctioning	Check the vehicle keyswitch circuit. Refer to Procedure 019-064 of the ISM Fuel System Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ⬇	

(Continued)

Communication Error – Electronic Service Tool or Control Device (Continued)

Cause	Correction
Battery voltage supply to the electronic control module (ECM) has been lost	Check the battery connections. Refer to Procedure 013-009 in the base engine Troubleshooting and Repair Manual. Check the fuses and the unswitched battery supply circuit. Refer to Procedures 019-198 and 019-087 of the ISM Fuel System Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ⬇	
Electronic control module (ECM) is **not** grounded correctly	Check the ECM for correct placement of star washers. Refer to Procedure 019-031 of the ISM Fuel System Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ⬇	
Electronic service tool is malfunctioning	Check the electronic service tool by trying it on another engine .
OK ⬇	
Monitor devices are connected to the data link	Turn off or disconnect the monitor devices while using the electronic service tool.
OK ⬇	
Datalink circuit is malfunctioning	Check the datalink circuit. Refer to Procedure 019-028 of the ISM Fuel System Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ⬇	
Datalink is locked up	Turn off the keyswitch and the electronic service tool and disconnect the battery cables for a least 5 minutes. Connect the battery cables and turn on the keyswitch and the electronic service tool to establish communication.
OK ⬇	
Electronic control module (ECM) is malfunctioning	Replace the ECM. Refer to Procedure 019-031 of the ISM Fuel System Troubleshooting and Repair Manual, Bulletin No. 3666266.

Coolant Loss – External

This is symptom tree T020.

Cause	Correction
Coolant level is above specification	Check the coolant level. Refer to the OEM service manual.
OK ↓	
External coolant leak	Inspect the engine for coolant leaking from hoses, drain cocks, water manifold, jumper tubes, expansion and pipe plugs, fittings, radiator core, air compressor and cylinder head gaskets, lubricating oil cooler, water pump seal, and OEM-mounted components that have coolant flow. If necessary, pressure-test the cooling system. Refer to Procedure 008-018 and 008-045.
OK ↓	
Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047.
OK ↓	
Fill line or vent lines are restricted, obstructed, or **not** routed correctly	Check the vent lines and the fill line for correct routing and for restriction. Refer to Procedure 008-017 or the OEM specifications.
OK ↓	
Air or combustion gases are entering the cooling system	Check for air or combustion gases in the cooling system. Refer to Procedure 008-019.
OK ↓	
Engine is overheating	Refer to the Coolant Temperature Above Normal symptom tree.

Coolant Loss – Internal

This is symptom tree T021.

Cause	Correction
Air compressor cylinder head is cracked or porous, or has a leaking gasket	Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-103, 012-104, or 012-106.
OK ▼	
Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks. Refer to Procedure 007-003.
OK ▼	
Air or combustion gases are entering the cooling system	Check for air or combustion gases in the cooling system. Refer to Procedure 008-019.
OK ▼	
Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002–004.
OK ▼	
Cylinder head is cracked or porous, or an injector sleeve is leaking	Pressure-test the cylinder head and inspect the injector sleeves. Refer to Procedure 002-004.
OK ▼	
Fuel heater is malfunctioning (if equipped)	Check the fuel heater and replace if necessary. Refer to the manufacturer's instructions.
OK ▼	
Transmission oil cooler or torque converter cooler is leaking	Check the transmission oil cooler and torque converter cooler for coolant leaks. Refer to the manufacturer's instructions.
OK ▼	
Cylinder liner is corroded or cracked, or the cylinder block is cracked or porous	Remove the oil pan. Pressure-test the cooling system to check for leaks. Refer to Procedure 001-027 .

Coolant Temperature Above Normal – Gradual Overheat

This is symptom tree T022.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to View and troubleshoot the fault codes with Insite. Refer to Section T in the Troubleshooting and Repair Manual, Bulletin No. 3666266 for fault code troubleshooting.
OK ▼	
Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge if necessary. Refer to Procedure 008-004 and the OEM service manual.
OK ▼	
Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 784 cm^2 [120 in^2] or approximately 28 cm x 28 cm [11 in x 11 in] of opening at all times.
OK ▼	
Coolant level is below specification	Inspect the engine and cooling system for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedure 008-018.
OK ▼	
Charge air cooler (CAC) fins, radiator fins, or air conditioner condenser fins are damaged or obstructed with debris	Inspect the CAC, air conditioner condenser, and radiator fins. Clean if necessary. Refer to Procedures 010-027 and 008-042 and the OEM service manual.
OK ▼	
Cooling system hose is collapsed, restricted, or leaking	Inspect the radiator hoses. Refer to Procedure 008-045.
OK ▼	
Fan drive belt is loose	Check the belt tension and tighten if necessary. Refer to Procedure 008-002.
OK ▼	
Lubricating oil level is above or below specification	Check the oil level. Add or drain oil if necessary. Refer to Procedure 007-025. Check the dipstick calibration. Refer to Procedure 007-009.
OK ▼	

(Continued)

Coolant Temperature Above Normal – Gradual Overheat (Continued)

Cause	Correction
Fan shroud is damaged or missing, or the air recirculation baffles are damaged or missing	Inspect the shroud and the recirculation baffles. Repair, replace, or install if necessary. Refer to Procedure 008-038 and the OEM service manual.
OK ▼	
Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047.
OK ▼	
Supplemental coolant additive (SCA) level is above specification or the coolant is overconcentrated with antifreeze	Check the SCA level. Verify the antifreeze concentration. Refer to Cooling System Specifications in Section 8.
OK ▼	
Fill line or vent lines are restricted, obstructed, or **not** routed correctly	Check the vent lines and the fill line for correct routing and for restriction. Refer to Procedure 008-017 or the OEM specifications.
OK ▼	
Intake manifold air temperature is above specification	Refer to the Intake Manifold Air Temperature Above Specification symptom tree.
OK ▼	
Radiator shutters are **not** opening completely or the shutterstat setting is wrong	Inspect the radiator shutters. Repair or replace if necessary. Refer to the manufacturer's instructions. Check the shutterstat setting. Refer to Procedure 008-020 or 008-049.
OK ▼	
Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure(s) 008-024, 008-025, 008-026, 008-027, or 008-028.
OK ▼	
Thermostat is **not** correct or is malfunctioning	Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013.
OK ▼	

(Continued)

Coolant Temperature Above Normal – Gradual Overheat (Continued)

Cause	Correction
Air or combustion gases are entering the cooling system	Check for air or combustion gases in the cooling system. Refer to Procedure 008-019.
OK ↓	
Cooling system component is malfunctioning	Perform the Cooling System Diagnostics Test. Refer to Procedure 008-020.
OK ↓	
Radiator core is internally obstructed or damaged, or the check valve or J-tube is malfunctioning	Inspect the radiator and clean if necessary. Refer to.
OK ↓	
Check valve is damaged (with remote mounted engine coolant heater)	Inspect the check valve. Replace if necessary. Refer to the manufacturer's instructions.
OK ↓	
Torque converter is malfunctioning	Check the torque converter. Refer to the OEM service manual.
OK ↓	
Vehicle cooling system is **not** adequate	Verify that the engine and vehicle cooling systems are using the correct components. Refer to the OEM specifications.

Coolant Temperature is Above Normal – Sudden Overheat

This is symptom tree T023.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to Section T in the Troubleshooting and Repair Manual, Bulletin No. 3666266 for fault code troubleshooting.
OK ⬇	
Fan drive belt is broken	Check the fan drive belt. Replace the belt if necessary. Refer to Procedure 008-002.
OK ⬇	
Coolant level is below specification	Inspect the engine and cooling system for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedure 008-018.
OK ⬇	
Cooling system hose is collapsed, restricted, or leaking	Inspect the radiator hoses. Refer to Procedure 008-045.
OK ⬇	
Radiator shutters are **not** opening completely or the shutterstat setting is wrong	Inspect the radiator shutters. Repair or replace if necessary. Refer to the manufacturer's instructions. Check the shutterstat setting. Refer to Procedure 008-020 or 008-049.
OK ⬇	
Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure(s) 008-024, 008-025, 008-026, 008-027, or 008-028.
OK ⬇	
Cooling system component is malfunctioning	Perform the Cooling System Diagnostics Test. Refer to Procedure 008-020.
OK ⬇	
Thermostat is **not** correct or is malfunctioning	Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013.

Coolant Temperature is Below Normal

This is symptom tree T024.

Cause	Correction
Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge if necessary. Refer to Procedure 008-004 and the OEM service manual.
OK ▼	
Engine is operating at low ambient temperature	Check the winterfront, shutters, and underhood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual. Use intake air from under the hood in cold weather.
OK ▼	
Coolant fill line is **not** routed correctly	Check the routing of the coolant fill line. Refer to the OEM service manual.
OK ▼	
Radiator shutters are stuck open or opening early	Check the shutter operation. Repair or replace the shutters if necessary. Refer to the OEM service manual and Procedure 008-020 or 008-049 019-019 in Bulletin No. 3666130-02.
OK ▼	
Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure(s) 008-024, 008-025, 008-026, 008-027, or 008-028.
OK ▼	
Cooling system component is malfunctioning	Perform the Cooling System Diagnostics Test. Refer to Procedure 008-020.
OK ▼	
Thermostat is **not** correct or is malfunctioning	Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013.
OK ▼	
Thermostat seal is damaged, missing, or **not** installed correctly	Check the thermostat seal. Check the thermostat for correct seating. Refer to Procedure 008-013 or 008-016.
OK ▼	

(Continued)

Coolant Temperature is Below Normal (Continued)

Cause	Correction
Coolant flow through the radiator is **not** correct	Check for correct coolant flow through the radiator. Refer to Procedure 008-042.

Coolant in the Lubricating Oil

This is symptom tree T025.

Cause	Correction
Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks. Refer to Procedure 007-003.
OK ↓	
Air compressor cylinder head is cracked or porous, or has a leaking gasket	Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-103, 012-104, and 012-106.
OK ↓	
Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-004 or 002-021.
OK ↓	
Cylinder head is cracked or porous, or an injector sleeve is leaking	Pressure-test the cylinder head and inspect the injector sleeves. Refer to Procedure 002-004.
OK ↓	
Cylinder block is cracked or porous	Remove the oil pan. Pressure-test the cooling system to check for leaks. Refer to Procedure 001-027 .

Crankcase Gases (Blowby) Excessive

This is symptom tree T027.

Cause	Correction
Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to 003-002
OK ⬇	
Centrifugal bypass filter is malfunctioning	Disconnect and plug the air supply line to the filter. Refer to Procedure 0007-012. Check for blowby again. If blowby is within specifications, repair the filter. Refer to the OEM service manual.
OK ⬇	
Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-040 or 010-049.
OK ⬇	
Air compressor is malfunctioning	Isolate the air compressor by disconnecting the air inlet and outlet lines. Refer to Procedure 012-003. Check blowby. If blowby is within specifications, rebuild or replace the air compressor.
OK ⬇	
Rocker lever housing or rocker lever housing gasket is leaking intake air into the crankcase	Inspect the rocker lever housing for cracks. Inspect the gasket for tears and breaks. Inspect the gasket sealing surface for scratches and cracks. Refer to Procedure 003-013 .
OK ⬇	
Cylinder head valve guides are excessively worn	Check the valve guides for wear. Replace the cylinder head if necessary. Refer to Procedure 002-004 .
OK ⬇	
Piston, piston rings, or cylinder liner is worn or damaged	Check the pistons, piston rings, and cylinder liner. Refer to Procedures 001-043, 001-047, and 001-028.

Cranking Fuel Pressure is Low

This is symptom tree T029.

Cause	Correction
Fuel inlet restriction excessive	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ↓	
Fuel leak is causing fuel to drain back in the suction line	Check for fuel drain back. Refer to Procedure 005-011.
OK ↓	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ↓	
Fuel pump (gear or shaft) is **not** rotating	Check the fuel pump for shaft rotation and fuel flow. Refer to Procedure 005-016.
OK ↓	
In-line check valve(s) are installed backwards or have incorrect part number	Check the in-line check valves for the correct part number. Check the arrow on the check valve(s) for the correct orientation.
OK ↓	
Fuel pump gear pump check valve is stuck open	Replace the check valve. Refer to Procedure 005-026.
OK ↓	
Fuel pump pressure regulator is stuck	Check the fuel pump pressure regulator. Refer to Procedure 005-060.
OK ↓	
Injector o-rings are damaged or missing	Remove and check the injectors. Replace the injector o-rings. Refer to Procedure 006-026.

Engine Acceleration or Response Poor

This is symptom tree T033.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF for fault code troubleshooting.
OK ▼	
Engine protection fault code(s) inactive	View the fault codes and the engine protection data with an electronic service tool. Refer to the appropriate electronic service tool manual. Refer to the corresponding fault code in Section TF.
OK ▼	
Verify the complaint	Test the engine operation while under load. Perform an engine acceleration test. Perform an engine load test. Observe the percent load with an electronic service tool. Refer to the Operability/Low Power form.
OK ▼	
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 or Section 019-078 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Programmable parameters or selected features are **not** correct	Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again if necessary. Refer to the appropriate electronic service tool manual or Section 019-078 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Turbocharger is **not** correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin No. 3379133. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK ▼	

(Continued)

Engine Acceleration or Response Poor (Continued)

Cause	Correction
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications.
OK ▼	
Accelerator pedal is restricted or malfunctioning	Check the percent throttle reading on an electronic service tool. Verify that it reads 100 percent with the accelerator pedal depressed and zero percent when released. Calibrate the accelerator if possible. Replace the accelerator pedal if necessary. Refer to the OEM service manual.
OK ▼	
J1939 control device causing engine to derate	Check the J1939 history using electronic service tool .
OK ▼	
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006–020 .
OK ▼	
Fuel drain line restriction	Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012.
OK ▼	
Air in the fuel system	Check for air in the fuel system. Bleed air from the system. Refer to Procedure 006-003.
OK ▼	
Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedure 006-026 or 014-008.
OK ▼	
Ambient air pressure sensor is malfunctioning	check the ambient air pressure sensor. Refer to Procedure 019-004.
OK ▼	

(Continued)

Engine Acceleration or Response Poor (Continued)

Cause	Correction
Fuel inlet temperature to pump is above specification	Fill the fuel tank, turn off or bypass the fuel heaters, and check the fuel cooler. Refer to the OEM service manuals.
OK ▼	
Charge air cooler (CAC) is restricted or leaking	Inspect the CAC for air restriction or leaks. Refer to Procedure 010-027.
OK ▼	
Intake manifold pressure (boost) is below specification	Refer to the Intake Manifold Pressure (Boost) is Below Normal symptom tree.
OK ▼	
Intake manifold pressure (boost) sensor or circuit is malfunctioning	Check the boost sensor and circuit. Refer to Procedure 019-061 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ▼	
Air intake system restriction is above specification	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ▼	
Exhaust system restriction is above specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ▼	
Fuel pump is malfunctioning	Check the fuel pump output pressure, pulsation damper, and pressure regulator. Replace the fuel pump if necessary. Refer to Procedures 005-011, 005-016, and 005-031.
OK ▼	

(Continued)

Engine Acceleration or Response Poor (Continued)

Cause	Correction
Drivetrain is **not** correctly matched to the engine	Check for correct gearing and drivetrain components. Refer to the OEM vehicle specifications.
OK ↓	
Vehicle speed sensor (VSS) or circuit is malfunctioning	Check the vehicle speed sensor and circuit. Refer to Procedures 019-090 and 019-091 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Vehicle parasitics are excessive	Check the vehicle brakes for dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to the OEM service manual.
OK ↓	
Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-001.
OK ↓	
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to 003-004.
OK ↓	
Fuel supply line restriction between the fuel pump and the injectors	Check the fuel supply line from the fuel pump to the cylinder head for sharp bends that can cause restrictions. Refer to Procedure 005-024
OK ↓	
Turbocharger wastegate actuator is malfunctioning (if equipped)	Check the turbocharger wastegate actuator for correct operation. Refer to Procedure 010-050.
OK ↓	
Turbocharger wastegate controller is malfunctioning (if equipped)	Inspect the wastegate controller components. Refer to Procedure 010-050.
OK ↓	

(Continued)

Engine Acceleration or Response Poor (Continued)

Cause	Correction
Injectors are **not** correct	Remove the injectors and compare the part numbers to the Control Parts List (CPL), Bulletin No. 3379133. Replace the injectors if necessary. Refer to Procedure 006-026.
OK ⬇	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.

Engine Brake Does Not Operate

This is symptom tree T036.

Cause	Correction
Engine brake ON/OFF switch is OFF	Turn ON the switch.
OK	
Engine brake ON/OFF switch or circuit is malfunctioning	Check the engine brake ON/OFF switch and circuit. Refer to Procedures 019-034, 019-035, 020–034, 020–035, 020–008 and 020–009 in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK	
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK	
Engine brake harness connectors are loose or broken	Check the engine brake harness connectors. Check the engine brake harness for continuity.
OK	
Clutch switch or circuit is malfunctioning	Check the clutch switch adjustment, switch, and circuit. Refer to Procedure 019-009 or 019-010 in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK	
Throttle position sensor or circuit is malfunctioning	Check for foot pedal restriction. Check the throttle position sensor and circuit.
OK	
Service brake pressure switch or circuit is malfunctioning	Check the service brake pressure switch and circuit. Refer to the OEM service manual.
OK	
Solenoid valve is malfunctioning	Check for voltage at the solenoid valve.
OK	

(Continued)

Engine Brake Does Not Operate (Continued)

Cause	Correction
Solenoid valve filter screen is covered with debris	Remove the solenoid valve and clean or replace the screen.
OK ↓	
Lubricating oil leak (internal)	Check the engine brake hose connections, the engine brake housing, and the jumper tube o-rings for oil leaks.
OK ↓	
Engine brake lubricating oil supply line is restricted	Remove the oil supply line. Inspect the supply line for a restriction.
OK ↓	
Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-001.

Engine Brake – Low Retarding Power or Slow to Activate

This is symptom tree T037.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual, Bulletin No. 3666084 for fault code troubleshooting.
OK ▼	
Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal symptom tree.
OK ▼	
Lubricating oil pressure is below specification	Check the oil pressure. Refer to Procedure 007–028. If the pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK ▼	
Air in the lubricating oil system	Check the oil level. If level is high, check for a cracked suction tube. Refer to Procedure 007-025 .
OK ▼	
Lubricating oil leak (internal)	Check the engine brake hose connections, the engine brake housing, and the jumper tube o-rings for oil leaks.
OK ▼	
Engine brake lubricating oil supply line is restricted	Remove the oil supply line. Inspect the supply line for a restriction.
OK ▼	
Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-001.
OK ▼	
Engine brake harness connectors are loose or broken	Check the engine brake harness connectors. Check the engine brake harness for continuity in the Troubleshooting and Repair Manual, Bulletin No. 3666130, or Troubleshooting and Repair Manual, Bulletin No. 3666084.
OK ▼	

(Continued)

Engine Brake – Low Retarding Power or Slow to Activate (Continued)

Cause	Correction
Master piston is stuck	Check the master piston for freedom of movement. Replace the master piston if necessary.
OK ▼	
Engine brake solenoid(s) is malfunctioning	Use engine brake breakout diagnostic tool. Refer to Procedure 020-001.

Engine Brake — One or More Cylinders Braking with Power Switch Off

This is symptom tree T038.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Engine brake ON/OFF switch or circuit is malfunctioning	Check the engine brake ON/OFF switch and wiring. Refer to Procedures 019-034 and 019-035 in the Troubleshooting and Repair Manual, Bulletin No. 3666130, or Procedure 1-14 in the Troubleshooting and Repair Manual, Bulletin No. 3666084.
OK ▼	
Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-001.

Engine Decelerates Slowly

This is symptom tree T041.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266..
OK ▼	
Accelerator pedal is sticking	Check for a sticking accelerator pedal. Refer to the OEM service manual.
OK ▼	
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the Troubleshooting and Repair Manual, Bulletin No. 3666130, or Procedure 4-01 in the Troubleshooting and Repair Manual, Bulletin No. 3666084.
OK ▼	
Fuel pump pulsation damper is cracked	Inspect the fuel pump pulsation damper. Replace the pulsation damper if necessary. Refer to Procedure 005-031.
OK ▼	
Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedure 006-026 or 014-008.

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

This is symptom tree T043.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Fuel level low in the tank	Fill the supply tank.
OK ▼	
Engine cranking speed is too slow	Check the engine cranking speed with a handheld tachometer or electronic service tool. If the cranking speed is slower than 150 rpm, refer to the Engine Will **Not** Crank or Cranks Slowly symptom tree.
OK ▼	
Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to Procedure 013-009 . Refer to Procedure 019-087 in the ISM Trouble-shooting and Repair Manual, Bulletin No. 3666266 and.
OK ▼	
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual.
OK ▼	
Fuel pump is malfunctioning	Check the fuel pump output pressure, pulsation damper, and pressure regulator. Replace the fuel pump if necessary. Refer to Procedures 005-011, 005-016, and 005-031.
OK ▼	
Fuel drilling in the cylinder head are plugged	Check for a plastic fuel passage plug blocking the fuel supply to the injectors. Refer to Procedure 002-004.
OK ▼	

(Continued)

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

Cause	Correction
Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal symptom tree.
OK ↓	
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032.
OK ↓	
Engine position sensor (EPS) or circuit is malfunctioning	Check the engine position sensor and circuit. Refer to Procedures 019-038 and 019-039 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Vehicle parasitics are excessive	Check the vehicle brakes for dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to the OEM service manual.
OK ↓	
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ↓	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ↓	
Air intake system restriction is above specification	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ↓	
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	

(Continued)

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

Cause	Correction
Injector o-rings are damaged or missing	Remove and check the injectors. Replace the injector o-rings. Refer to Procedure 006-026.
OK ▼	
Injector is malfunctioning	Perform the single-cylinder cutout test. Replace the injectors as necessary. Refer to Procedure(s) 006–005
OK ▼	
Exhaust system restriction is above specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ▼	
Fuel supply line restriction between the fuel pump and the injectors	Check the fuel supply line from the fuel pump to the cylinder head for sharp bends that can cause restrictions.
OK ▼	
Engine brakes are malfunctioning	Check the engine brake operation, adjustment, and solenoid resistance. Repair or adjust as necessary. Refer to Procedure 020-001.
OK ▼	
Valve protrusion is below specification	Check the valve protrusion. Replace the valve seat inserts or the cylinder head. Refer to Procedures 002-019 and 002-004.
OK ▼	
Camshaft end clearance is excessive	Check the camshaft end clearance. Refer to Procedure 001–008 or 001-065.
OK ▼	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.

Engine Difficult to Start or Will Not Start (No Exhaust Smoke)

This is symptom tree T044.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Fuel level low in the tank	Fill the supply tank.
OK ▼	
Engine cranking speed is too slow	Check the engine cranking speed with a handheld tachometer or electronic service tool. If the cranking speed is slower than 150 rpm, refer to the Engine Will **Not** Crank or Cranks Slowly symptom tree.
OK ▼	
Vehicle anti-theft feature active	Enter the correct "PIN" or verify the anti-theft feature is disabled using electronic service tool.
OK ▼	
Keyswitch circuit is malfunctioning	Check the vehicle keyswitch circuit. Refer to Procedure 019-064 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to Procedure 013-009 . Refer to Procedure 019-087 and.
OK ▼	
Fuel pump is malfunctioning	Check the fuel pump output pressure, pulsation damper, and pressure regulator. Replace the fuel pump if necessary. Refer to Procedures 005-011, 005-016, and 005-031.
OK ▼	

(Continued)

Engine Difficult to Start or Will Not Start (No Exhaust Smoke) (Continued)

Cause	Correction
Fuel drilling in the cylinder head are plugged	Check for a plastic fuel passage plug blocking the fuel supply to the injectors. Refer to Procedure 002-004.
OK ↓	
Fuel shutoff valve(s) closed (electronic fuel system)	Check the fuel shutoff valve and circuit. Refer to Procedures 019-049 and 019-050 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Engine position sensor (EPS) or circuit is malfunctioning	Check the engine position sensor and circuit. Refer to Procedures 019-038 and 019-039 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ↓	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ↓	
Electronic control module (ECM) is locked up	Disconnect the battery cables for 5 minutes. Connect the battery cables and start the engine.
OK ↓	
Moisture in the wiring harness connectors	Dry the connectors with Cummins electronic cleaner, Part No. 3824510.
OK ↓	

(Continued)

Engine Difficult to Start or Will Not Start (No Exhaust Smoke) (Continued)

Cause	Correction
In-line check valve(s) are installed backwards or have incorrect part number	Check the in-line check valves for the correct part number. Check the arrow on the check valve(s) for the correct orientation.
OK ⬇	
Starting motor rotation is **not** correct	Check the direction of crankshaft rotation. Replace the starting motor if necessary. Refer to Procedure 013-020 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266 and the manufacturer's instructions.
OK ⬇	
Injector is malfunctioning	Perform the cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-005, 006-026 or 014–008.
OK ⬇	
Fuel supply line restriction between the fuel pump and the injectors	Check the fuel supply line from the fuel pump to the cylinder head for sharp bends that can cause restrictions.
OK ⬇	
Fuel drilling in the cylinder head are plugged	Check for a plastic fuel passage plug blocking the fuel supply to the injectors. Refer to Procedure 002-004.
OK ⬇	
Camshaft end clearance is excessive	Check the camshaft end clearance. Refer to Procedure 001–008 or 001-065.
OK ⬇	
Electronic control module (ECM) is malfunctioning	Replace the ECM. Refer to Procedure 019-031.
OK ⬇	
Camshaft is broken	Check the rocker lever movement while rotating the crankshaft. Refer to Procedure 003-004 for instructions to rotate the crankshaft.
OK ⬇	

(Continued)

Engine Difficult to Start or Will Not Start (No Exhaust Smoke) (Continued)

Cause	Correction
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.

Engine Noise Excessive

This is symptom tree T047.

NOTE: When troubleshooting for the cause of engine noise, make sure that the engine accessories (air compressor, fan clutch, freon compressor, or hydraulic pump) are **not** causing the noise. Refer to Engine Noise Diagnostic Procedures — General Information at the end of this section before using this symptom tree.

Cause	Correction
Lubricating oil level is below specification	Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedures 007-009 and 007-025.
OK ▼	
Lubricating oil pressure is below specification	Check the oil pressure. Refer to Procedure 007-028. If the pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK ▼	
Coolant temperature is above specification	Refer to the Coolant Temperature is Above Normal - Sudden Overheat or the Coolant Temperature is Above Normal - Gradual Overheat symptom tree.
OK ▼	
Lubricating oil is thin or diluted	Refer to Lubricating Oil System-General Information in Section 7. Refer to the Lubricating Oil Contaminated symptom tree.
OK ▼	
Fan drive belt is loose, tight, or **not** in alignment	Check the fan drive belt. Refer to Procedure 008-002.
OK ▼	
Fan is loose, damaged, or **not** balanced	Check the fan. Refer to Procedure 008-040.
OK ▼	
Engine mounts are worn, damaged, loose or **not** correct	Verify the condition of the mounts. Refer to Procedure 016-010. Refer to OEM service manual.
OK ▼	
Air intake or exhaust piping is contacting the chassis or cab	Inspect the air piping, chassis, and cab for contact points.
OK ▼	

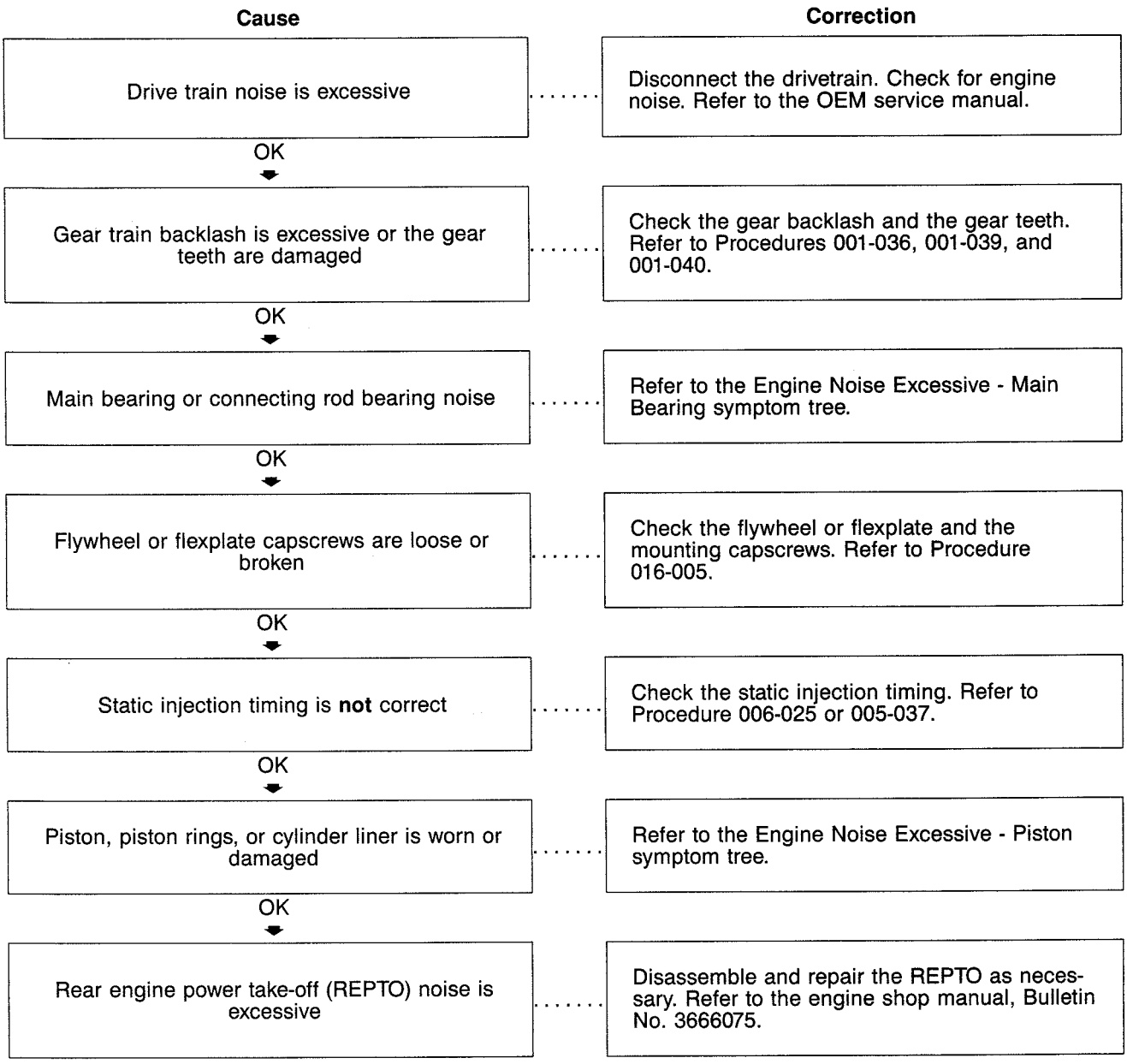
(Continued)

Engine Noise Excessive (Continued)

Cause	Correction
Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ↓	
Turbocharger noise	Refer to the Engine Noise Excessive - Turbocharger symptom tree.
OK ↓	
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	
Overhead components are damaged	Inspect the rocker levers, rocker shafts, cam followers, tappets, push rods, and valves for damage or excessive wear. Refer to Procedure 003-004, 003-009, 004-001, 004-014, or 002-004.
OK ↓	
Injector is malfunctioning	Perform the single-cylinder cutout test. Replace the injectors as necessary. Refer to Procedure(s) 006-005
OK ↓	
Accessory drive is worn (axial end play is out of specification)	Check the accessory drive axial end play. Inspect the shaft for wear. Refer to Procedure 009-016.
OK ↓	
Vibration damper is damaged	Inspect the vibration damper. Refer to Procedure 001-052.
OK ↓	
Air compressor noise is excessive	Refer to the Air Compressor Noise is Excessive - Air Compressor symptom tree.
OK ↓	
Fan clutch, hydraulic pump, or freon compressor noise is excessive	Isolate each component and check for noise. Refer to the OEM service manuals.
OK ↓	

(Continued)

Engine Noise Excessive (Continued)



Engine Noise Excessive — Combustion Knocks

This is symptom tree T048.

NOTE: Refer to Engine Noise Diagnostic Procedures — General Information at the end of this section before using this symptom tree.

Cause	Correction
Ether starting aid is malfunctioning	Repair or replace the ether starting aids. Refer to the manufacturer's instructions.
OK ▼	
Injector is malfunctioning	Perform the single-cylinder cutout test. Replace the injectors as necessary. Refer to Procedure(s) 006-026
OK ▼	
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK ▼	
Incomplete combustion (white smoke)	Refer to engine smoke excessive — white symptom chart.

Engine Noise Excessive — Connecting Rod

This is symptom tree T049.

NOTE: Refer to Engine Noise Diagnostic Procedures — General Information at the end of this section before using this symptom tree.

Cause	Correction
Lubricating oil pressure is below specification	Check the oil pressure. Refer to Procedure 007-028. If the pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK ▼	
Lubricating oil level is below specification	Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedures 007-009 and 007-025.
OK ▼	
Lubricating oil is thin or diluted	Refer to Lubricating Oil System-General Information in Section 7. Refer to the Lubricating Oil Contaminated symptom tree.
OK ▼	
Connecting rod capscrews are loose or **not** tightened correctly	Check the torque on the connecting rod capscrews. Refer to Procedure 001-014.
OK ▼	
Connecting rod bearings are damaged or worn, are **not** assembled correctly, or are the wrong bearings	Inspect the connecting rod bearings. Refer to Procedure 001-005.
OK ▼	
Connecting rod is bent or out of alignment	Remove and inspect the connecting rods. Refer to Procedure 001-014 and the Engine Shop Manual, Bulletin No. 3666075.
OK ▼	
Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to the Engine Shop Manual, Bulletin No. 3666075.

Engine Noise Excessive — Main Bearing

This is symptom tree T050.

NOTE: Refer to Engine Noise Diagnostic Procedures — General Information at the end of this section before using this symptom tree.

Cause	Correction
Lubricating oil pressure is below specification	Check the oil pressure. Refer to Procedure 007-028. If the pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK ▼	
Lubricating oil level is below specification	Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedures 007-009 and 007-025.
OK ▼	
Lubricating oil is thin or diluted	Refer to Lubricating Oil System-General Information in Section 7. Refer to the Lubricating Oil Contaminated symptom tree.
OK ▼	
Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-005.
OK ▼	
Torque converter is loose	Check the torque converter. Refer to the OEM service manual.
OK ▼	
Main bearing capscrews are loose, worn, or **not** tightened correctly	Check the torque on the main bearing capscrews. Inspect the capscrews for wear. Refer to Procedure 001-006 .
OK ▼	
Main bearings are damaged or worn, or the wrong bearings are installed	Inspect the main bearings for damage, excessive wear, and the correct part number. Refer to Procedure 001-006.
OK ▼	
Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to the Engine Shop Manual, Bulletin No. 3666075.

Engine Noise Excessive — Piston

This is symptom tree T051.

NOTE: Refer to Engine Noise Diagnostic Procedures — General Information at the end of this section before using this symptom tree.

Cause	Correction
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manualfor your engine application.
OK ▼	
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK ▼	
Injector is malfunctioning	Perform the single-cylinder cutout test. Replace the injectors as necessary. Refer to Procedure(s) 006-026
OK ▼	
Piston pin or bushing is loose, worn, or **not** installed correctly	Remove the pistons and inspect the piston pin and bushing for damage, wear, and correct installation. Refer to Procedure 001-043.
OK ▼	
Piston, piston rings, or cylinder liner is worn or damaged	Check the pistons, piston rings, and cylinder liner. Refer to Procedures 001-043, 001-047, and 001-028.
OK ▼	
Connecting rod is bent or out of alignment	Remove and inspect the connecting rods. Refer to Procedure 001-014 and the Engine Shop Manual, Bulletin No. 3666075.

Engine Noise Excessive — Turbocharger

This is symptom tree T052.

NOTE: Refer to Engine Noise Diagnostic Procedures — General Information at the end of this section before using this symptom tree.

Cause	Correction
Wastegated turbocharger	Wastegated turbochargers make more noise than non-wastegated turbochargers.
OK ▼	
Turbocharger is **not** correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin No. 3379133. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK ▼	
Air intake or exhaust piping is contacting the chassis or cab	Inspect the air piping, chassis, and cab for contact points.
OK ▼	
Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ▼	
Air intake system restriction is above specification	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ▼	
Exhaust system restriction is above specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ▼	
Turbocharger is worn or damaged	Check the turbocharger for damage. Measure the turbine and compressor wheel clearances. Refer to Procedure 010-038, 010-039, and 010-047.

Engine Power Output Low

This is symptom tree T057.

Cause	Correction
Interview the operator to verify the complaint	Refer to Driveability-General Information, the Driveability/Low Power Customer Complaint Form, and the Driveability Checklist at the end of Section TS. Follow the instructions on the forms before continuing with this tree.
OK ▼	
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Programmable parameters or selected features are **not** correct	Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again if necessary. Refer to the appropriate electronic service tool manual or Section 019-078.
OK ▼	
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032.
OK ▼	
Engine protection fault code(s) inactive	View the fault codes and the engine protection data with an electronic service tool. Refer to the appropriate electronic service tool manual. Refer to the corresponding fault code in Section TF.
OK ▼	
Accelerator pedal position sensor or circuit is malfunctioning	Check for accelerator pedal restriction. Check the percent throttle reading on an electronic service tool. Check the accelerator pedal position sensor and the circuit. Refer to Procedures 019-085 and 019-086 . Calibrate the accelerator pedal to the ECM. Refer to Procedure 019-084. Check that the accelerator pedal is within the OEM specification. If necessary, replace the accelerator pedal. Refer to the OEM service manual.
OK ▼	

(Continued)

Engine Power Output Low (Continued)

Cause	Correction
Tachometer or speedometer is **not** calibrated or is malfunctioning	Compare the vehicle tachometer and speedometer readings with an electronic service tool reading. Check the calibration values for the flywheel teeth, rear axle ratio, and tire revolutions. Adjust the values if necessary. Refer to the appropriate electronic service tool manual. Calibrate or replace the tachometer or speedometer as necessary. Refer to the OEM service manuals.
OK ↓	
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual.
OK ↓	
Lubricating oil level is above specification	Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-009 or 007-025.
OK ↓	
Accelerator pedal is restricted or malfunctioning	Check the percent throttle reading on an electronic service tool. Verify that it reads 100 percent with the accelerator pedal depressed and zero percent when released. Calibrate the accelerator if possible. Replace the accelerator pedal if necessary. Refer to the OEM service manual.
OK ↓	
Turbocharger is **not** correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin No. 3379133. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK ↓	
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ↓	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ↓	

(Continued)

Engine Power Output Low (Continued)

Cause	Correction
Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedure 006-026 or 014-008.
OK ↓	
Ambient air pressure sensor is malfunctioning (if equipped)	Check the ambient air pressure sensor. Refer to Procedure 019-004 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Vehicle speed sensor (VSS) or circuit is malfunctioning	Check the vehicle speed sensor and circuit. Refer to Procedures 019-090 and 019-091.
OK ↓	
Intake manifold temperature sensor is malfunctioning	Check the intake manifold temperature sensor. Refer to Procedure 019-059 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Engine is operating above recommended altitude	Engine power decreases above recommended altitude. Refer to the Engine Data Sheet for specifications.
OK ↓	
Intake manifold pressure (boost) is below specification	Refer to the Intake Manifold Pressure (Boost) is Below Normal symptom tree.
OK ↓	
Intake manifold pressure (boost) sensor or circuit is malfunctioning	Check the boost sensor and circuit. Refer to Procedure 019-061 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Charge air cooler (CAC) is restricted or leaking	Inspect the CAC for air restriction or leaks. Refer to Procedure 010-027.
OK ↓	

(Continued)

Engine Power Output Low (Continued)

Cause	Correction
Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ▼	
Air intake system restriction is above specification	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Fuel inlet temperature to pump is above specification	Fill the fuel tank, turn off or bypass the fuel heaters, and check the fuel cooler. Refer to the OEM service manuals.
OK ▼	
Fuel pump is malfunctioning	Check the fuel pump output pressure, pulsation damper, and pressure regulator. Replace the fuel pump if necessary. Refer to Procedures 005-011, 005-016, and 005-031.
OK ▼	
Fuel drilling in the cylinder head are plugged	Check for a plastic fuel passage plug blocking the fuel supply to the injectors. Refer to Procedure 002-004.
OK ▼	
Fuel supply pressure is below specification	Measure the fuel supply pressure. Refer to Procedure 005-011. If the fuel pressure is low, refer to the Operating Fuel Pressure is Low symptom tree.
OK ▼	
Drivetrain is **not** correctly matched to the engine	Check for correct gearing and drivetrain components. Refer to the OEM vehicle specifications.
OK ▼	
Exhaust system restriction is above specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ▼	

(Continued)

Engine Power Output Low (Continued)

Cause	Correction
Vehicle parasitics are excessive	Check the vehicle brakes for dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to the OEM service manual.
OK ↓	
Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-001.
OK ↓	
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	
Engine brakes are malfunctioning	Check the engine brake operation, adjustment, and solenoid resistance. Repair or adjust as necessary. Refer to Procedure 020-001 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Turbocharger is malfunctioning	Monitor the turbocharger boost pressure with an electronic service tool. Refer to the appropriate electronic service tool manual. Replace the turbocharger if necessary. Refer to Procedure 010-033 or 010-037.
OK ↓	
Turbocharger wastegate actuator is malfunctioning (if equipped)	Check the turbocharger wastegate actuator for correct operation. Refer to Procedure 010-050.
OK ↓	
Turbocharger wastegate controller is malfunctioning (if equipped)	Inspect the wastegate controller components. Refer to Procedure 010-109.
OK ↓	
Turbocharger wheel clearance is out of specification	Check the radial bearing clearance and axial clearance. Inspect the turbocharger. Repair or replace the turbocharger if necessary. Refer to Procedures 010-038 and 010-047.
OK ↓	

(Continued)

Engine Power Output Low (Continued)

Cause	Correction
Fuel supply line restriction between the fuel pump and the injectors	Check the fuel supply line from the fuel pump to the cylinder head for sharp bends that can cause restrictions.
OK ▼	
Injectors are **not** correct	Remove the injectors and compare the part numbers to the Control Parts List (CPL), Bulletin No. 3379133. Replace the injectors if necessary. Refer to Procedure 006-026.
OK ▼	
Fuel or air delivery malfunction	Perform a road test or dynamometer test. Use the data to follow the Engine Power Output Low - Performance Measurement symptom tree. Refer to Procedure 014-005 and the Engine Power Output Low - Performance Measurement symptom tree.
OK ▼	
Static injection timing is **not** correct	Check the static injection timing. Refer to Procedure 006-025 or 005-037.
OK ▼	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.

Engine Runs Rough at Idle

This is symptom tree T061.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Engine is operating at low ambient temperature	Check the winterfront, shutters, and underhood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual. Use intake air from under the hood in cold weather.
OK ▼	
Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to the OEM service manual and Procedure 016-003.
OK ▼	
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual.
OK ▼	
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ▼	
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ▼	

(Continued)

Engine Runs Rough at Idle (Continued)

Cause	Correction
Fuel supply pressure is below specification	Measure the fuel supply pressure. Refer to Procedure 005-011. If the fuel pressure is low, refer to the Operating Fuel Pressure is Low symptom tree.
OK ▼	
Fuel pump pulsation damper is cracked	Inspect the fuel pump pulsation damper. Replace the pulsation damper if necessary. Refer to Procedure 005-031.
OK ▼	
Engine position sensor (EPS) or circuit is malfunctioning	Check the engine position sensor and circuit. Refer to Procedures 019-038 and 019-039 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Injector is malfunctioning	Perform the single-cylinder cutout test. Replace the injectors as necessary. Refer to Procedure 006-026 or 014-008.
OK ▼	
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK ▼	
Static injection timing is **not** correct	Check the static injection timing. Refer to Procedure 006-025 or 005-037.
OK ▼	
Camshaft end clearance is excessive	Check the camshaft end clearance. Refer to Procedure 001–008 or 001-065.
OK ▼	
Cylinder head valve leak	Check the cylinder head for fuel leaks between the valves and valve seats. Refer to Procedure 002-004 .
OK ▼	

(Continued)

Engine Runs Rough at Idle (Continued)

Cause	Correction
Injectors are **not** correct	Correct the injector timing. Refer to Procedure .
OK ▼	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.
OK ▼	
Vibration damper is damaged	Inspect the vibration damper. Refer to Procedure 001-052.

Engine Runs Rough or Misfires

This is symptom tree T062.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Condition occurs **only** at idle	Refer to the Engine Runs Rough at Idle symptom tree.
OK ▼	
Engine is operating at low ambient temperature	Check the winterfront, shutters, and underhood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual , Bulletin No. 3666319. Use intake air from under the hood in cold weather.
OK ▼	
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual , Bulletin No. 3666319.
OK ▼	
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Engine mounts are worn, damaged, loose or **not** correct	Verify the condition of the mounts. Refer to Procedure 016-010. Refer to OEM service manual.
OK ▼	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ▼	

(Continued)

Engine Runs Rough or Misfires (Continued)

Cause	Correction
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ↓	
Engine position sensor (EPS) or circuit is malfunctioning	Check the engine position sensor and circuit. Refer to Procedures 019-038 and 019-039 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Injector is malfunctioning	Perform the single-cylinder cutout test. Replace the injectors as necessary. Refer to Procedure 006-026 or 014-008.
OK ↓	
Fuel pump pulsation damper is cracked	Inspect the fuel pump pulsation damper. Replace the pulsation damper if necessary. Refer to Procedure 005-031.
OK ↓	
Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-001.
OK ↓	
Engine brakes are malfunctioning	Check the engine brake operation, adjustment, and solenoid resistance. Repair or adjust as necessary. Refer to Procedure 020-001.
OK ↓	
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	
Outlet check valve struck open	Remove the oil replenishment hose from the outlet check valve and check for oil leakage through the check valve.
OK ↓	
Camshaft timing is **not** correct	Refer to Procedure 001-008.
OK ↓	

(Continued)

Engine Runs Rough or Misfires (Continued)

Cause	Correction
Camshaft is damaged	Inspect the camshaft for damage. Refer to Procedure 001-008.
OK ⬇	
Cylinder head valve leak	Check the cylinder head for fuel leaks between the valves and valve seats. Refer to Procedure 002-004 .
OK ⬇	
Vibration damper is damaged	Inspect the vibration damper. Refer to Procedure 001-052.
OK ⬇	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.

Engine Shuts Off Unexpectedly or Dies During Deceleration

This is symptom tree T064.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Idle shutdown or PTO shutdown features are activated	Check the time limit on idle and PTO shutdown with an electronic service tool. Refer to the appropriate electronic service tool manual.
OK ▼	
Engine will **not** restart	Refer to the Engine Difficult to Start or Will **Not** Start symptom treecheck the time limit on idle and PTO shutdown with an electronic service tool. Refer to the appropriate electronic service tool manual..
OK ▼	
Engine protection fault code(s) inactive	View the fault codes and the engine protection data with an electronic service tool. Refer to the appropriate electronic service tool manual. Refer to the corresponding fault code in Section TF.
OK ▼	
Keyswitch circuit is malfunctioning	Check the vehicle keyswitch circuit. Refer to Procedure 019-064 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to Procedure 013-009 . Refer to Procedure 019-087 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266 and.
OK ▼	

(Continued)

Engine Shuts Off Unexpectedly or Dies During Deceleration (Continued)

Cause	Correction
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ↓	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ↓	
Fuel pump is malfunctioning	Check the fuel pump output pressure, pulsation damper, and pressure regulator. Replace the fuel pump if necessary. Refer to Procedures 005-011, 005-016, and 005-031.
OK ↓	
Engine brakes are malfunctioning	Check the engine brake operation, adjustment, and solenoid resistance. Repair or adjust as necessary. Refer to Procedure 020-001.
OK ↓	
Static injection timing is **not** correct	Check the static injection timing. Refer to Procedure 006-025 or 005-037.
OK ↓	
Injector o-rings are damaged or missing	Remove and check the injectors. Replace the injector o-rings. Refer to Procedure 006-026.
OK ↓	
Camshaft end clearance is excessive	Check the camshaft end clearance. Refer to Procedure 001–008 or 001-065.

Engine Speed Surges at Low or High Idle

This is symptom tree T066.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Fuel level low in the tank	Fill the supply tank.
OK ▼	
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ▼	
Fuel drain line restriction	Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012.
OK ▼	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ▼	
Engine position sensor (EPS) or circuit is malfunctioning	Check the engine position sensor and circuit. Refer to Procedures 019-038 and 019-039 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	

(Continued)

Engine Speed Surges at Low or High Idle (Continued)

Cause	Correction
Vehicle speed sensor (VSS) or circuit is malfunctioning	Check the vehicle speed sensor and circuit. Refer to Procedures 019-090 and 019-091 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Alternator is malfunctioning	Temporarily disconnect the alternator and run the engine. Replace the alternator if necessary. Refer to the OEM service manuals.
OK ↓	
Moisture in the wiring harness connectors	Dry the connectors with Cummins electronic cleaner, Part No. 3824510.
OK ↓	
Fuel pump is malfunctioning	Check the fuel pump output pressure, pulsation damper, and pressure regulator. Replace the fuel pump if necessary. Refer to Procedures 005-011, 005-016, and 005-031.
OK ↓	
Idling with excessive load	Use the PTO feature for loaded conditions at low engine speeds. Refer to the Operation and Maintenance Manual, .
OK ↓	
Electronic control module (ECM) calibration is outdated	Compare the calibration stored in the ECM with the most recent calibration version available on electronic software database and network (ESDN). If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Injector is malfunctioning	Replace the malfunctioning injector. Refer to Procedure 006-005.
OK ↓	
Camshaft end clearance is excessive	Check the camshaft end clearance. Refer to Procedure 001–008 or 001-065.

Engine Speed Surges Under Load or in Operating Range

This is symptom tree T067.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to in the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Engine speed also surges at idle	Refer to the Engine Speed Surges at Low or High Idle symptom tree.
OK ▼	
Accelerator pedal position sensor or circuit is malfunctioning	Check for accelerator pedal restriction. Check the percent throttle reading on an electronic service tool. Check the accelerator pedal position sensor and the circuit. Refer to Procedures 019-085 and 019-086 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Electronic control module (ECM) calibration is outdated	Compare the calibration stored in the ECM with the most recent calibration version available on electronic software database and network (ESDN). If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Vehicle speed sensor (VSS) or circuit is malfunctioning	Check the vehicle speed sensor and circuit. Refer to Procedures 019-090 and 019-091 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ▼	

(Continued)

Engine Speed Surges Under Load or in Operating Range (Continued)

Cause	Correction
Fuel drain line restriction	Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012.
OK ▼	
Fuel pump is malfunctioning	Check the fuel pump output pressure, pulsation damper, and pressure regulator. Replace the fuel pump if necessary. Refer to Procedures 005-011, 005-016, and 005-031.
OK ▼	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ▼	
Air intake system restriction is above specification	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ▼	
Engine position sensor (EPS) or circuit is malfunctioning	Check the engine position sensor and circuit. Refer to Procedures 019-038 and 019-039 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Moisture in the wiring harness connectors	Dry the connectors with Cummins electronic cleaner, Part No. 3824510.
OK ▼	
Exhaust system restriction is above specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ▼	
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	

(Continued)

Engine Speed Surges Under Load or in Operating Range (Continued)

Cause	Correction
Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-001.
OK ↓	
Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedure 006-026 or 014-008, or 006-005.
OK ↓	
Camshaft end clearance is excessive	Check the camshaft end clearance. Refer to Procedure 001–008 or 001-065.
OK ↓	
Turbocharger is **not** correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin No. 3379133. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK ↓	
Turbocharger wastegate is malfunctioning (if equipped)	Check the wastegate for correct operation. Refer to Procedure 010-050.
OK ↓	
Turbocharger wastegate controller is malfunctioning (if equipped)	Inspect the wastegate controller components. Refer to Procedure 010-109.

Engine Starts But Will Not Keep Running

This is symptom tree T072.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Idle shutdown or PTO shutdown features are activated	Turn off the keyswitch for 5 seconds. Turn on the keyswitch and check fault lamp operation.
OK ▼	
Fuel level low in the tank	Fill the supply tank.
OK ▼	
Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to Procedure 013-009 . Refer to Procedure 019-087 in the ISM Trouble-shooting and Repair Manual, Bulletin No. 3666266 and.
OK ▼	
Keyswitch circuit is malfunctioning	Check the vehicle keyswitch circuit. Refer to Procedure 019-064.
OK ▼	
Vehicle parasitics are excessive	Check for transmission malfunctioning, cooling fan operation cycle time, and engine-driven units. Refer to the OEM service manuals.
OK ▼	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003Refer to the OEM Service manual..
OK ▼	
Fuel pump is malfunctioning	Check the fuel pump output pressure. Replace the fuel pump if necessary. Refer to Procedure 005-016 .
OK ▼	

(Continued)

Engine Starts But Will Not Keep Running (Continued)

Cause	Correction
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual, Bulletin No. 3666319.
OK ▼	
Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-001.
OK ▼	
Static injection timing is **not** correct	Check the static injection timing. Refer to Procedure 006-025 or 005-037.

Engine Vibration Excessive

This is symptom tree T075.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Engine is misfiring	Refer to the Engine Runs Rough or Misfires symptom tree.
OK ▼	
Engine idle speed is set too low (electronically controlled fuel systems)	Verify the correct idle speed setting. Increase the idle speed with the idle increment switch or an electronic service tool.
OK ▼	
Fan is loose, damaged, or **not** balanced	Check the fan. Refer to Procedure 008-040.
OK ▼	
Belt-driven accessories are malfunctioning	Check the fan hub, alternator, freon compressor, and hydraulic pump for interference. Isolate belt-driven accessories and check for vibration.
OK ▼	
Engine mounts are worn, damaged, loose or **not** correct	Verify the condition of the mounts. Refer to Procedure 016-010. Refer to OEM service manual.
OK ▼	
Vibration damper is damaged	Inspect the vibration damper. Refer to Procedure 001-052.
OK ▼	
Drive train components are malfunctioning or are **not** correct	Compare the drivetrain components to the engine and equipment specifications. Isolate the drivetrain components and check for vibrations. Refer to the OEM specifications.
OK ▼	

(Continued)

Engine Vibration Excessive (Continued)

Cause	Correction
Power take-off (PTO) is damaged	Check the PTO for damage and correct installation. Refer to the manufacturer's instructions.
OK ↓	
Gear-driven accessories are malfunctioning	Check the hydraulic pump and air compressor. Isolate gear-driven accessories and check for vibration.
OK ↓	
Flywheel housing is **not** aligned correctly	Check the flywheel housing alignment. Refer to Procedure 016-006.
OK ↓	
Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-005.

Engine Will Not Crank or Cranks Slowly (Air Starter)

This is symptom tree T077.

Cause	Correction
Air pressure is low in the air tanks	Increase air pressure with an external air source.
OK ↓	
Engine-driven units are engaged	Disengage engine-driven units .
OK ↓	
Lubricating oil temperature is below specification	Install an oil pan heater, or drain the oil and fill the system with warm oil.
OK ↓	
Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007–013 or 007-025. Use the oil type recommended in Section V of the engine operation and maintenance manual.
OK ↓	
Crankshaft rotation is impaired	Check crankshaft for ease of rotation. Refer to Procedure 001-016.
OK ↓	
Starting motor is malfunctioning or starting motor is **not** correct	Check the starting motor operation. Compare the starting motor with the engine and vehicle specifications. Refer to the manufacturer's instructions.
OK ↓	
Starting motor pinion or ring gear is damaged	Remove the starting motor, and inspect the gear. Refer to Procedure 013-020 and the manufacturer's instructions.
OK ↓	
Hydraulic lock in a cylinder	Remove the injectors, and rotate the crankshaft. Look for the source of fluid in the cylinder. Refer to Procedures 006-026 and 001-016.
OK ↓	

(Continued)

Engine Will Not Crank or Cranks Slowly (Air Starter) (Continued)

Cause	Correction
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.

Engine Will Not Crank or Cranks Slowly (Electric Starter)

This is symptom tree T078.

Cause	Correction
Battery voltage is low	Inspect the batteries and the unswitched battery supply circuit. Refer to Procedure 013-009. Refer to Procedure 019-087 in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009.
OK ▼	
Engine-driven units are engaged	Disengage engine-driven units .
OK ▼	
Lubricating oil temperature is below specification	Install an oil pan heater, or drain the oil and fill the system with warm oil.
OK ▼	
Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007–013 or 007-025. Use the oil type recommended in Section V of the engine operation and maintenance manual.
OK ▼	
Crankshaft rotation is impaired	Check crankshaft for ease of rotation. Refer to Procedure 001-016.
OK ▼	
Battery capacity is below specification	Refer to Electrical System Specifications in Section 13. Replace the batteries if necessary.
OK ▼	
Battery cables are **not** the correct gauge or length	Replace the battery cables with larger gauge or shorter length cables. Refer to Electrical System Specifications in Section 13.
OK ▼	

(Continued)

Engine Will Not Crank or Cranks Slowly (Electric Starter) (Continued)

Cause	Correction
Starting circuit component is malfunctioning	Check the starting circuit components. Refer to the OEM service manual.
OK ↓	
Starting motor pinion or ring gear is damaged	Remove the starting motor, and inspect the gear. Refer to Procedure 013-020 and the manufacturer's instructions.
OK ↓	
Hydraulic lock in a cylinder	Remove the injectors, and rotate the crankshaft. Look for the source of fluid in the cylinder. Refer to Procedures 006-026 and 001-016.
OK ↓	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.

Engine Will Not Shut Off

This is symptom tree T081.

Cause	Correction
Keyswitch circuit is malfunctioning	Check the vehicle keyswitch circuit. Refer to Procedure 019-064 of the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Fuel shutoff valve (FSOV) solenoid or circuit is malfunctioning (electronic controlled fuel systems)	Check the fuel shutoff valve solenoid and circuit. Refer to Procedures 019-049 and 019-050 of the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Engine is running on fumes drawn into the air intake	Check the air intake ducts. Locate and isolate the source of the fumes. Repair as necessary. Refer to the OEM service manuals.
OK ▼	
Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-040 or 010-049.

Fuel Consumption Excessive

This is symptom tree T087.

Cause	Correction
Interview the operator to verify the complaint	Refer to Fuel Consumption General Information and Customer Complaint Form at the end of Section TS. Follow the instructions on the form before continuing with this tree.
OK ⬇	
Operator technique is **not** correct	Explain the correct engine operation to the operator. Refer to the , Bulletin No. 3666319.
OK ⬇	
VE/VMS analysis uses incorrect data	Review the VE/VMS data and compare it to the vehicle and engine specifications. Do **not** use more than 20 percent for the Aero value. Refer to the VE/VMS User's Manual.
OK ⬇	
Equipment and environmental factors are affecting fuel consumption	Consider ambient temperatures, wind, tire size, axle alignment, routes, and use of aerodynamic aids when evaluating fuel consumption.
OK ⬇	
Drivetrain is **not** correctly matched to the engine	Check for correct gearing and drivetrain components. Refer to the OEM vehicle specifications.
OK ⬇	
Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF for fault code troubleshooting.
OK ⬇	
Programmable parameters or selected features are **not** correct	Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again if necessary. Refer to the appropriate electronic service tool manual or Section 019-078.
OK ⬇	

(Continued)

Fuel Consumption Excessive (Continued)

Cause	Correction
Turbocharger is **not** correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin No. 3379133. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK ↓	
Fuel leak	Check the fuel lines, fuel connections, and fuel filters for leaks. Refer to Procedure 006-024. Check the fuel lines to the supply tanks. Refer to OEM service manuals.
OK ↓	
Hubometer or odometer is miscalibrated	Check the hubometer and odometer calibrations. Calibrate or replace the hubometer or odometer if necessary. Calculate fuel consumption with new mileage figures.
OK ↓	
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual, Bulletin No. 3666319.
OK ↓	
Lubricating oil level is above specification	Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-009 or 007-025.
OK ↓	
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ↓	
Air intake system restriction is above specification	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ↓	

(Continued)

Fuel Consumption Excessive (Continued)

Cause	Correction
Intake manifold pressure (boost) is below specification	Refer to the Intake Manifold Pressure (Boost) is Below Normal symptom tree.
OK ↓	
Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ↓	
Charge air cooler (CAC) is restricted or leaking	Inspect the CAC for air restriction or leaks. Refer to Procedure 010-027.
OK ↓	
Exhaust system restriction is above specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ↓	
Injector is malfunctioning	Perform the single-cylinder cutout test. Replace the injectors as necessary. Refer to Procedure 006-026 or 014-008.
OK ↓	
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	
Fuel consumption has increased after an engine repair	Evaluate the engine repair to determine its effect on fuel consumption. Check part numbers to make sure the correct parts were used. Refer to the Control Parts List (CPL), Bulletin No. 3379133.
OK ↓	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.

Fuel in Coolant

This is symptom tree T091.

Cause	Correction
Bulk coolant supply is contaminated	Check the bulk coolant supply. Drain the coolant and replace with noncontaminated coolant. Replace the coolant filters. Refer to Procedure 008-018.
OK ↓	
Fuel heater is malfunctioning (if equipped)	Check the fuel heater and replace if necessary. Refer to the manufacturer's instructions.
OK ↓	
Cylinder head is cracked or porous, or an injector sleeve is leaking	Pressure-test the cylinder head and inspect the injector sleeves. Refer to Procedure 002-004.

Fuel in the Lubricating Oil

This is symptom tree T092.

Cause	Correction
Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with noncontaminated oil. Replace the oil filters. Refer to Procedure 007-025.
OK ↓	
Engine idle time is excessive	Low oil and coolant temperatures can be caused by long idle time (greater than 10 minutes). Shut off the engine rather than idle for long periods. If idle time is necessary, raise the idle speed. for your engine application
OK ↓	
Top injector o-ring or injector timing plunger is damaged	Perform the fluorescent dye tracer test to find the bad injector. Replace the injector or o-ring. Refer to Procedure 006-026.
OK ↓	
Top injector o-ring or injector timing plunger is damaged	Perform the fluorescent dye tracer test to find the bad injector. Replace the injector or o-ring. Refer to Procedure 006-026.
OK ↓	
Injector adapter wall is damaged behind the balance orifice	Check the injectors for damage. Refer to Procedure 006-026.
OK ↓	
Injector cup is damaged or is **not** correct	Check the injector cups for damage and for correct part numbers. Refer to Procedure 006-026.
OK ↓	
Fuel pump gear pump main shaft seals are leaking	Check the gear pump main shaft and seals. Refer to the Engine Shop Manual, Bulletin No. 3666075.
OK ↓	
Cylinder head is cracked or porous	Pressure-test the cylinder head. Refer to Procedure 002-004.

Intake Manifold Air Temperature Above Specification

This is symptom tree T096.

Cause	Correction
Intake manifold temperature sensor is malfunctioning	Check the intake manifold temperature sensor. Refer to Procedure 019-059 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Intake manifold temperature gauge is malfunctioning, if equipped	Test the temperature gauge. Refer to the OEM service manual.
OK ▼	
Vehicle speed is too low for adequate cooling with high engine load	Reduce the engine load. Increase the engine (fan) rpm by downshifting.
OK ▼	
Radiator shutters are **not** opening completely or the shutterstat setting is wrong	Inspect the radiator shutters. Repair or replace if necessary. Refer to the manufacturer's instructions. Check the shutterstat setting. Refer to Procedure 008-020 or 008-049.
OK ▼	
Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 384 cm^2 [60 in^2] or approximately 19.6 cm x 19.6 cm [7.5 in x 7.5 in] of opening at all times.
OK ▼	
Charge air cooler (CAC) fins, radiator fins, or air conditioner condenser fins are damaged or obstructed with debris	Inspect the CAC, air conditioner condenser, and radiator fins. Clean if necessary. Refer to Procedures 010-027 and 008-042 and the OEM service manual.
OK ▼	
Fan shroud is damaged or missing, or the air recirculation baffles are damaged or missing	Inspect the shroud and the recirculation baffles. Repair, replace, or install if necessary. Refer to Procedure 008-038 and the OEM service manual.
OK ▼	
Fan drive belt is loose	Check the belt tension and tighten if necessary. Refer to Procedure 008-002.
OK ▼	

(Continued)

Intake Manifold Air Temperature Above Specification (Continued)

Cause	Correction
Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure(s) 008-024, 008-025, 008-026, 008-027, or 008-028.
OK ▼	
Fan is **not** an adequate size for the application	Verify that the fan is the correct size. Refer to the engine and OEM specifications.
OK ▼	
Fan is in automatic mode and only coolant temperature controlled	Switch fan on manually or add intake manifold temperature fan switch.

Intake Manifold Pressure (Boost) is Below Normal

This is symptom tree T097.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ⬇	
Turbocharger is **not** correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin No. 3379133. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK ⬇	
Turbocharger is worn or damaged	Check the turbocharger for damage. Measure the turbine and compressor wheel clearances. Refer to Procedure 010-038.
OK ⬇	
Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ⬇	
Charge air cooler (CAC) is restricted or leaking	Inspect the CAC for air restriction or leaks. Refer to Procedure 010-027.
OK ⬇	
Rocker lever housing gasket is leaking	Check the rocker lever housing gasket. Refer to Procedure 003–011 or 003-013.
OK ⬇	
Air compressor connection is loose or damaged	Check the connection between the head and the air compressor. Repair or replace if necessary.
OK ⬇	
Air intake system restriction is above specification	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ⬇	

(Continued)

Intake Manifold Pressure (Boost) is Below Normal (Continued)

Cause	Correction
Exhaust system restriction is above specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ▼	
Engine power output is low	Refer to the Engine Power Output Low symptom tree.
OK ▼	
Turbocharger wastegate actuator is malfunctioning (if equipped)	Check the turbocharger wastegate actuator for correct operation. Refer to Procedure 010-050.
OK ▼	
Turbocharger wastegate controller is malfunctioning (if equipped)	Inspect the wastegate controller components. Refer to Procedure 010-109.

Low Idle Adjust Switch Does Not Work

This is symptom tree T099.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual, Bulletin No. 3666084 for fault code troubleshooting.
OK ▼	
Intake manifold air temperature is below specification	Refer to the Coolant Temperature Below Normal symptom tree.
OK ▼	
Low idle adjust switch and circuit is malfunctioning	Check the idle adjust switch and circuit. Refer to Procedures 019–052 and 019–053 in the Troubleshooting and Repair Manual, Bulletin No. 3666130, or Procedure 001-015 in the Troubleshooting and Repair Manual, Bulletin No. 3666084.

Lubricating Oil Consumption Excessive

This is symptom tree T102.

Cause	Correction
Verify the oil consumption rate	Check the amount of oil added versus the mileage.
OK ↓	
Lubricating oil leak (external)	Inspect the engine for external oil leaks. Tighten the capscrews, pipe plugs, and fittings. Replace gaskets if necessary. Refer to Section V for specifications.
OK ↓	
Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to 003-002
OK ↓	
Air compressor is pumping lubricating oil into the air system	Check the air lines for carbon buildup and lubricating oil. Refer to the Air Compressor is Pumping Excessive Lubricating Oil into the Air System symptom tree.
OK ↓	
Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-040 or 010-049.
OK ↓	
Lubricating oil cooler is leaking	Check for lubricating oil in the coolant. Refer to the Lubricating or Transmission Oil in the Coolant symptom tree.
OK ↓	
Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated symptom tree.
OK ↓	
Lubricating oil dipstick calibration is **not** correct	Check the dipstick calibration. Refer to Procedure 007-009.
OK ↓	

(Continued)

Lubricating Oil Consumption Excessive (Continued)

Cause	Correction
Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007–013 or 007-025. Use the oil type recommended in Section V of the engine operation and maintenance manual.
OK ↓	
Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to Section V of the Operation and Maintenance manual for your engine application.
OK ↓	
Piston, piston rings, or cylinder liner is worn or damaged	Check for air intake system leaks. Refer to Procedure 010-024. Check the pistons, piston rings, and liners for wear or damage. Refer to Procedures 001-043, 001-047 , or 001-028.
OK ↓	
Piston rings are **not** seated correctly (after an engine rebuild or piston installation)	Check blowby. Refer to Section 14. If blowby is excessive, check the piston rings for correct seating. Refer to Procedures 001-043 and 001-047.

Lubricating Oil Contaminated

This is symptom tree T103.

Cause	Correction
Identify lubricating oil contamination	Perform an oil analysis to determine the contaminants.
OK ➡ Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with noncontaminated oil. Replace the oil filters. Refer to Procedure 007-025.
OK ➡ Internal coolant leaks	Refer to the Coolant Loss - Internal symptom tree.
OK ➡ Lubricating oil sludge is excessive	Refer to the Lubricating Oil Sludge in the Crankcase is Excessive symptom tree.
OK ➡ Fuel in the lubricating oil	Refer to the Fuel in the Lubricating Oil symptom tree.

Lubricating Oil Degradation (Centinel)

This is symptom tree T103-2.

Cause	Correction
Centinel makeup tank is empty	Check makeup tank oil level daily. Add oil if necessary.
OK ↓	
Lubricating oil lines are bent or crimped	Check to see that all oil lines are free of crimps and sharp bends.
OK ↓	
Lubricating oil lines leak oil	Check all oil lines and fittings for leaks. tighten loose fittings and replace leaking oil lines if necessary.
OK ↓	
Oil temperature never sensed above 125 degrees Fahrenheit.	ECM will not cycle valve below 125 degree Fahrenheit. Confirm proper operation of oil pressure temperature sensor.
OK ↓	
Oil rifle supply never exceeds 20 psi	Check for restriction from the oil rifle to the Centinel valve solenoid.
OK ↓	
Makeup system lost prime	Perform priming procedure. Refer to Procedure(s) 007-071.
OK ↓	
Internal Centinel valve failure	Replace Centinel valve. Refer to Procedure(s) 007-071.

Lubricating Oil Pressure High

This is symptom tree T104.

Cause	Correction
Lubricating oil pressure switch, gauge, or sensor is malfunctioning or is **not** in the correct location	Check the oil pressure switch, gauge, or sensor for correct operation and location. Refer to Procedure 007-052.
OK ▼	
Coolant temperature is below specification	Refer to the Coolant Temperature Below Normal symptom tree.
OK ▼	
Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007–013 or 007-025. Use the oil type recommended in Section V of the engine operation and maintenance manual.
OK ▼	
Main oil pressure regulator is malfunctioning	Check the main oil pressure regulator assembly. Refer to Procedure 007-029.
OK ▼	
Lubricating oil viscosity sensor is plugged or defective	Check the viscosity sensor. Clean or replace if necessary. Refer to Procedure 007-041.

Lubricating Oil Pressure Low

This is symptom tree T105.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Lubricating oil level is above or below specification	Check the oil level. Add or drain oil if necessary. Refer to Procedure 007-025. Check the dipstick calibration. Refer to Procedure 007-009.
OK ▼	
Lubricating oil leak (external)	Inspect the engine for external oil leaks. Tighten the capscrews, pipe plugs, and fittings. Replace gaskets if necessary. Refer to Section V for specifications.
OK ▼	
Engine angularity during operation exceeds specification	Refer to the Engine Specification data sheet.
OK ▼	
Lubricating oil pressure sensor or gauge is malfunctioning or is **not** in the correct location	Check the oil pressure switch or gauge for correct operation and location. Refer to Procedure 007-052.
OK ▼	
Lubricating oil pressure sensor or circuit is malfunctioning	Check the oil pressure switch or circuit. Refer to Procedure 019-066 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Lubricating oil temperature is above specification	Refer to the Lubricating Oil Temperature Above Specification symptom tree.
OK ▼	
Lubricating oil filter is plugged	Change the oil and filter. Refer to Procedures 007-025 and 007-013. Review the oil change interval. Refer to the operation and maintenance manual.
OK ▼	

(Continued)

Lubricating Oil Pressure Low (Continued)

Cause	Correction
Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007–013 or 007-025. Use the oil type recommended in Section V of the engine operation and maintenance manual.
OK ↓	
Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated symptom tree.
OK ↓	
Lubricating oil cooler is plugged	Check the oil cooler. Refer to Procedure 007-003.
OK ↓	
Lubricating oil suction or transfer tube is loose or broken, or the gasket or o-rings are leaking	Remove and inspect the oil pan or suction tube. Refer to Procedure 007-025.
OK ↓	
Piston cooling nozzles are damaged or are **not** installed correctly	Check the piston cooling nozzles for damage and correct installation. Refer to Procedure 001-046.
OK ↓	
Main oil pressure regulator is malfunctioning	Check the main oil pressure regulator assembly. Refer to Procedure 007-029.
OK ↓	
Lubricating oil high-pressure relief valve is malfunctioning	Remove and inspect the high-pressure relief valve or lubricating pump pressure regulator. Refer to Procedure 007-021.
OK ↓	
Lubricating oil pump is malfunctioning or the o-rings are damaged	Inspect the lubricating oil pump and o-rings. Refer to Procedure 007-031.
OK ↓	

(Continued)

Lubricating Oil Pressure Low (Continued)

Cause	Correction
Internal engine damage or internal lubricating oil leak	Analyze the lubricating oil. Inspect the oil filter. Refer to Procedure 007-002. Check the main bearings, rod bearings, cam bushings, and rocker lever bushings for excessive wear. Refer to Section 1.

Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree T106.

Cause	Correction
Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with noncontaminated oil. Replace the oil filters. Refer to Procedure 007-025.
OK ▼	
Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007–013 or 007-025. Use the oil type recommended in Section V of the engine operation and maintenance manual.
OK ▼	
Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to Section V of the Operation and Maintenance Manual for your engine application.
OK ▼	
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manualfor your engine application.
OK ▼	
Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated symptom tree.
OK ▼	
Injector cup is damaged or is **not** correct	Check the injector cups for damage and for correct part numbers. Refer to Procedure 006-026.
OK ▼	
Static injection timing is **not** correct	Check the static injection timing. Refer to Procedure 006-025.

Lubricating Oil Temperature Above Specification

This is symptom tree t107.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user guide, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Lubricating oil level is above or below specification	Check the oil level. Add or drain oil if necessary. Refer to Procedure 007-025. Check the dipstick calibration. Refer to Procedure 007-009.
OK ▼	
Coolant temperature is above specification	Refer to the Coolant Temperature is Above Normal - Sudden Overheat or the Coolant Temperature is Above Normal - Gradual Overheat symptom tree.
OK ▼	
Lubricating oil pressure sensor or gauge is malfunctioning or is **not** in the correct location	Check the oil pressure switch or gauge for correct operation and location. Refer to Procedure 007-052.
OK ▼	
Lubricating oil pressure sensor or circuit is malfunctioning	Check the oil pressure switch or circuit. Refer to Procedure 019-066 in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Lubricating oil thermostat is malfunctioning	Check the oil thermostat. Refer to Procedure 007-039.
OK ▼	
Lubricating oil cooler is malfunctioning	Check the oil cooler. Refer to Procedure 007-003.

Lubricating or Transmission Oil in the Coolant

This is symptom tree T108.

Cause	Correction
Bulk coolant supply is contaminated	Check the bulk coolant supply. Drain the coolant and replace with noncontaminated coolant. Replace the coolant filters. Refer to Procedure 008-018.
OK ▼	
Lubricating oil cooler is malfunctioning	Check the oil cooler. Refer to Procedure 007-003.
OK ▼	
Torque converter cooler or hydraulic oil cooler is malfunctioning	Remove and inspect the cooler cores and o-rings. Refer to the OEM service manual.
OK ▼	
Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-004.
OK ▼	
Cylinder head is cracked or porous	Pressure-test the cylinder head. Refer to Procedure 002-004.
OK ▼	
Cylinder block is cracked or porous	Remove the oil pan. Pressure-test the cooling system to check for leaks. Refer to Procedure 001-027 .

Oil Pan Level Incorrect – Low (Centinel)

This is symptom tree 108-10.

Cause	Correction
OEM starter interlock devices engaged	Check the starter interlock devices. Refer to the OEM service manuals.
OK ↓	
OEM starter interlock devices engaged	Check the starter interlock devices. Refer to the OEM service manuals.
OK ↓	
Makeup tank vent clogged	Check makeup tank vent. Clean if necessary.
OK ↓	
Lubricating oil hoses are bent or crimped	Check to see that all oil lines are free of crimps and sharp bends.
OK ↓	
Lubricating oil hoses leak oil	Check all hose fittings for leaks. Tighten loose fittings and replace leaking oil hoses if necessary.
OK ↓	
Makeup system lost prime	Perform priming procedure. Refer to Procedure(s) 007-071.
OK ↓	
Internal control valve failure	Replace the control valve. Refer to Procedure 007-071.

Oil Pan Level Incorrect – High (Centinel)

This is symptom tree t108-11.

Cause	Correction
Makeup tank oil usage excessive	Calculate actual fuel burn ratio by dividing fresh oil usage by fuel burned. Compare actual fuel burn percentage to published fuel burn percentage.
OK ▼	
Rifle check valve stuck open	Loosen rifle hose from rifle check valve to check that rifle pressure remains in rifle hose after key-off. Oil in rifle hose **must** be under pressure.
OK ▼	
Outlet check valve struck open	Remove the oil replenishment hose from the outlet check valve and check for oil leakage through the check valve.
OK ▼	
Internal control valve failure	Replace the control valve. Refer to Procedure 007-071.

Operating Fuel Pressure is Low

This is symptom tree T109.

Cause	Correction
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ↓	
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ↓	
In-line check valve(s) are installed backwards or have incorrect part number	Check the in-line check valves for the correct part number. Check the arrow on the check valve(s) for the correct orientation.
OK ↓	
Fuel pump pressure regulator is stuck	Check the fuel pump pressure regulator. Refer to Procedure 005-060.
OK ↓	
Injector o-rings are damaged or missing	Remove and check the injectors. Replace the injector o-rings. Refer to Procedure 006-026.

Smoke, Black — Excessive

This is symptom tree T116.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal symptom tree.
OK ▼	
Turbocharger is **not** correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin No. 3379133. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK ▼	
Intake manifold pressure (boost) sensor is **not** correct	Check the boost sensor part number and compare it to the Control Parts List (CPL), Bulletin No. 3379133. Replace the boost sensor if necessary. Refer to Procedure 019-061in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Intake manifold pressure (boost) sensor or circuit is malfunctioning	Check the boost sensor and circuit. Refer to Procedure 019-061in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Intake air temperature sensor is malfunctioning	Check the intake air temperature sensor. Refer to Procedure 019-059 in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual.
OK ▼	

(Continued)

Smoke, Black — Excessive (Continued)

Cause	Correction
Electronic control module (ECM) calibration is **not** correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ▼	
Air intake system restriction is above specification	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ▼	
Exhaust system restriction is above specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ▼	
Charge air cooler (CAC) is restricted or leaking	Inspect the CAC for air restriction or leaks. Refer to Procedure 010-027.
OK ▼	
Intake manifold pressure (boost) is below specification	Refer to the Intake Manifold Pressure (Boost) is Below Normal symptom tree.
OK ▼	
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK ▼	
Injector is malfunctioning	Remove or tilt back the exhaust manifold and identify the smoking cylinder. Replace the malfunctioning injector. Refer to Procedure 006-026.
OK ▼	

(Continued)

Smoke, Black — Excessive (Continued)

Cause	Correction
Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube.
OK ↓	
Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-040 or 010-049.
OK ↓	
Turbocharger wheel clearance is out of specification	Check the radial bearing clearance and axial clearance. Inspect the turbocharger. Repair or replace the turbocharger if necessary. Refer to Procedures 010-038 and 010-047.
OK ↓	
Static injection timing is **not** correct	Check the static injection timing. Refer to Procedure 006-025 or 005-037.
OK ↓	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.

Smoke, White — Excessive

This is symptom tree T118.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™. Refer to the ISM Insite software user manual, Bulletin No. 3666894. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Electronic control module (ECM) is **not** calibrated or has incorrect calibration	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032in the ISM Troubleshooting and Repair Manual, Bulletin No. 3666266.
OK ▼	
Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal symptom tree.
OK ▼	
Engine is operating at low ambient temperature	Check the winterfront, shutters, and underhood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual. Use intake air from under the hood in cold weather.
OK ▼	
Coolant temperature sensor is malfunctioning	Check the coolant temperature sensor. Refer to Procedure 019-019.
OK ▼	
Intake air temperature sensor is malfunctioning	Check the intake air temperature sensor. Refer to Procedure019-059.
OK ▼	
Fuel grade is **not** correct for the application, or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual.
OK ▼	

(Continued)

Smoke, White — Excessive (Continued)

Cause	Correction
Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure .
OK ↓	
Injector is malfunctioning	Perform the single-cylinder cutout test. Replace the injectors as necessary. Refer to Procedure 006-026 or 014-008.
OK ↓	
Coolant is leaking into the combustion chamber	Refer to the Coolant Loss - Internal symptom tree.
OK ↓	
Static injection timing is **not** correct	Check the static injection timing. Refer to Procedure 006-025 or 005-037.
OK ↓	
Injector protrusion is **not** correct	Check the injector protrusion. Refer to Procedure 002-022.
OK ↓	
Pistons or piston rings are worn, damaged, or **not** correct	Check the pistons for correct part numbers. Refer to Control Parts List (CPL), Bulletin No. 3379133. Check the pistons and rings for wear and damage. Refer to Procedures 001-043 and 001-047.
OK ↓	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-002.

Turbocharger Leaks Engine Oil or Fuel

This is symptom tree T122.

Cause	Correction
Engine is operating for extended periods under light or no-load conditions (slobbering)	Review the engine operating instructions of Section 1 of the Operating and Maintenance Manual for your engine application.
OK ▼	
Turbocharger is **not** correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin No. 3379133. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK ▼	
Turbocharger drain line is restricted	Remove the turbocharger drain line and check for restriction. Clean or replace the drain line.
OK ▼	
Crankcase pressure is excessive	Check for excessive blowby. Refer to Section 14. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.
OK ▼	
Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-040 or 010-049.

Engine Noise Diagnostic Procedures — General Information

NOTE: When diagnosing engine noise problems, make sure that noises caused by accessories, such as the air compressor and power takeoff, are **not** mistaken for engine noises. Remove the accessory drive belts to eliminate noise caused by these units. Noise will also travel to other metal parts **not** related to the problem. The use of a stethoscope can help locate an engine noise.

Engine noises heard at the crankshaft speed, engine rpm, are noises related to the crankshaft, rods, pistons, and piston pins. Noises heard at the camshaft speed, one-half of the engine rpm, are related to the valve train. A hand-held digital tachometer can help to determine if the noise is related to components operating at the crankshaft or camshaft speed.

Engine noise can sometimes be isolated by performing a cylinder cutout test. Refer to Procedure 014-008. If the volume of the noise decreases or the noise disappears, it is related to that particular engine cylinder.

There is **not** a definite rule or test that will positively determine the source of a noise complaint.

Engine driven components and accessories, such as gear-driven fan clutches, hydraulic pumps, belt-driven alternators, air-conditioning compressors, and turbochargers can contribute to engine noise. Use the following information as a guide to diagnosing engine noise.

Main Bearing Noise

(Refer to Engine Noise Excessive — Main Bearing symptom tree)

The noise caused by a loose main bearing is a loud dull knock heard when the engine is pulling a load. If all main bearings are loose, a loud clatter will be heard. The knock is heard regularly every other revolution. The noise is the loudest when the engine is lugging or under heavy load. The knock is duller than a connecting rod noise. Low oil pressure can also accompany this condition.

If the bearing is **not** loose enough to produce a knock by itself, the bearing can knock if the oil is too thin, or if there is no oil at the bearing.

An irregular noise can indicate worn crankshaft thrust bearings.

An intermittent sharp knock indicates excessive crankshaft end clearance. Repeated clutch disengagements can cause a change in the noise.

Connecting Rod Bearing Noise

(Refer to Engine Noise Excessive — Connecting Rod symptom tree)

Connecting rods with excessive clearance knock at all engine speeds, and under both idle and load conditions. When the bearings begin to become loose, the noise can be confused with piston slap or loose piston pins. The noise increases in volume with engine speed. Low oil pressure can also accompany this condition.

Piston Noise

(Refer to Engine Noise Excessive — Piston symptom tree)

It is difficult to tell the difference between piston pin, connecting rod, and piston noise. A loose piston pin causes a loud double knock which is usually heard when the engine is idling. When the injector to this cylinder is cut out, a noticeable change will be heard in the sound of the knocking noise. However, on some engines the knock becomes more noticeable when the vehicle is operated on the road at steady speed condition.

Driveability — General Information

Driveability is a term which in general describes vehicle performance on the road. Driveability problems for an engine can be caused by several different factors. Some of the factors are engine related and some are not.

Before troubleshooting, it is important to determine the exact complaint and whether the engine has a real driveability problem or if it simply does **not** meet driver expectations. The Driveability-Low Power Customer Complaint Form is a valuable list of questions that **must** be used to assist the service technician in determining what type of driveability problem the vehicle is experiencing. Complete the checklist before troubleshooting the problem. The form can be found at the end of this section. If an engine is performing to factory specifications but does **not** meet the customer's expectations, it **must** be explained to the customer that nothing is wrong with the vehicle and why.

The troubleshooting symptom charts have been set up to divide driveability problems into two different symptoms: Engine Power Output Low and Engine Acceleration or Response Poor.

Low power is a term that is used in the field to describe many different performance problems. However, in this manual low power is defined as the inability of the engine to produce the power necessary to move the vehicle at a speed that can be reasonably expected under the given conditions of load, grade, wind, and so on. Low power is usually caused by the lack of fuel flow which can be caused by any of the following factors:

- Lack of full travel of the throttle pedal
- Failed boost sensor
- Excessive fuel inlet, intake, exhaust, or drainline restriction
- Loose fuel pump suction lines

Low power is **not** the inability of the vehicle to accelerate satisfactorily from a stop or the bottom of a grade. Refer to the symptom tree Engine Power Output Low for the proper procedures to locate and correct a low power problem. The chart starts off with basic items which can cause lower power.

Poor acceleration or response is described in this manual as the inability of the vehicle to accelerate satisfactorily from a stop or from the bottom of a grade. It can also be the lag in acceleration during an attempt to pass or overtake another vehicle at conditions less than rated speed and load. Poor acceleration or response is difficult to troubleshoot since it can be caused by factors such as:

- Engine or pump related factors
- Driver technique
- Improper gearing
- Improper engine application
- Worn clutch or clutch linkage

Engine related poor acceleration or response can be caused by several different factors such as:

- Failed boost sensor
- Excessive drainline restriction
- Throttle deadband

Refer to the symptom tree Engine Acceleration or Response Poor for the proper procedures to locate and correct a poor acceleration or response complaint. For additional information, see Troubleshooting Driveability Complaints, Bulletin No. 3387245.

Driveability/Low Power — Customer Complaint Form

Customer Name/Company _____ Date _____

1. How did the problem occur? ..... Suddenly _____ Gradually _____
2. At what hour/mileage did the problem begin? ..... Hours _____ Miles _____ Since New _____

— After engine repair? ..... Yes _____ No _____
— After equipment repair? ..... Yes _____ No _____
— After change in equipment use? ..... Yes _____ No _____
— After change in selectable programmable parameters? ..... Yes _____ No _____
— If so, what was repaired and when?_____
— Does the vehicle also experience poor fuel economy? ..... Yes _____ No _____

Answer questions 4 through 8 using selections (A through F) listed below. Circle the letter or letters that best describes the complaint.

A — Compared to fleet
B — Compared to competition
C— Compared to previous engine
D — Personal expectation
E — Won't pull on hill
F— Won't pull on flat

A B C D E F

- Can the vehicle obtain the expected road speed? ..... Yes _____ No _____
- What is desired speed? ..... rpm/mph _____
- What is achieved speed? ..... rpm/mph _____
- GVW _____

A B C D

- Is the vehicle able to pull the load? ..... Yes _____ No _____

When?

- _____ In the hills
- _____ With a loaded trailer
- _____ On the flat
- _____ Other _____

IF QUESTION 4 OR 5 WAS ANSWERED NO, FILL OUT THE DRIVEABILITY/LOW POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST AND GO TO THE LOW POWER SYMPTOM TREE.A B C D E F

- Is the vehicle slow to accelerate or respond? ..... Yes _____ No _____
- From a stop? ..... Yes _____ No _____
- After a shift? ..... Yes _____ No _____ rpm _____
- Before a shift? ..... Yes _____ No _____ rpm _____
- No shift? ..... Yes _____ No _____ rpm _____

A B C D

- Does the vehicle hesitate after periods of long deceleration or coasting? ..... Yes _____ No _____ rpm _____

IF QUESTION 6 OR 7 WAS ANSWERED YES, FILL OUT THE DRIVEABILITY/LOW POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST AND GO TO THE POOR ACCELERATION/RESPONSE SYMPTOM TREE.

A B C D E F

Additional Comments:

- _____
  _____
  _____

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Driveability/Low Power/Excessive Fuel Consumption — Checklist

Vehicle/Equipment Specifications

Year, Type and Model: _____

Transmission (RT 14609, etc.): _____, Duty Cycle: _____

Rear Axle Ratio, No. of Axles: _____, Application: Industrial ____, Marine ____. Genset ____. Automotive ____

Typical GVW: _____, Engine Rating: _____

Trailer Type and Size: _____, Height: _____, Weight: _____

Tire Size (11R x 24.5, Low Profile, etc.) _____

Tire Type: Radial _____, Standard Tread _____, Extra Tread _____

Fan Type: Direct Drive _____, Viscous _____, Clutch _____

Power Steering: ..... Yes _____ No _____
Air Conditioner: ..... Yes _____ No _____
Air Shield: ..... Yes _____ No _____
Freon Compressor: ..... Yes _____ No _____

General Information:					
DO No.:			SC No.:		
Fuel Pump Code:			Fuel Pump Serial No.:		
Mileage:			Engine Serial No.:		
Date in Service:			Engine Model and Rating:		
Cruise Speed and rpm:			Rated Speed and rpm:		
Road Speed Governor:	Yes	No	Type:		
Engine Brake:	Yes	No	Type/Brand:		
Chassis and Other Related Items					
Tank Vents:	OK	Not OK	Obvious Fuel Leaks:	Yes	No
Brake Drag:	OK	Not OK	Axle Alignment:	OK	Not OK
Altitude:			Ambient Temperature:		
Fuel Heater:					
Fuel Type:	No. 1D	No. 2D	Other		
Typical Terrain:	Flat	Hilly	% Asphalt	% Concrete	

Additional Comments:

_____

_____

Recommended Literature:

Troubleshooting Driveability Complaints, Bulletin No. 3387137

Guide to Troubleshooting, Bulletin No. 3379090

Professional Driver Techniques, Bulletin No. 3804818

Guide to LCPM, Bulletin No. 3382021

Troubleshooting Excessive Fuel Consumption, Bulletin No. 3387245

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Fuel Consumption — General Information

The cause of excessive fuel consumption is hard to diagnose and correct because of the potential number of factors involved. Actual fuel consumption problems can be caused by any of the following factors:

- — Engine factors
- — Vehicle factors and specifications
- — Environmental factors
- — Driver technique and operating practices
- — Fuel system factors
- — Low power/driveability problems.

Before troubleshooting, it is important to determine the exact complaint. Is the complaint based on whether the problem is real or perceived, or does **not** meet driver expectations? The "Fuel Consumption — Customer Complaint Form" (on the next page) is a valuable list of questions that can be used to assist the service technician in determining the cause of the problem. Complete the form before troubleshooting the complaint. The following are some of the factors that **must** be considered when troubleshooting fuel consumption complaints.

1. **Result of a Low Power/Driveability Problem:** An operator will change driving style to compensate for a low power/driveability problem. Some things the driver is likely to do are, (a) shift to a higher engine rpm or (b) run on the droop curve in a lower gear instead of upshifting to drive at part throttle conditions. These changes in driving style will increase the amount of fuel used.
2. **Driver Technique and Operating Practices:** As a general rule, a 1 mph increase in road speed equals a 0.1 mpg increase in fuel consumption. This means that increasing road speed from 50 to 60 mph will result in a loss of fuel mileage of 1 mpg.
3. **Environmental and Seasonal Weather Changes:** As a general rule, there can be as much as a 1 to 1.5 mpg difference in fuel consumption depending on the season and the weather conditions.
4. **Excessive Idling Time:** Idling the engine can use from 0.5 to 1.5 gallons per hour depending on the engine idle speed.
5. **Truck Route and Terrain:** East/west routes experience almost continual cross winds and head winds. Less fuel can be used on north/south routes where parts of the trip are **not only** warmer, but see less wind resistance.
6. **Vehicle Aerodynamics:** The largest single power requirement for a truck is the power needed to overcome air resistance. As a general rule, each 10 percent reduction in air resistance results in a 5 percent increase in mpg.
7. **Rolling Resistance:** Rolling resistance is the second largest consumer of power on a truck. The type of tire and tread design have a sizeable effect on fuel economy and performance. Changing from a bias ply to a low profile radial tire can reduce rolling resistance by about 36 percent.

Additional vehicle factors, vehicle specifications, and axle alignment can also affect fuel consumption. For additional information on troubleshooting fuel consumption complaints, refer to Troubleshooting Excessive Fuel Consumption, Bulletin No. 3387245.

Fuel Consumption — Customer Complaint Form

Customer Name/Company _____ Date _____

Answer the following questions. Some questions require making an X next to the appropriate answer.

1. What fuel mileage is expected? _____ Expected mpg
2. What are the expectations based on?
   Original mileage _____, Other units in fleet _____, Competitive engines _____
   Previous engine owned _____, Expectations only _____, VE/VMS report _____
3. When did the problem occur?
   Since New _____, Suddenly _____, Gradually _____
4. Did the problem start after a repair? Yes _____ No _____
   If so, what was repaired and when? _____
5. Is the vehicle also experiencing a Driveability problem (Low Power or Poor Acceleration/Response)? Yes _____ No _____

IF ANSWERED YES, FILL OUT THE DRIVEABILITY/LOW POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST AND GO TO THE ENGINE POWER OUTPUT LOW TROUBLESHOOTING SYMPTOM CHART.

6. Is the problem seasonal? Yes _____ No _____
7. Weather conditions during fuel consumption check?
   Rain _____, Snow _____, Windy _____, Hot Temperatures _____, Cold Temperatures _____
8. How is the fuel mileage measured? Tank _____, Trip _____, Month _____, Year _____
   Hubometer _____, Odometer _____
9. Are accurate records kept of fuel added on the road? Yes _____ No _____
10. Do routes vary between compared vehicles? Yes _____ No _____
11. Have routes changed for the engine being checked? Yes _____ No _____
12. What are the loads hauled, compared to comparison unit? GVW _____
    Heavier _____, Lighter _____
13. What is the altitude during operation?
    Below 10,000 feet _____, Above 10,000 feet _____
14. How much of the time is the truck spent idling? Hours/day _____
15. Is the driver technique or operating practices affecting fuel economy?
    - — High road speed: mph _____
    - — Operate at rated speed or above: rpm _____
    - — Incorrect shift rpm: Shift rpm _____, Torque Peak _____
    - — Operate at a cruise speed: rpm _____
    - — Believe compensating for low power: Yes _____ No _____

IF AFTER FILLING OUT THIS FORM IT APPEARS THAT THE PROBLEM IS NOT CAUSED BY VEHICLE FACTORS, ENVIRONMENTAL FACTORS, OR DRIVER TECHNIQUE, FILL OUT THE DRIVEABILITY/LOW POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST AND GO TO THE FUEL CONSUMPTION EXCESSIVE TROUBLESHOOTING SYMPTOM TREE.

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Oil Consumption

In addition to the information that follows, a service publication is available entitled Technical Overview of Oil Consumption, Bulletin No. 3379214.

Cummins Engine Company, Inc. defines "Acceptable Oil Usage" as outlined in the following table.

ACCEPTABLE OIL USAGE									
ANY TIME DURING COVERAGE PERIOD									
ENGINE FAMILY	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART
A	10.0	10.6	12.0	400	425	475	650	675	775
4B	10.0	10.6	12.0	400	425	475	650	675	775
6B	10.0	10.6	12.0	400	425	475	650	675	775
6C	10.0	10.6	12.0	400	425	475	650	675	775
V/VT-378	4.0	4.3	5.0	-	-	-	-	-	-
V/VT-504	4.0	4.3	5.0	250	265	310	400	425	485
V/VT-555	4.0	4.3	5.0	250	265	310	400	425	485
L Series	4.0	4.3	5.0	250	265	310	400	425	485
M Series	4.0	4.3	5.0	250	265	310	400	425	485
N Series	4.0	4.3	5.0	250	265	310	400	425	485
V/VT/VTA-903	4.0	4.3	5.0	250	265	310	400	425	485
KT/KTA-19	3.0	3.2	3.75	200	210	250	320	340	390
V/VT/VTA28	2.0	2.1	2.5	-	-	-	-	-	-
KT/KTA38	1.5	1.6	1.8	-	-	-	-	-	-
KTA50	1.1	1.2	1.3	-	-	-	-	-	-

ACCEPTABLE OIL USAGE (Transit Bus, Shuttle Bus and School Bus)									
ANY TIME DURING COVERAGE PERIOD									
ENGINE FAMILY	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART
B	10.0	10.6	12.0	200	210	240	320	340	385
C	8.0	8.5	10.0	150	160	180	240	255	290
L, M, N	4.0	4.3	5.0	100	105	120	160	170	195

Cummins
Engine Company, Inc.
Box 3005
Columbus, IN, U.S.A.
47202-3005

15200020

Engine Lubricating Oil Consumption Report

Owner's Name	Date of Delivery			Engine Serial Number
	Month	Day	Year	
Address	Equipment Manufacturer			Engine Model & HP
City	State/Province	Equipment Serial No.		Fuel Pump Serial No.
Engine Application (Describe)	Oil and Filter Change Interval		Complaint Originally Registered	
	Oil	Filters	Date	Mile/Hours/Kilometers

Lubricating Oil Added

Date Added Oil	Engine Operation Miles/Hours/Kilometers	Quarts - Liters Oil Added	Brand and Viscosity of Oil Used
Start Test			

Last Mileage/Hours/Kilometers _____ Minus Start Mileage/Hours/Kilometers _____

Equals Test Mileage/Hours/Kilometers _____ Divided By Oil Added _____

Equals _____ Usage Rate _____

Customer Signature	Cummins Dealer	Cummins Distributor

Cummins Engine Company, Inc.
Form 4755

Cummins
Engine Company, Inc.
Box 3005
Columbus, IN, U.S.A.
47202-3005

15200020

OIL CONSUMPTION REPORT

Customer Name:	Dist/Dir:
Engine Model:	Mi/Km/Hr:
Engine Serial No.:	CPL No.:
Vehicle Make/Model:	Date:

1. Review of maintenance history:

   List any previous failures that could have had a detrimental effect on cylinder component life. Failures could include fuel, coolant, and/or foreign abrasives in the oil, second ring groove beat-out, filter plugging, etc.

- Lube Oil Used:
  - Brand
  - Viscosity
  - Change Interval (mi/km/hr)

- Combination Oil Filter:
  - Model
  - Element
  - Change Interval (mi/km/hr)

- Bypass Oil Filter:
  - Model
  - Element
  - Change Interval (mi/km/hr)

- Full Flow Oil Filter:
  - Model
  - Element
  - Change Interval (mi/km/hr)

- Air Cleaner:
  - Make and Model
  - Change Interval

2. List any external engine leaks.

3. Visually check for any internal leaks and list. Check turbocharger seals, valve guides, air compressor, etc.

4. Had the fuel pump been tampered with? _____ What is maximum rail pressure readings? _____ If yes, the pump must be reset to factory specifications and the customer sent out to re-evalute his oil consumption rate and the eligibility requirements must be met again.

5. Drain and refill oil pan to check dipstick markings and notes findings. **Warning: Governmental agencies have determined that used engine oil is toxic and carcinogenic. Avoid breathing, injestion, and excessive contact.**

6. Only after above checks are completed, leaks corrected and proper documentation is completed, disassemble engine to determine cause for the failure and repair as required.

7. State reason for oil consumption.

Signed: _____

Response Test

This procedure can be used for testing response on heavy duty engines.

For this test, a boost pressure gauge, associated plumbing lines, and a stop watch will be needed.

1. Attach the tractor to a loaded trailer, GVW **must** be 65,000 to 80,000 pounds.
2. Make sure the engine is warmed to operating temperature.
3. Determine the full boost pressure at torque peak engine speed while applying full throttle. The trailer brakes can also be applied for additional loading, if required. Record the boost pressure at torque peak engine speed.
4. Perform the coast down test. Select a secondary road that is level and has minimal traffic. Accelerate the vehicle up through the gears to direct fear (1 to 1) and to an engine speed at least 300 rpm above torque peak engine speed. From this point, allow the vehicle to coast down to torque peak engine speed then snap the throttle. Measure the time required to develop 50 percent of torque peak boost (determined in Step No. 3 above).
5. Repeat Step No. 4 two more times for a total of three data points.
6. Calculate the average time to 50 percent boost: Average time to 50 percent boost = (time 1 + time 2 ÷ time 3)/3.

The average time **must** be 3 seconds or less for acceptable performance.

Section 0 - Complete Engine - Group 00

Section Contents

Page

Complete Engine - General Information 0-1
General Information 0-1

Engine Installation 0-5
Install 0-5

Engine Removal 0-3
Remove 0-3

Service Tools 0-2
Engine Removal and Installation 0-2

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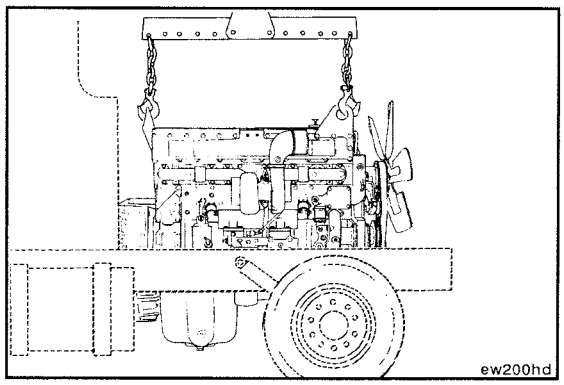
Complete Engine - General Information

General Information



The procedures required to replace an engine will vary with different engine models, the type of equipment, optional equipment, and the shop facilities. Use the following procedures as a guide.

All replacement steps will **not** apply to all types of equipment. Complete **only** the steps that apply to the equipment involved. Use the equipment manufacturer's recommendations and precautions for removal of chassis parts to gain access to the engine.

Service Tools

Engine Removal and Installation

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3162871	**Engine Lifting Fixture** Used to remove and install the engine.	

Engine Removal (000-001)

Remove (000-001-002)

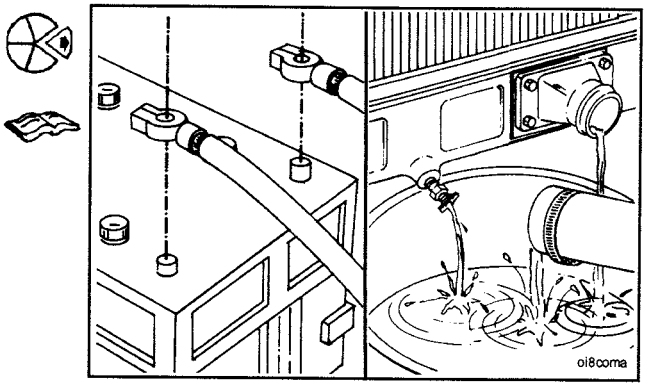
⚠ WARNING ⚠

Coolants can be toxic. Keep children and pets away.

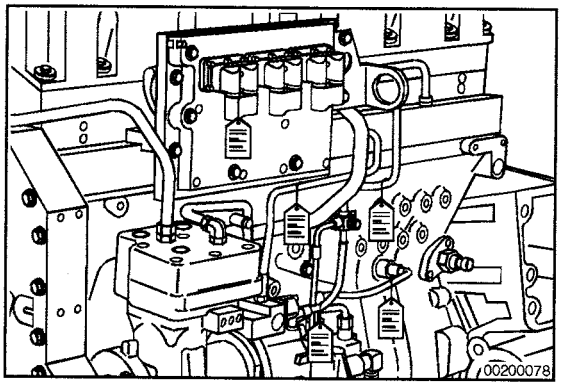
Disconnect the battery cables.

Drain the engine coolant. Refer to Procedure 008-018.

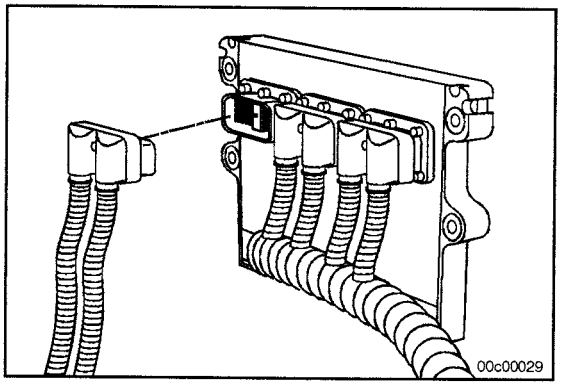
NOTE: If the coolant is **not** going to be reused, dispose of the used coolant or antifreeze in accordance with federal, state, and local laws and regulations.



Place a tag on all hoses, lines, linkage, and electrical connections as they are removed, to identify their locations.



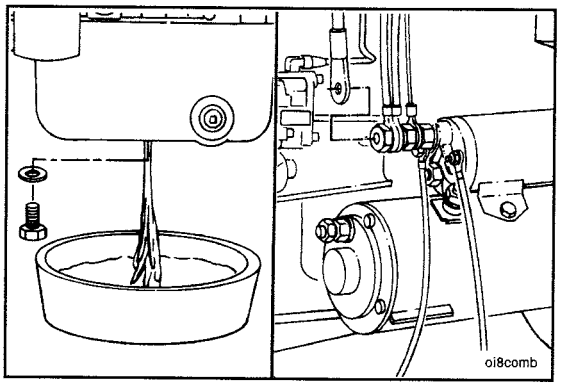
Disconnect the OEM wiring harness from the ECM. Refer to Procedure 019-031 in the Troubleshooting and Repair Manual, ISM Fuel System, ISM Engines, Bulletin No. 3666266.

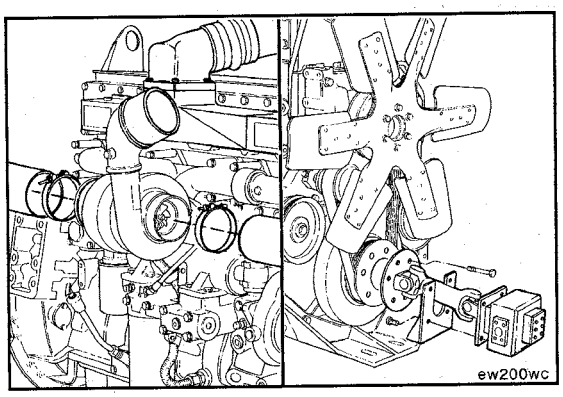


Drain the lubricating oil. Refer to Procedure 007-025.

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

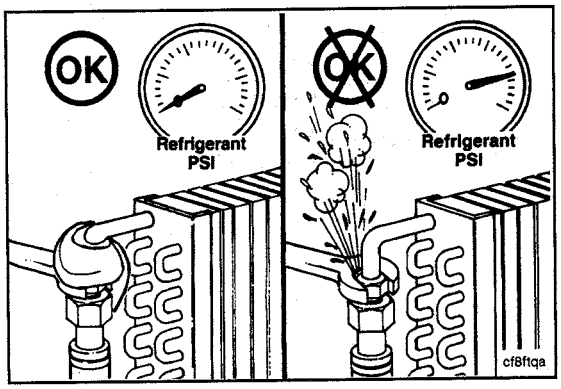
NOTE: Dispose of used oil in accordance with federal, state, and local laws and regulations.





Disconnect the intake and exhaust air pipes.

Disconnect all chassis-mounted engine-driven accessories.

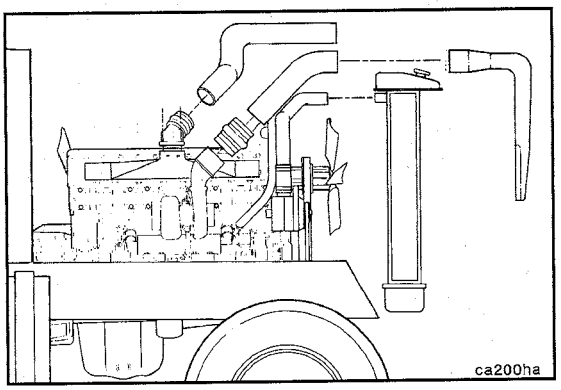


⚠ WARNING ⚠

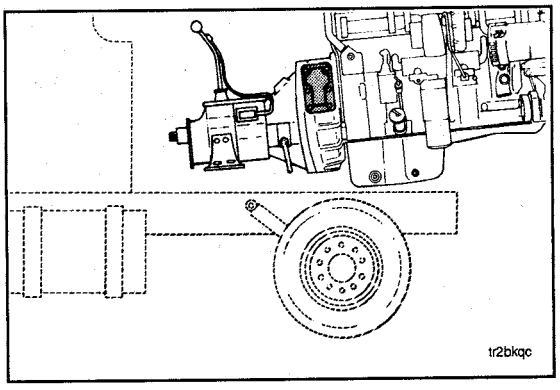
If a liquid refrigerant system (air conditioning) is used, wear eye and face protection, and wrap a cloth around the fittings before removing. Liquid refrigerant can cause serious eye and skin injuries.

⚠ WARNING ⚠

To protect the environment, liquid refrigerant systems must be properly emptied and filled using equipment that prevents the release of refrigerant gas into the atmosphere. Federal law requires capturing and recycling the refrigerant.



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



⚠ WARNING ⚠

The engine lifting equipment must be designed to lift the engine and the transmission safely as an assembly. The wet weight of the standard engine with accessories is 996 kg [2193 lb]. Refer to the equipment manufacturer's specifications for the transmission weight.

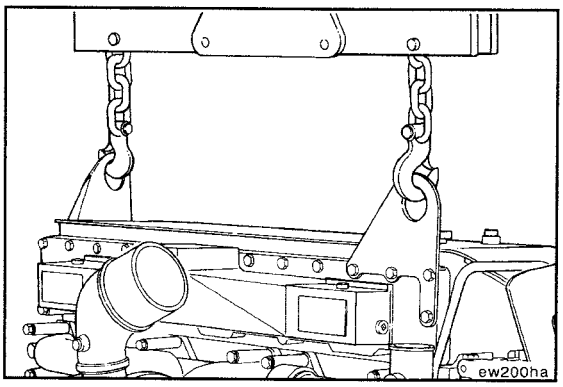
The dry weight of the engine is approximately 940 kg [2070 lb]. Refer to the equipment manufacturer's specifications for the transmission weight.

On applications in which the rear engine mounts are attached to the transmission, it will be necessary to remove the engine and transmission as an assembly.

Use a properly rated hoist and engine lifting fixture, Part No. 3162871, attached to the engine-mounted lifting brackets, to remove the engine.

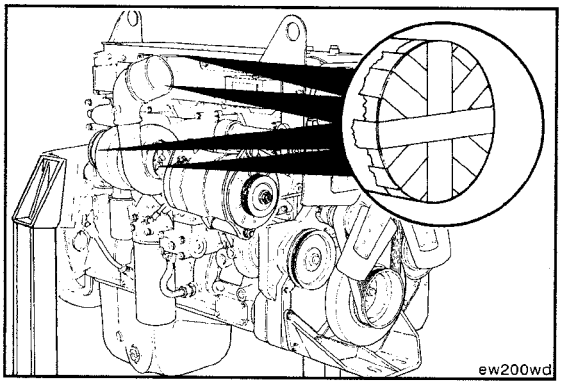
NOTE: If the transmission is **not** removed, place a support under the transmission to prevent it from falling.

Remove the engine.

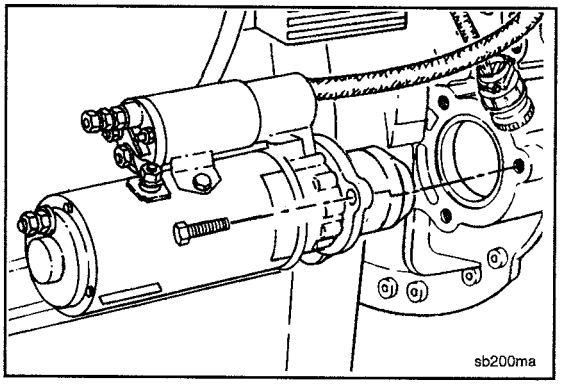


Cover all engine openings to prevent dirt and debris from entering the engine.

Place the engine on suitable engine support stands.



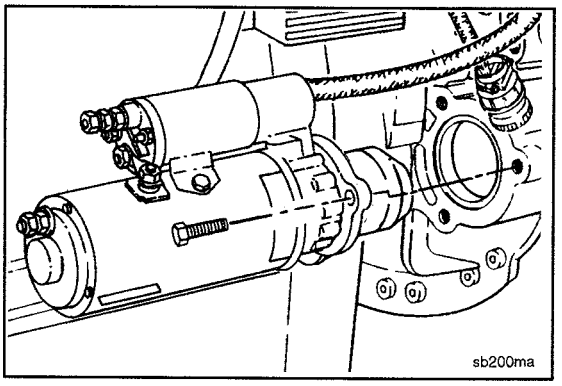
Remove all remaining accessories and brackets that will be used with the replacement engine.

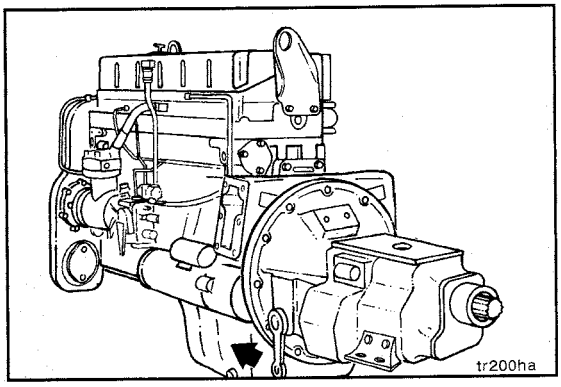


Engine Installation (000-002)

Install (000-002-026)

Install all accessories and brackets that were removed from the previous engine.



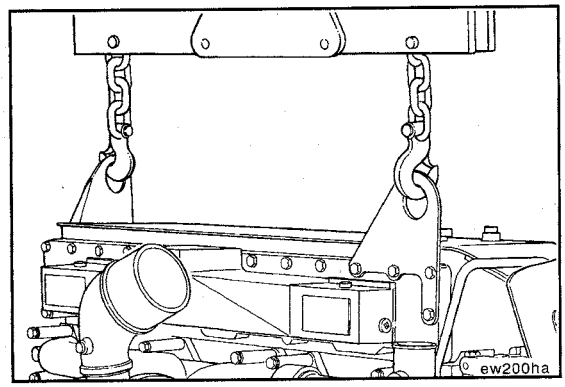


⚠ WARNING ⚠

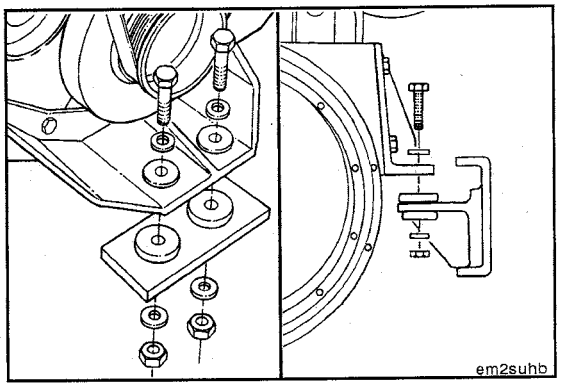
The engine lifting equipment must be designed to lift the engine and the transmission safely as an assembly. The wet weight of the standard engine with accessories is 996 kg [2193 lb]. Refer to the equipment manufacturer's specifications for the transmission weight.

The dry weight of the engine is approximately 940 kg [2070 lb]. Refer to the equipment manufacturer's specifications for the transmission weight.

On applications in which the rear engine mounts are attached to the transmission, it will be necessary to install the engine and transmission as an assembly.



Use a properly rated hoist and engine lifting bracket, Part No. 3162871, attached to the engine-mounted lifting brackets, to install the engine.

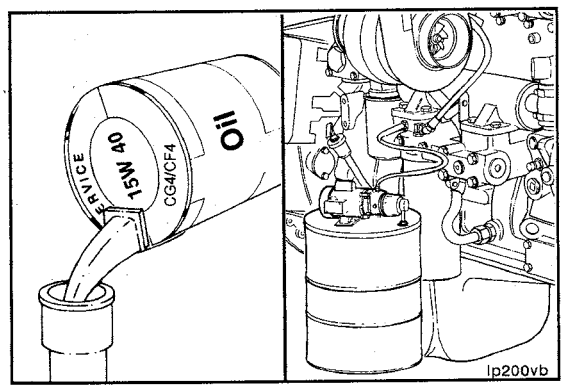


Inspect all of the rubber isolators to be sure they are in good condition.

Align the engine in the chassis and tighten the engine mounting capscrews. Refer to the equipment manufacturer's torque specifications.

Connect all engine- and chassis-mounted accessories that were removed.

NOTE: Be sure all lines, hoses, and tubes are properly routed and fastened to prevent damage.

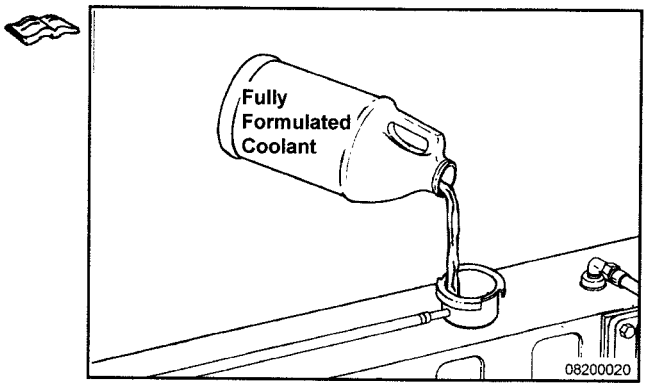


Fill the engine with clean 15W-40 lubricating oil. Refer to Procedure 007-025. Refer to Section E for the correct oil capacity.

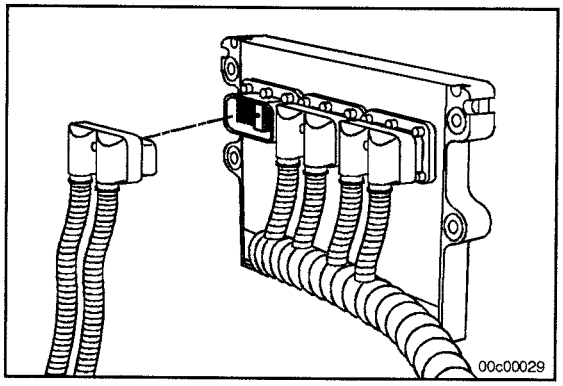
NOTE: The engine lubricating oil system **must** be pressurized before the engine is operated. Refer to Procedure 007-037.

Fill the cooling system with fully formulated coolant or a 50/50 mixture of fully formulated antifreeze and good-quality water. Refer to Procedure 008-018.

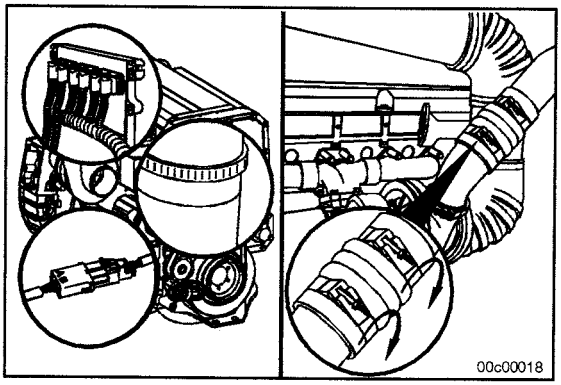
Refer to the equipment manufacturer's specifications for radiator and system capacity.



Connect the OEM wiring harness to the ECM. Refer to Procedure 019-031 in the Troubleshooting and Repair Manual, ISM Fuel System, ISM Engines, Bulletin No. 3666266.



Perform a final inspection to make sure that all hoses, wires, linkages, and components have been properly installed and tightened.

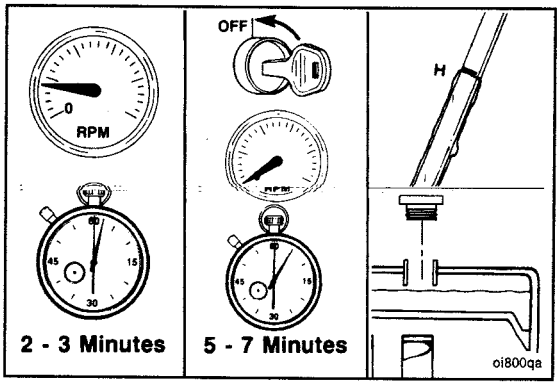


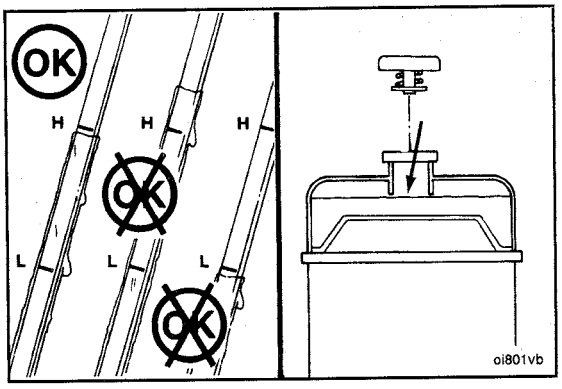
⚠ WARNING ⚠

Do not remove the radiator cap from a hot engine. Hot steam can cause serious personal injury. The engine coolant temperature must be below 50°C [120°F].

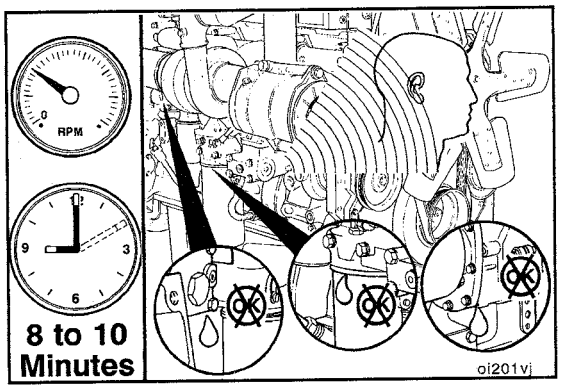
Operate the engine at low idle for 2 to 3 minutes.

Stop the engine and wait 5 to 7 minutes for the oil to drain to the oil pan, and check the oil and coolant levels again.





Fill the engine to the correct coolant and oil levels, if necessary. Refer to Procedures 008-018 and 007-025.



Operate the engine for 8 to 10 minutes to check for proper operation, unusual noises, and coolant, fuel, or lubricating oil leaks.

Repair all leaks and component problems. Refer to the appropriate procedures.

Section 1 - Cylinder Block - Group 01

Section Contents

Page

Accessory Drive Seal 1-5
Clean 1-6
Install 1-6
Remove 1-5

Alternator Drive Seal 1-4
Clean 1-4
Install 1-4
Remove 1-4

Bearings, Connecting Rod 1-6
Clean 1-8
Inspect for Reuse 1-8
Install 1-9
Remove 1-6

Bearings, Main 1-11
Clean 1-12
Inspect for Reuse 1-12
Install 1-13
Remove 1-11

Bearings, Thrust 1-16
Install 1-17
Remove 1-16

Camshaft 1-19
Clean 1-22
Inspect for Reuse 1-23
Install 1-24
Remove 1-19

Camshaft Bushings 1-28
Clean 1-28
Inspect for Reuse 1-29
Install 1-29
Remove 1-28

Camshaft End Clearance 1-117
Measure 1-117

Camshaft Gear (Camshaft Installed) 1-32
Inspect for Reuse 1-33
Install 1-35
Remove 1-32

Camshaft Gear (Camshaft Removed) 1-38
Install 1-38
Remove 1-38

Connecting Rod 1-41
Clean 1-41
Inspect for Reuse 1-41
Install 1-43
Remove 1-41

Crankshaft 1-43
Rotation Check 1-43

Crankshaft Gear, Front (Crankshaft Installed) 1-43
Clean 1-44
Inspect for Reuse 1-44
Install 1-45
Remove 1-43

Crankshaft Pulley 1-46
Inspect for Reuse 1-47
Install 1-47
Remove 1-46

Page

Crankshaft Seal, Front 1-48
Clean 1-49
Install 1-49
Remove 1-48

Crankshaft Seal, Rear 1-50
Clean 1-51
Install 1-51
Remove 1-50

Cylinder Block and Liner Seats 1-52
Leak Test 1-52

Cylinder Liner 1-53
Clean 1-55
Inspect for Reuse 1-56
Install 1-58
Remove 1-53

Cylinder Liner Protrusion 1-112
Measure 1-113
Preparatory 1-112

Gear Cover, Front 1-60
Clean 1-62
Inspect for Reuse 1-62
Install 1-63
Remove 1-60

Gear Housing, Front 1-67
Clean 1-69
Inspect for Reuse 1-70
Install 1-70
Remove 1-67

Idler Gear, Camshaft 1-74
Clean 1-75
Inspect for Reuse 1-76
Install 1-78
Remove 1-74

Idler Gear, Hydraulic Pump 1-79
Clean 1-80
Inspect for Reuse 1-81
Install 1-83
Remove 1-79

Idler Gear, Water Pump 1-85
Clean 1-86
Inspect for Reuse 1-86
Install 1-88
Remove 1-85

Piston 1-90
Assemble 1-93
Clean 1-91
Disassemble 1-91
General Information 1-90
Inspect for Reuse 1-92
Articulated Piston 1-92
Install 1-93
Remove 1-90

Piston and Connecting Rod Assembly 1-101
Assemble 1-106
Clean 1-105
Disassemble 1-104
Inspect for Reuse 1-106
Install 1-108
Remove 1-101

Piston Cooling Nozzle 1-94
Inspect for Reuse 1-94

Page

Install 1-95
Remove 1-94

Piston Rings 1-96
Inspect for Reuse 1-96

Service Tools 1-1
Cylinder Block 1-1

Vibration Damper 1-96
Clean 1-96
Eccentricity Check 1-98
Install 1-98
Maintenance Check 1-97
Remove 1-96
Wobble Check 1-99

Water Header Plate, Cylinder Block 1-99
Clean 1-100
Inspect for Reuse 1-100
Install 1-100
Remove 1-99

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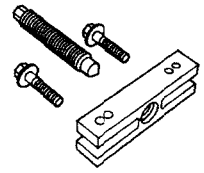
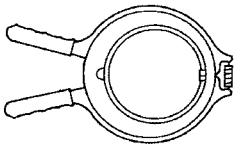
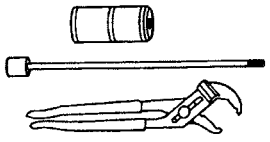
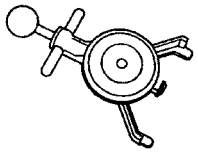
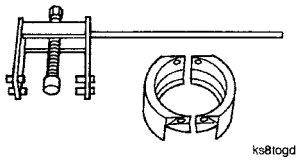
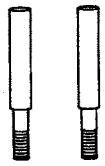
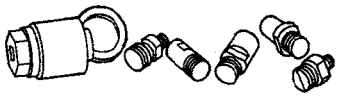
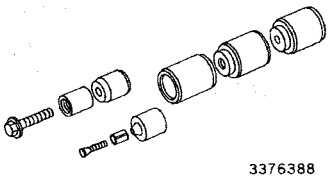
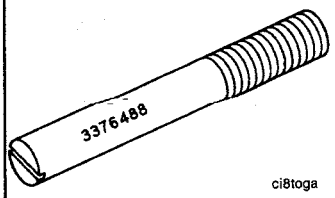
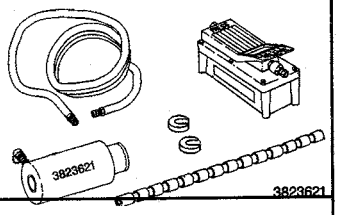
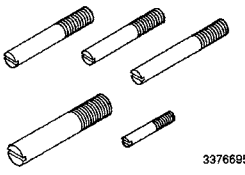
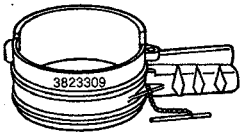
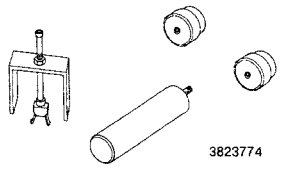
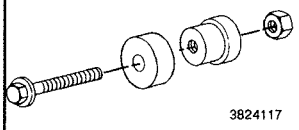
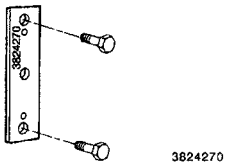
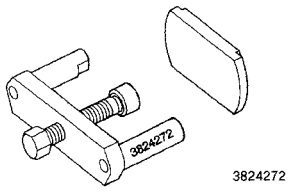
Service Tools

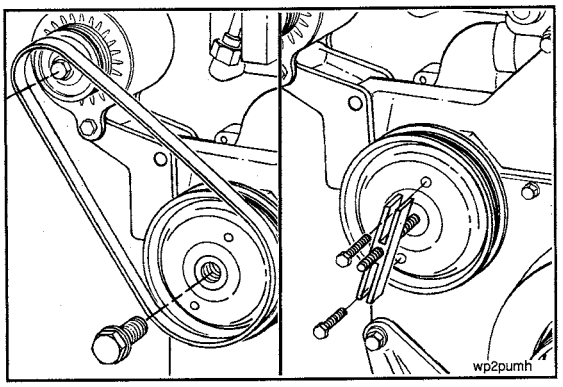
Cylinder Block

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-647	**Standard Puller** Remove alternator drive pulley. Use with two 5/16 x 18 x 2 inch capscrews.	 ad8toga
ST-821	**Piston Ring Expander** Remove and install piston rings on pistons.	 pi8togd
ST-1178	**Main Bearing Cap Puller** Remove main bearing caps.	 mb8toga
ST-1293	**Belt Tension Gauge** Measure drive v-ribbed belt tension.	 fa8togc
3162873	**Universal Cylinder Liner Puller** Remove cylinder liners from cylinder block. Requires cylinder liner puller plate, Part No. 3376049.	
3375840	**Crankshaft Gear Puller Kit** Remove the crankshaft gear. Requires puller, Part No. 3375834, and jaw, Part No. 3375839, to be used.	 ks8togd

Tool No.	Tool Description	Tool Illustration
3376038	**Connecting Rod Guide Pins** Guide connecting rods over crankshaft during removal or installation of connecting rods.	 cx8togg
3376326	**Pulley Installation Tool** Install drive pulleys. Use pulley pusher adapter, Part No. 3377401, to install the alternator drive pulley.	 ad8togb
3376388	**Camshaft Guide Pilot** Aid in removal and installation of the camshaft in cylinder block.	 3376388
3376488	**Guide Pin** Two guide pins are used to install the water header plate.	 ci8toga
3823621	**Hydraulic Actuator Kit** Used with installation/removal kit.	 3823621
3823642	**Installation/Removal Kit** Used to install/remove camshaft bushings.	
3376695	**Guide Pin Kit** Aid during installation of vibration damper. The kit consists of two each of guide pins, Part No's. 3376488, 3376638, 3376696, 3376697 and 3376698.	 3376695
3823309	**Piston Ring Compressor** Compress piston rings on pistons during installation of pistons in the cylinder block.	

Tool No.	Tool Description	Tool Illustration
3823495	**Gauge Block** Measure cylinder liner protrusion on the cylinder block and gear housing protrusion below the cylinder block.	
3823774	**Needle Bearing Kit** Used to remove and install needle bearings in the gear housing and hydraulic pump adapter. Use mandrel, Part No. 3823776, to install hydraulic pump needle bearings.	
3162895	**Cam Gear Puller Kit** Used to remove the camshaft gear from the camshaft without removing the camshaft from the engine.	
3824117	**Needle Bearing Installation Tool** Used to remove and install the water pump drive needle bearing in the gear housing.	
3824270	**Engine Barring Tool** Used to bar the engine by hand.	
3824272	**Liner/Installation Tool** Used to seat and hold the liner while liner protrusion is measured.	

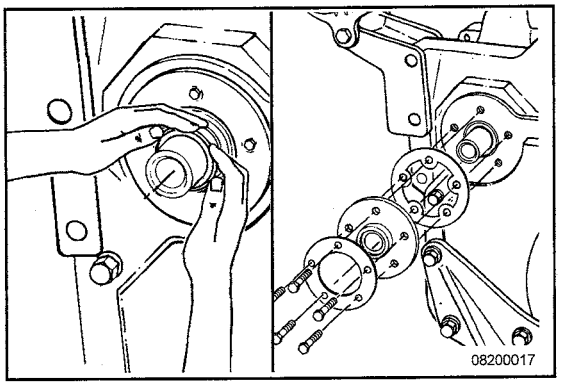


Alternator Drive Seal (001-001)

Remove (001-001-002)

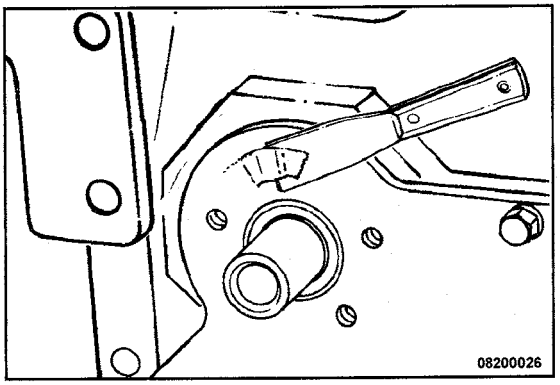
Remove the alternator drive belt. Refer to Procedure 013-005.

Remove the alternator drive pulley. Refer to Procedure 009-010.



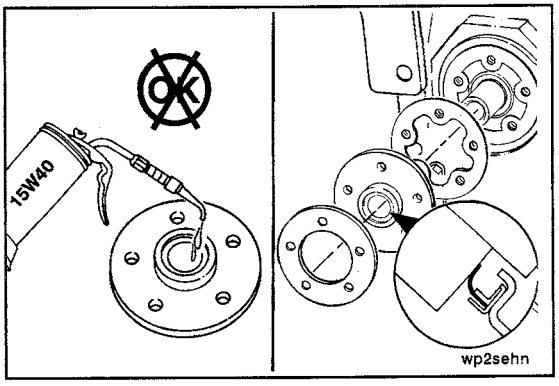
Remove the five capscrews and clamping ring.

Remove the dust seal and oil seal together.



Clean (001-001-006)

Clean the gasket surface of the gear cover.



Install (001-001-026)

Do **not** use lubricant to install the seal. The oil seal **must** be installed with the lip of the seal and the shaft clean and dry. The yellow dust lip of the seal **must** be facing out.

Use the installation sleeve provided with the new seal to install the new seal and gasket.

Apply sealant, Part No. 3375066 or equivalent, to the threads of the capscrews.

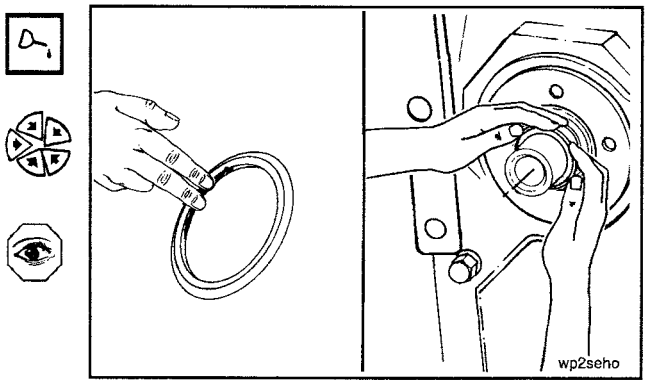
Install the clamping ring with five (M8-1.25 x 20) capscrews. Tighten the capscrews in a star pattern.

Torque Value: Step 1 7 N•m [60 in-lb]
2 20 N•m [175 in-lb]

Place a light film of oil or antifreeze on the inside diameter of a new oil seal dust seal.

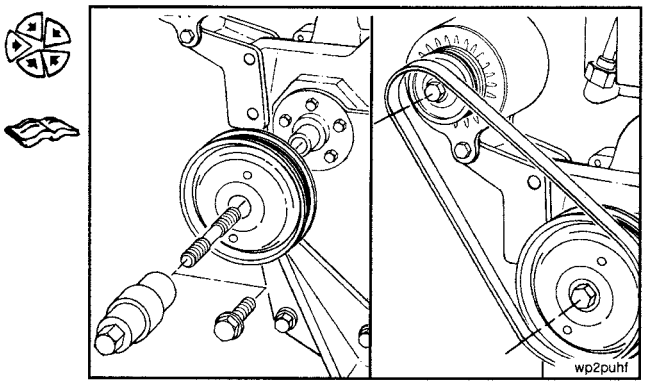
Install the dust seal onto the shaft with the larger outside diameter facing toward the engine.

Push the dust seal back by hand on the shaft until the entire dust seal contacts the oil seal case.



Install the alternator drive pulley. Refer to Procedure 009-010.

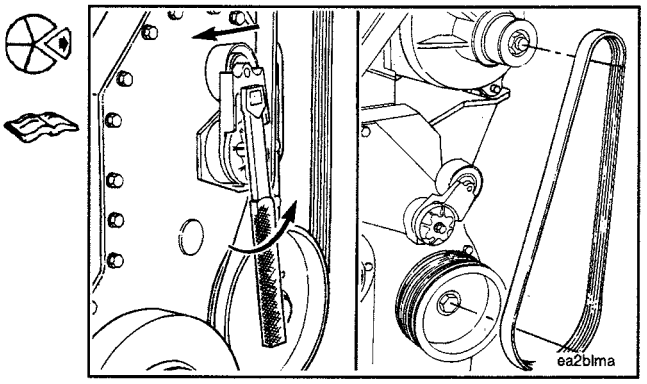
Install and adjust the alternator drive belt. Refer to Procedure 013-005.



Accessory Drive Seal (001-003)

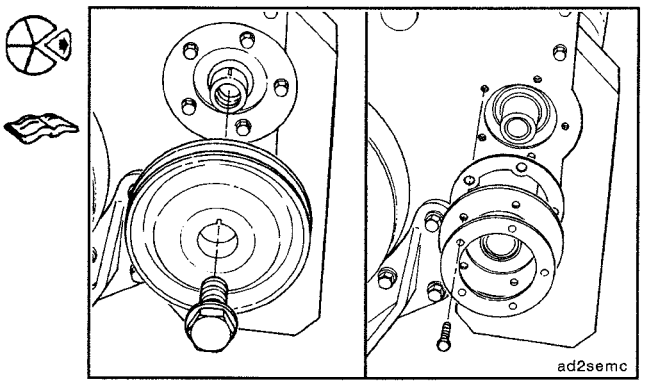
Remove (001-003-002)

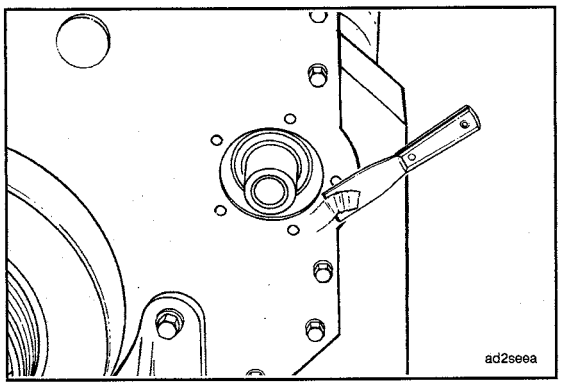
If equipped with an automatic belt tensioner, remove the alternator drive belt. Refer to Procedure 013-021.



Remove the accessory drive pulley. Refer to Procedure 009-004.

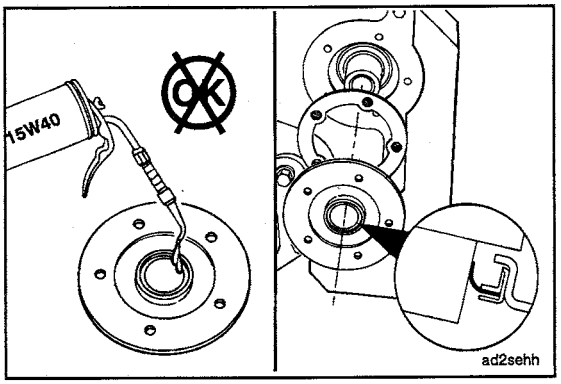
Remove the five capscrews, clamping ring, seal, and gasket.





Clean (001-003-006)

Clean the gasket surface of the gear cover.

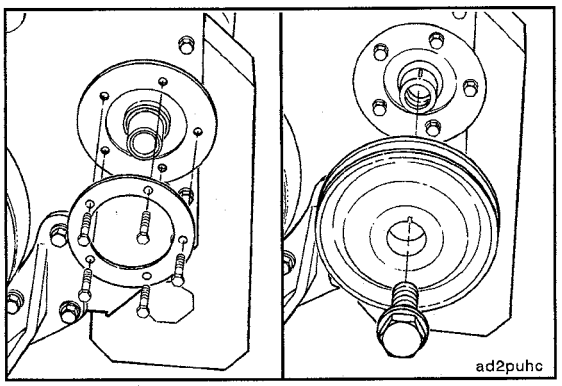


Install (001-003-026)

Do **not** use lubricant to install the seal. The oil seal **must** be installed with the lip of the seal and the shaft clean and dry.

The yellow dust lip of the seal **must** be facing out.

Use the installation sleeve provided with the new seal to install the new seal and gasket.



Apply a coating of thread sealant, Part No. 3823494, to the mounting capscrews.

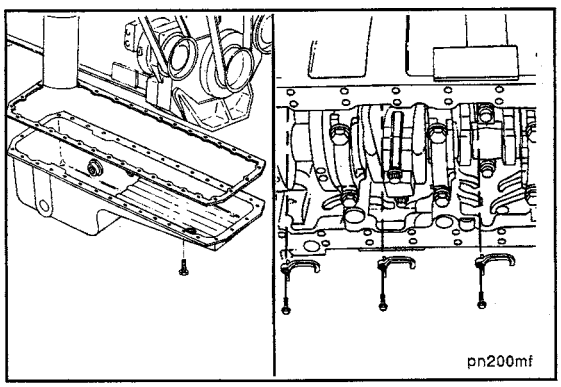
Install the clamping ring and five capscrews.

Tighten the capscrews in a star pattern in two steps.

Torque Value: Step 1 7 N•m [60 in-lb]
2 20 N•m [175 in-lb]

NOTE: The accessory drive pulley has a dust seal on the engine side of the pulley.

Install the accessory drive pulley. Refer to Procedure 009-004.



Bearings, Connecting Rod (001-005)

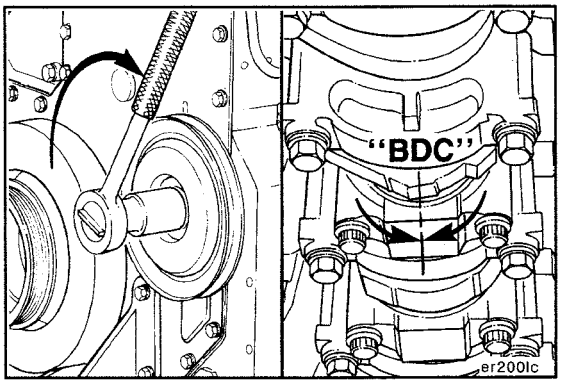
Remove (001-005-002)

Drain the lubricating oil. Refer to Procedure 007-025.

Remove the lubricating oil pan. Refer to Procedure 007-025.

Remove the piston cooling nozzles. Refer to Procedure 001-046.

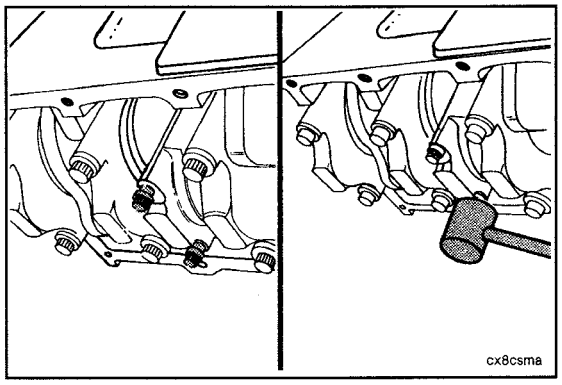
Use the accessory drive pulley to rotate the crankshaft so the connecting rod to be removed is at bottom dead center.



Loosen the connecting rod capscrews.

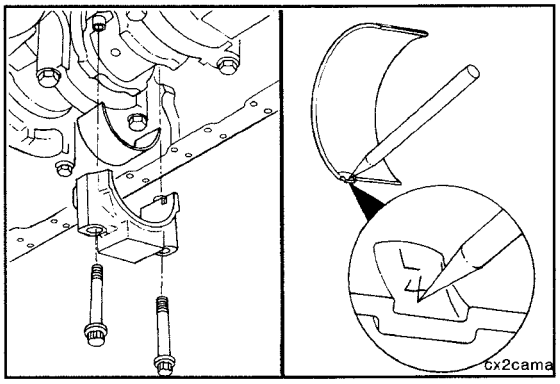
NOTE: Do **not** remove the capscrews.

Hit the connecting rod capscrews with a rubber hammer to loosen the rod caps from the dowel rings.



Remove the capscrews and rod caps.

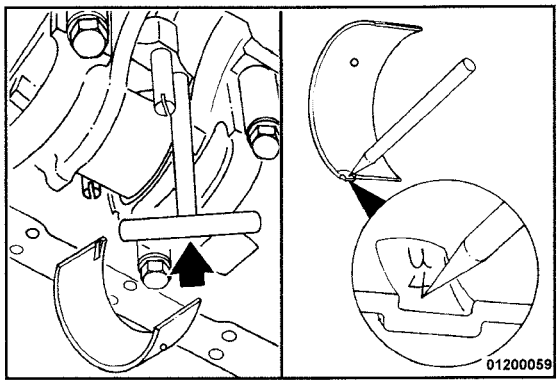
Remove the lower bearing shell from the rod cap. Mark it with the letter "L" (for lower) and the cylinder number it was removed from.

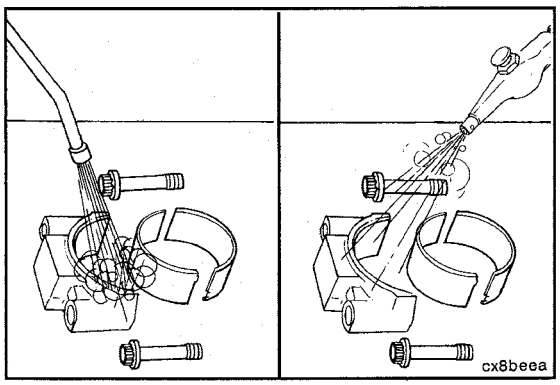


Install two connecting rod guide pins, Part No. 3376038.

Use a t-Handle piston pusher to push the rod away from the crankshaft to allow the upper bearing shell to be removed.

Remove the upper bearing shell. Mark it with the letter "U" (upper) and the cylinder number it was removed from.



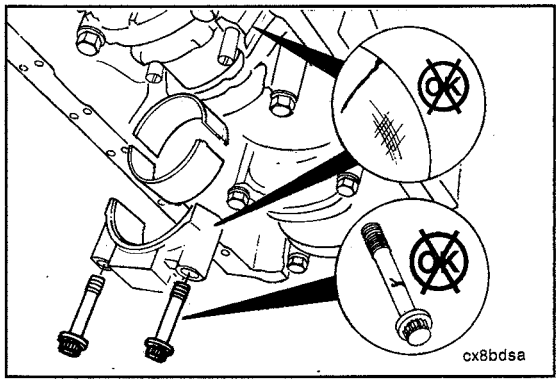


Clean (001-005-006)

⚠ WARNING ⚠

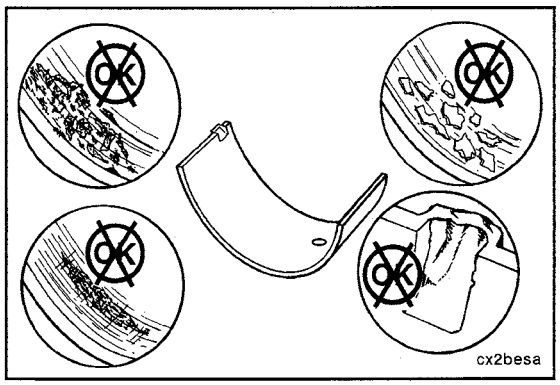
When using a steam cleaner, wear protective clothing, as well as, safety glasses or a face shield. Hot steam can cause serious personal injury.

Steam clean the parts and dry with compressed air.



Inspect for Reuse (001-005-007)

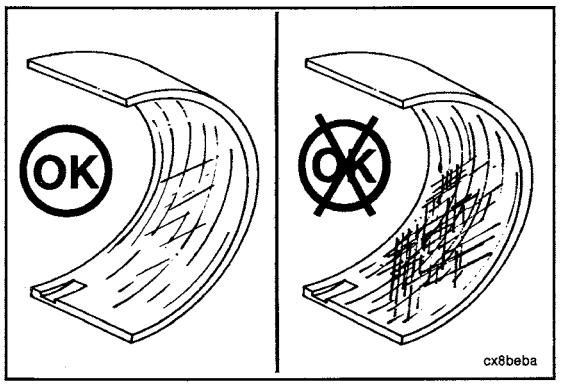
Inspect the rod caps, connecting rod bearing saddles and capscrews for nicks, cracks, burrs, scratches or frets.



Inspect the bearings for damage.

Replace any bearings with the following damage:

- Pits
- Flakes
- Corrosion
- Lock tang damage
- Scratches (deep enough to be felt with a fingernail).



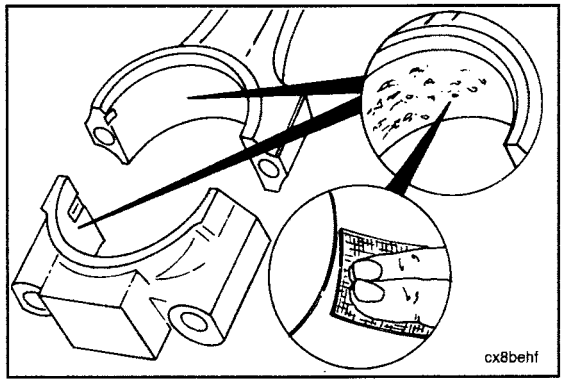
Normal bearing wear produces a smooth finish that will wear into the copper lining. Exposed copper does **not** always indicate worn bearings. Refer to the Parts Reuse Guidelines, Bulletin No. 3810303.

If large areas of copper lining are visible in the bearings before the engine has accumulated 241,000 km [150,000 mi] or 3750 hours, inspect the engine for contamination from fine dirt particles and correct the problem.

Inspect the bearing shell seating surface for nicks or burrs.

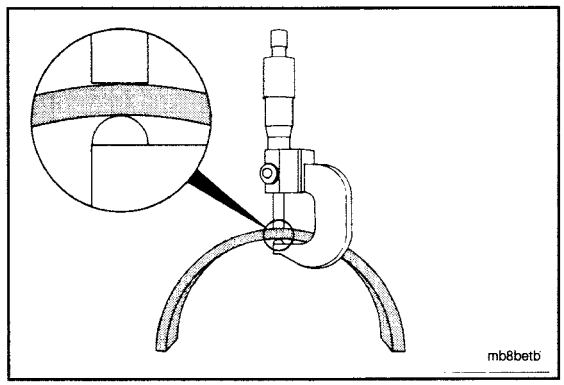
If nicks or burrs can **not** be removed with Scotch-Brite® 7448 or equivalent, the bearings **must** be replaced.

For more detailed information on bearing damage, refer to the Analysis and Prevention of Bearing Failures Manual, Bulletin No. 3810387.



Use an outside diameter ball-tipped micrometer to measure the rod bearing thickness.

Standard Connecting Rod Bearing Thickness		
mm		in
2.430	MIN	0.0957
2.473	MAX	0.0974



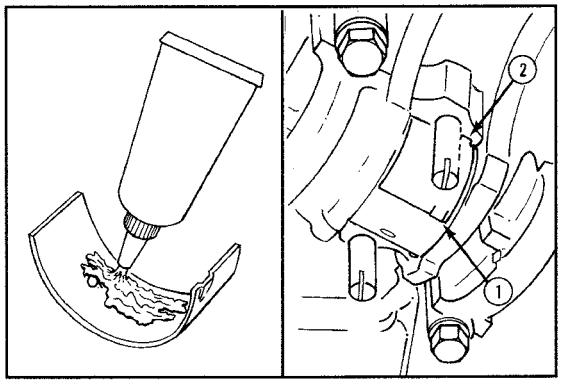
Install (001-005-026)

NOTE: Used bearings **must** be installed in the same location they were removed from.

Use Lubriplate™ 105, or equivalent, to coat the inside diameter of the bearing shell.

Install the upper bearing shell in the connecting rod with the tang (1) of the bearing in the slot (2) of the rod.

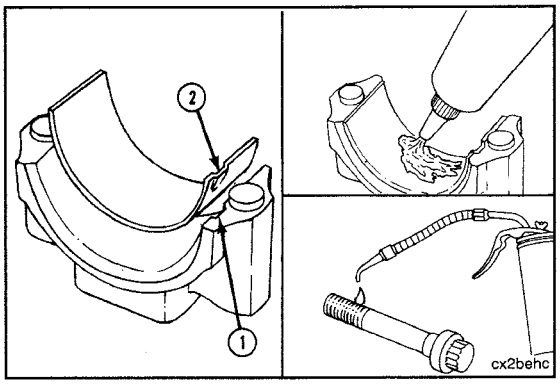
Remove the two connecting rod guide pins, Part No. 3376038.

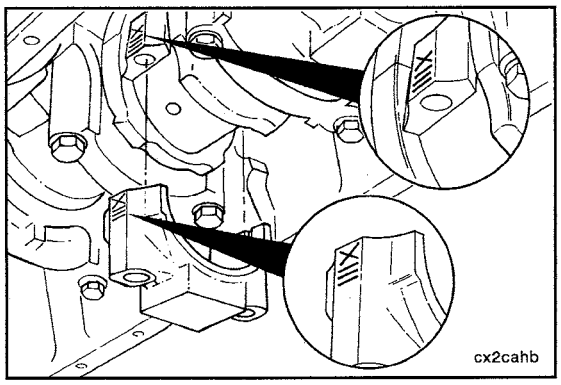


Install the bearing shell in the connecting rod cap with the tang (2) of the bearing in the slot (1) of the cap.

Use Lubriplate™ 105, or equivalent, to coat the inside diameter of the bearing shell.

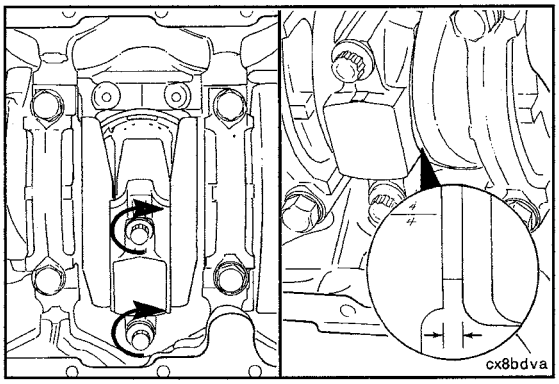
Use clean 15W-40 oil to lubricate under the head and the threads of the connecting rod capscrews.





The connecting rod and cap **must** be matched with the same number. The tang **must** be toward the camshaft side of the engine.

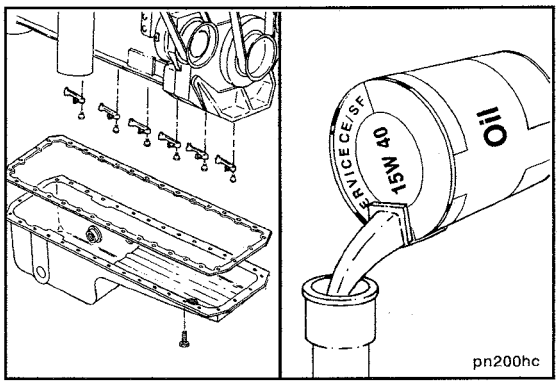
Install the connecting rod caps and capscrews.



Tighten the capscrews in alternating sequence to the following torque values:

Torque Value:	Step 1	68 N•m	[50 ft-lb]
	2	142 N•m	[105 ft-lb]
	3	210 N•m	[155 ft-lb]
	4	Loosen completely	
	5	Repeat steps 1 through 3	

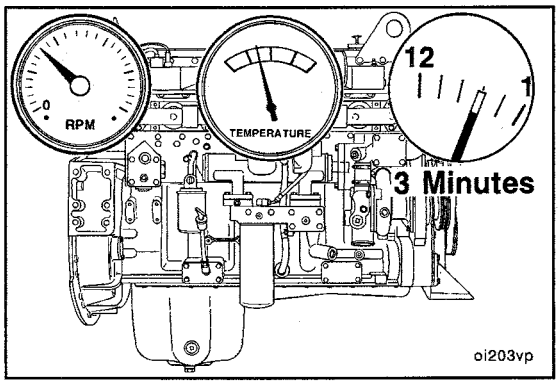
Measure the connecting rod side clearance. Refer to Procedure 001-014.



Install the piston cooling nozzles. Refer to Procedure 001-046.

Install the lubricating oil pan. Refer to Procedure 007-025.

Fill the lubricating oil pan. Refer to Procedure 007-025.



Operate the engine to normal operating temperature and check for leaks.

NOTE: The engine **must** have adequate oil pressure within 15 seconds after starting. If the warning light indicating low oil pressure has **not** gone out or there is no oil pressure indicated on a gauge within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

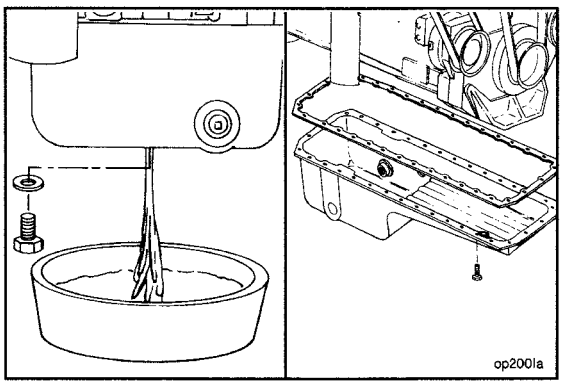
Bearings, Main (001-006)

Remove (001-006-002)

Cummins Engine Company, Inc., recommends replacing the thrust bearings when the main bearings are replaced. Refer to Procedure 001-007 for thrust bearing replacement.

Drain the lubricating oil. Refer to Procedure 007-025.

Remove the lubricating oil pan. Refer to Procedure 007-025.

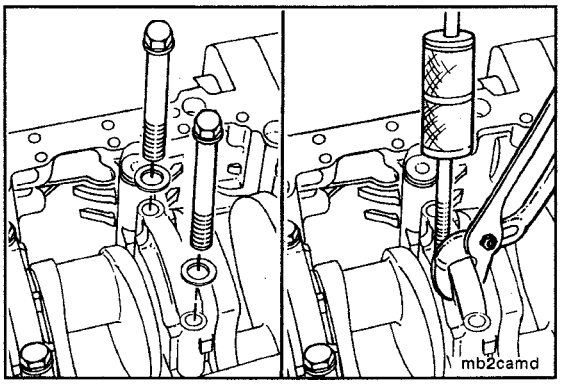


Replace the main bearings one at a time.

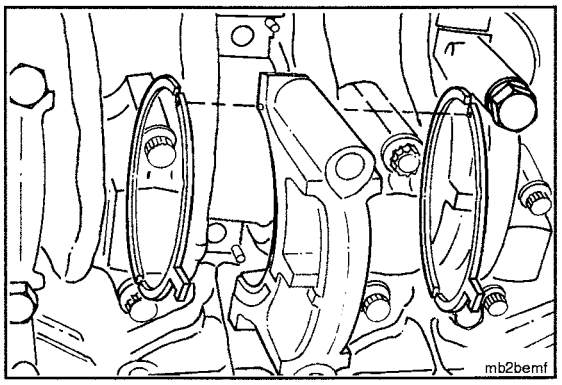
Remove the main bearing capscrews.

Use main bearing cap puller, Part No. ST-1178, to remove the cap.

The tool **must** be centered on the cap. Pull straight down to remove the cap.

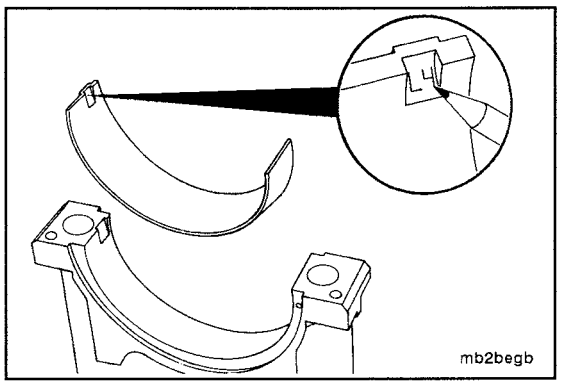


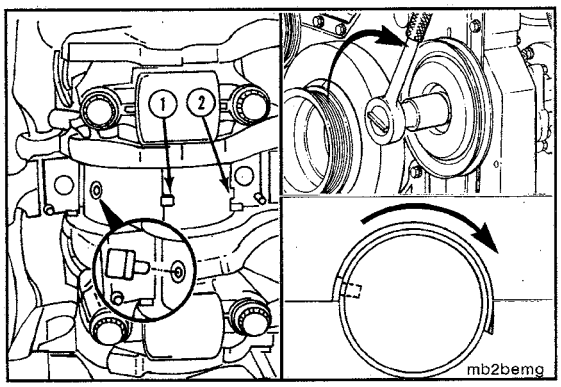
The number four main bearing cap has thrust bearings. The cap is located with two dowel pins.



Remove the lower main bearing shell from the cap.

Mark the bearing shell with the letter "L" (lower) and the journal number it was removed from.

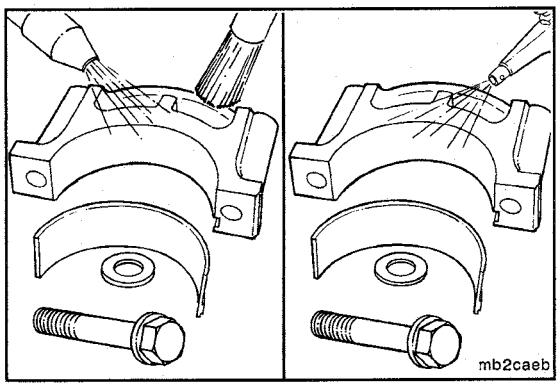




To remove the upper main bearing shell, install bearing rollout tool, Part No. 3823818, in the oil hole of the main bearing journal.

NOTE: Remove the tang side (1) of the main bearing shell first.

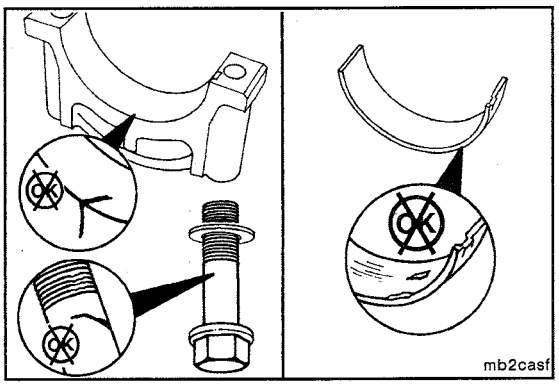
Rotate the crankshaft with the accessory drive pulley to remove the (2) upper main bearing shell.



Clean (001-006-006)

Use solvent and a soft bristle brush to clean the bearing cap, capscrews, washers, and bearings.

Dry the parts with compressed air.

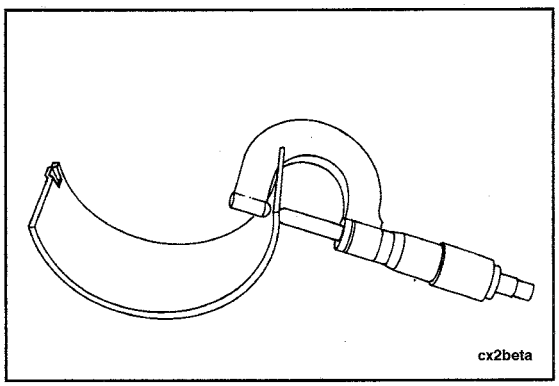


Inspect for Reuse (001-006-007)

Inspect the main cap, capscrews, and washers for damage.

Inspect the bearing shells for nicks, scratches, or damage.

If the main bearings are damaged, refer to the M11 Shop Manual, Bulletin No. 3666075, to inspect the crankshaft main bearing journals. If the crankshaft is damaged, the engine **must** be removed for repair. Refer to Procedure 000-001.



Use an outside diameter ball-tipped micrometer to measure the main bearing shell thickness.

Standard Main Bearing Shell Thickness

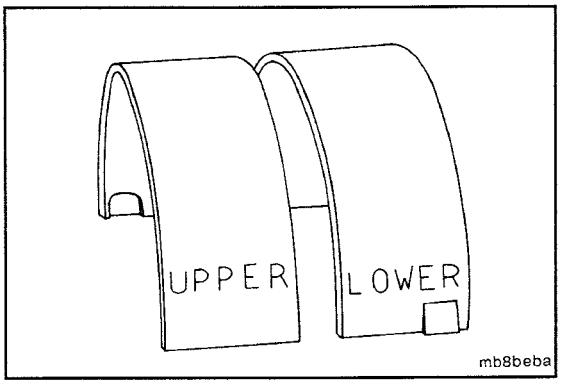
mm		in
3.894	MIN	0.1533
3.945	MAX	0.1553

For more detailed information of bearing damage, refer to the Analysis and Prevention of Bearing Failures Manual, Bulletin No. 3810387.

Install (001-006-026)

⚠ CAUTION ⚠

To prevent engine damage, the upper and lower bearings must be installed in the correct location. The upper bearing has an oil groove. The bearing shells are marked with the words "upper" and "lower" for identification.



⚠ CAUTION ⚠

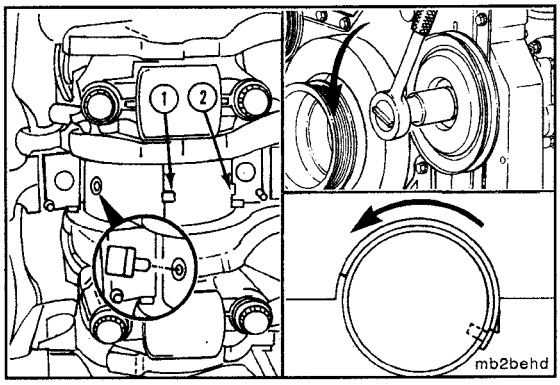
To correctly position the bearing and prevent engine damage, the bearing tang (1) must be in the slot (2) of the bearing saddle.

Used bearings **must** be installed in the same location they were removed from.

Use Lubriplate™ 105, or equivalent, to coat the inside diameter of the upper main bearing shell.

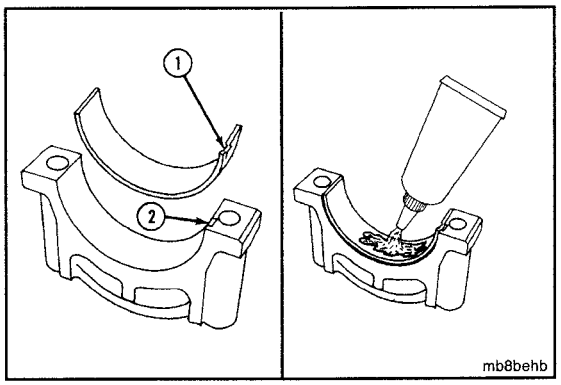
Install the (2) upper main bearing shells using the same method that was used to remove them.

The tang side (1) of the bearing **must** go into place last.



Install the lower main bearing shells with the bearing tang (1) in the slot (2) of the main bearing cap.

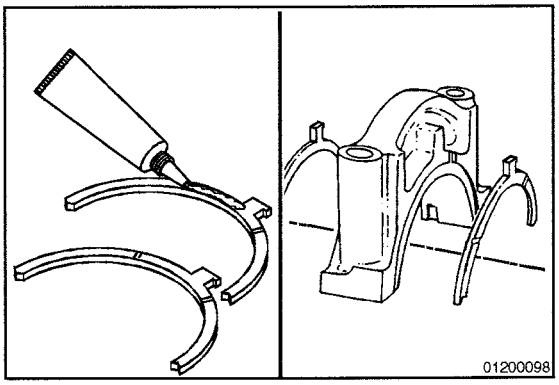
Use Lubriplate™ 105, or equivalent, to coat the inside diameter of the bearing shells.

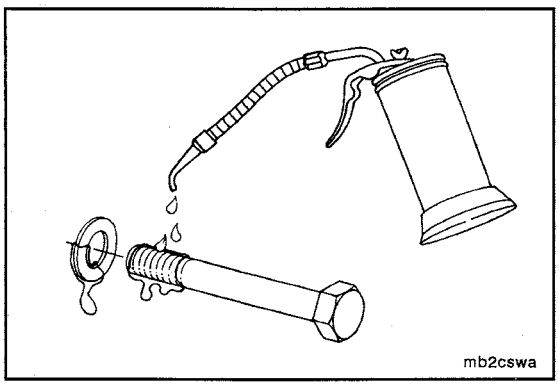


Use Lubriplate™ 105, or equivalent, to coat the lower thrust bearings.

Install the lower thrust bearings in the number four main bearing cap as shown.

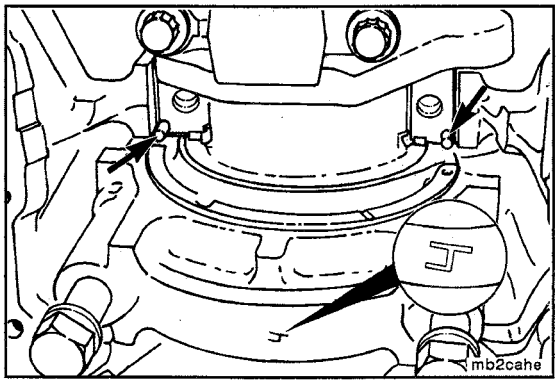
The grooves of the thrust bearing **must** be toward the crankshaft.





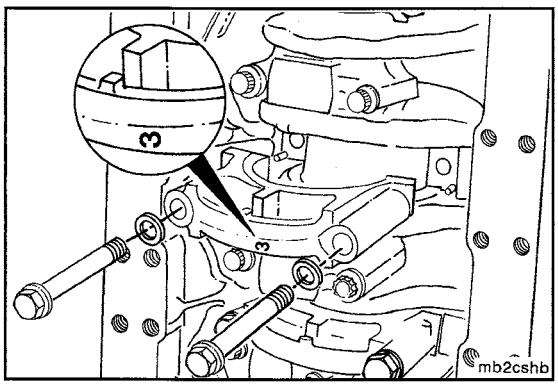
Use clean 15W-40 oil to coat the capscrew threads and on both sides of the washers.

Drain the excess oil from the capscrews before installing them in the cylinder block.



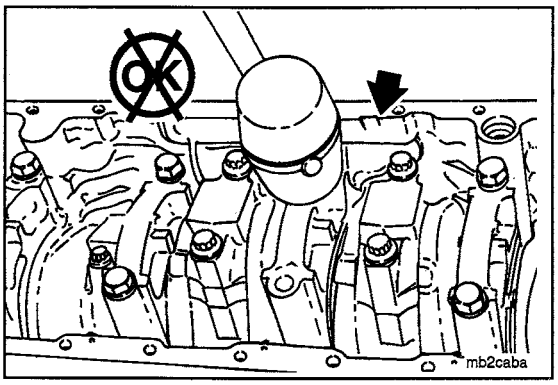
△ CAUTION △

To prevent damage to the cylinder block and main bearing cap when the capscrews are tightened, the number four main bearing cap must be aligned with the dowel pins in the bearing saddle.



The main bearing caps are numbered one through seven from front to rear in the cylinder block. The caps **must** be installed so the number on the cap matches the bearing saddle in the block. The lock tangs in the main bearing saddle and bearing cap **must** be on the same side.

Install the main bearing caps.

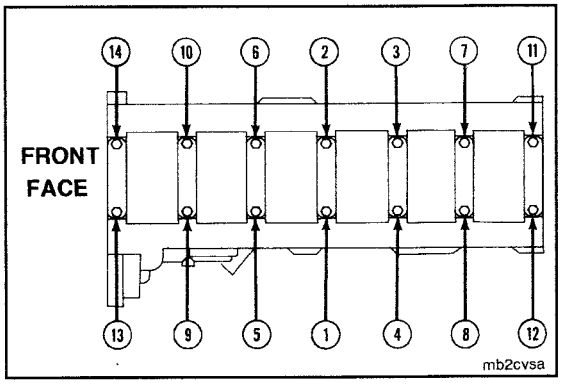


△ CAUTION △

To prevent damage to the main bearing cap and bearings, do not hit the main bearing cap with a hammer.

Tighten the main bearing capscrews in alternating sequence to the following torque values:

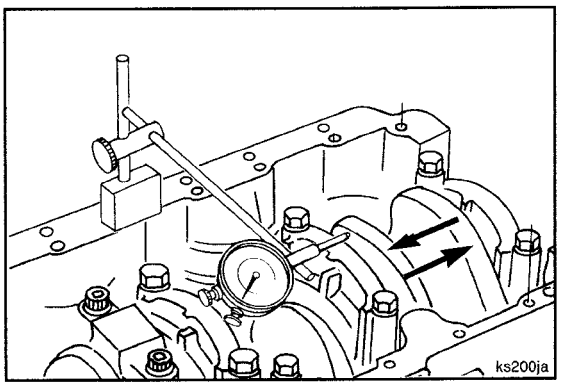
Torque Value: Step 1 68 N•m [50 ft-lb]
2 142 N•m [105 ft-lb]
3 210 N•m [155 ft-lb]
4 Loosen completely
5 Repeat steps 1 through 3



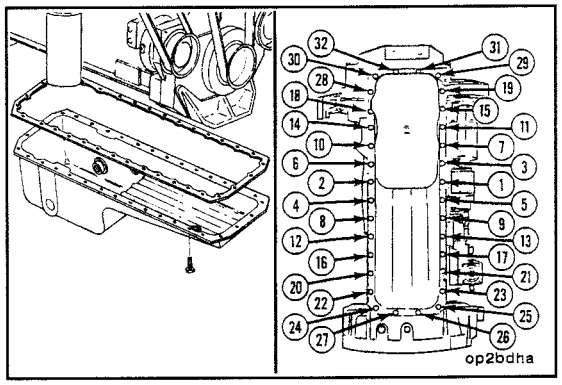
Use a dial indicator to measure the crankshaft end clearance.

Crankshaft End Clearance		
mm		in
0.10	MIN	0.004
0.56	MAX	0.022

If the end clearance is **not** within the specifications, refer to the M11 Shop Manual, Bulletin No. 3666075, to inspect the main bearing cap and thrust bearing surfaces in the cylinder block.



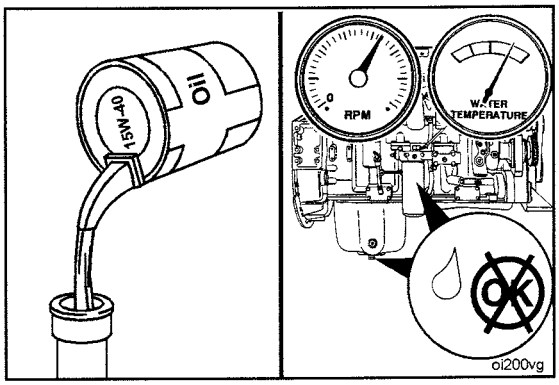
Install the lubricating oil pan. Refer to Procedure 007-025.

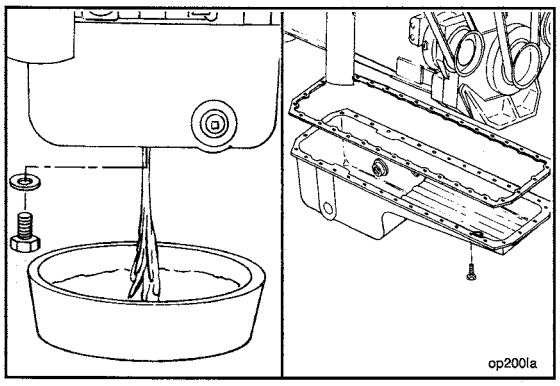


Fill the engine with lubricating oil. Refer to Procedure 007-025.

Operate the engine to normal operating temperature and check for leaks.

NOTE: The engine **must** have adequate oil pressure within 15 seconds after starting. If the warning light indicating low oil pressure has **not** gone out or there is no oil pressure indicated on a gauge within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level is in the oil pan.





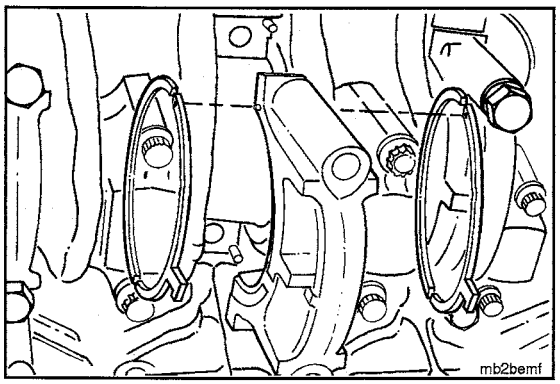
Bearings, Thrust (001-007)

Remove (001-007-002)

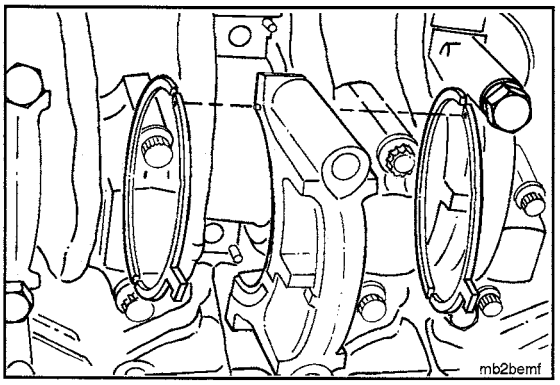
Cummins Engine Company, Inc., recommends replacing the thrust bearings when the main bearings are replaced.

Drain the lubricating oil. Refer to Procedure 007-025.

Remove the lubricating oil pan. Refer to Procedure 007-025.

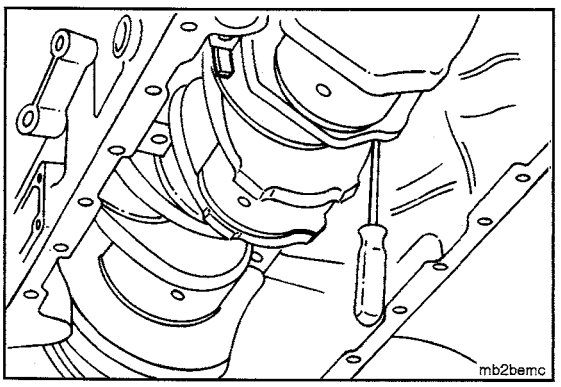


The number four main bearing cap has thrust bearings. The cap is located with two dowel pins.



Remove the thrust bearings from the number four main bearing cap.

Mark the thrust bearings in the oil passage groove as being front or rear bearings.



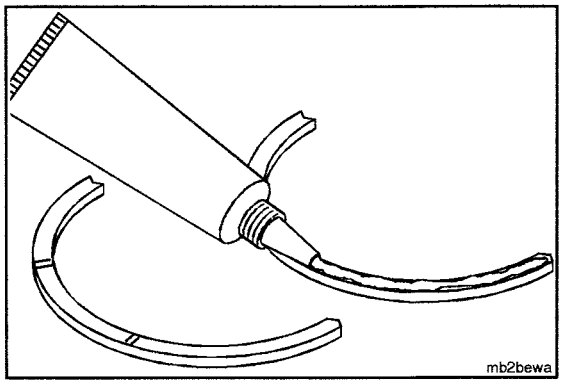
△ CAUTION △

Do not damage the crankshaft when removing the upper thrust bearings.

Use a blunt tool to remove the upper thrust bearings.

Install (001-007-026)

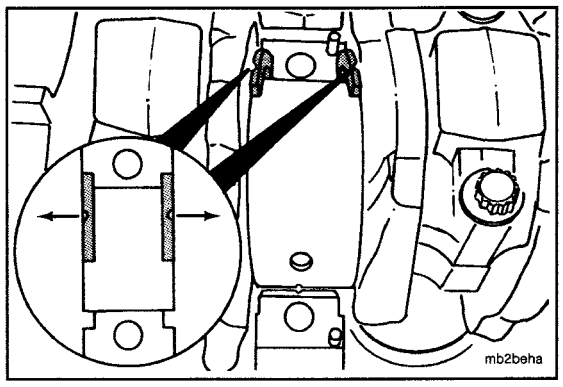
Use Lubriplate™ 105 Part No. 3163086 or 3163087, or equivalent, to coat the upper thrust bearings.



Push the crankshaft toward the rear of the engine to install the rear thrust bearing, and to the front of the engine to install the front thrust bearing.

Install the upper thrust bearings in the number four main bearing saddle.

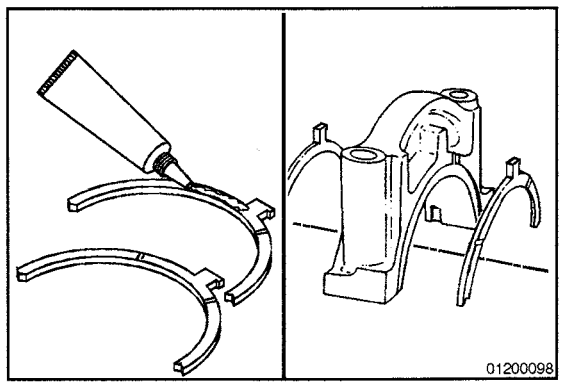
The grooves **must** be toward the crankshaft.



Use Lubriplate™ 105, or equivalent, to coat the lower thrust bearings.

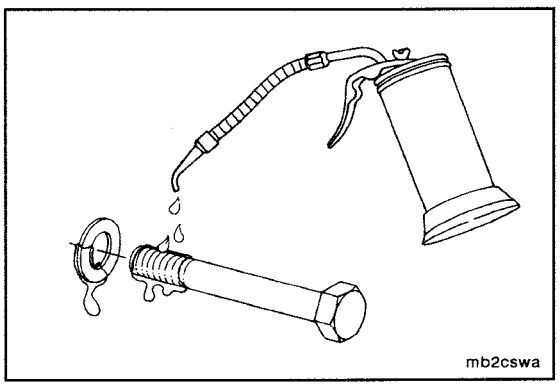
Install the lower thrust bearings in the number four main bearing cap as shown.

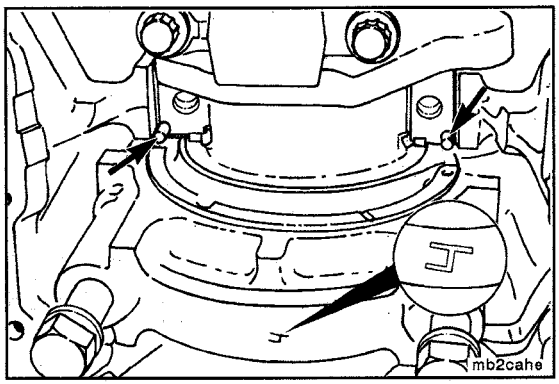
The grooves of the thrust bearing **must** be toward the crankshaft.



Use clean 15W-40 oil to coat the capscrew threads and on both sides of the washers.

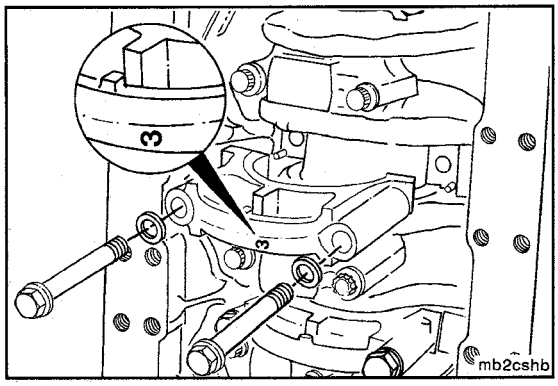
Drain the excess oil from the capscrews before installing them in the cylinder block.





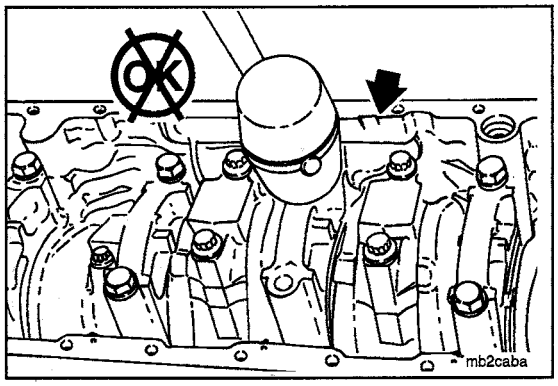
⚠ CAUTION ⚠

To prevent damage to the cylinder block and main bearing cap, the number four main bearing cap must be aligned with the dowel pins in the bearing saddle when the capscrews are tightened.



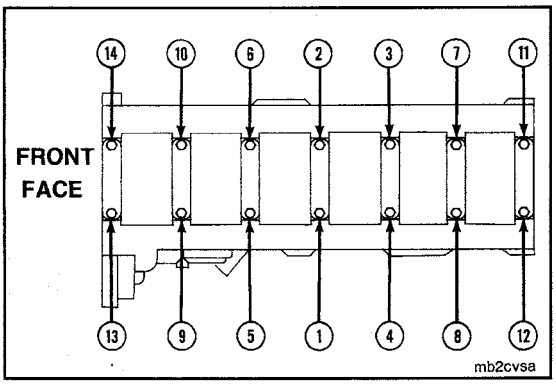
The main bearing caps are numbered one through seven from front to rear in the cylinder block. The caps **must** be installed so the number on the cap matches the bearing saddle in the block. The lock tangs in the main bearing saddle and bearing cap **must** be on the same side.

Install the main bearing caps.



⚠ CAUTION ⚠

To prevent damage to the main bearing cap and bearings, do not hit the main bearing cap with a hammer.



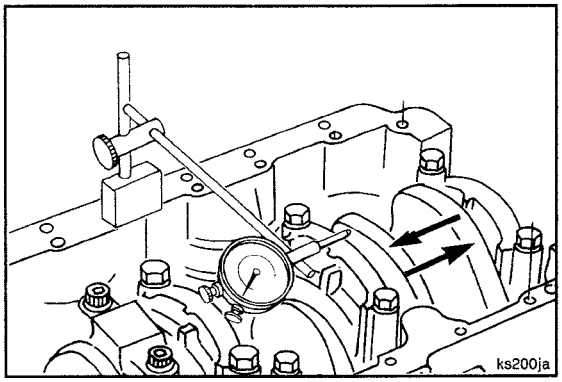
Tighten the main bearing capscrews in alternating sequence to the following torque values:

Torque Value:	Step 1	68 N•m	[50 ft-lb]
	2	142 N•m	[105 ft-lb]
	3	210 N•m	[155 ft-lb]
	4	Loosen completely	
	5	Repeat steps 1 through 3	

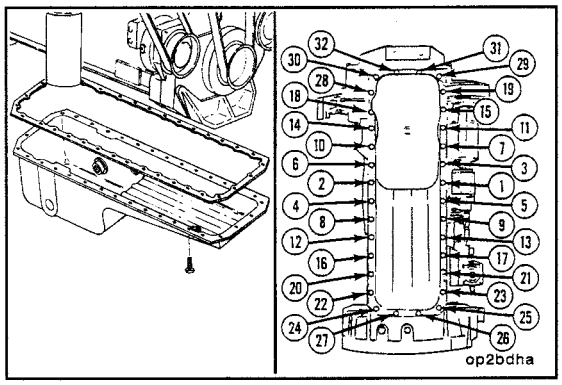
Use a dial indicator to measure the crankshaft end clearance.

Crankshaft End Clearance		
mm		in
0.10	MIN	0.004
0.56	MAX	0.022

If the end clearance is **not** within the specifications, refer to the M11 Shop Manual, Bulletin No. 3666075, to inspect the main bearing cap and thrust bearing surfaces in the cylinder block.



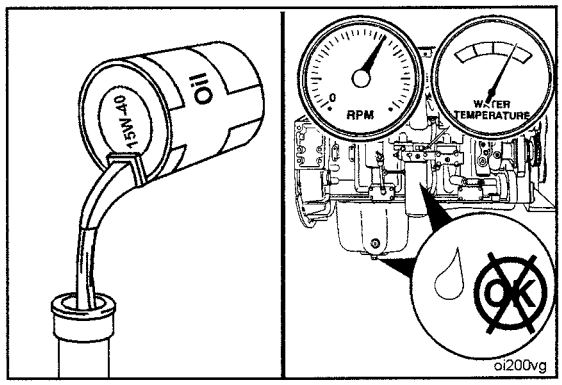
Install the lubricating oil pan. Refer to Procedure 007-025.



Fill the engine with lubricating oil. Refer to Procedure 007-025.

Operate the engine to normal operating temperature and check for leaks.

NOTE: The engine **must** have adequate oil pressure within 15 seconds after starting. If the warning light indicating low oil pressure has **not** gone out or there is no oil pressure indicated on a gauge within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level is in the oil pan.

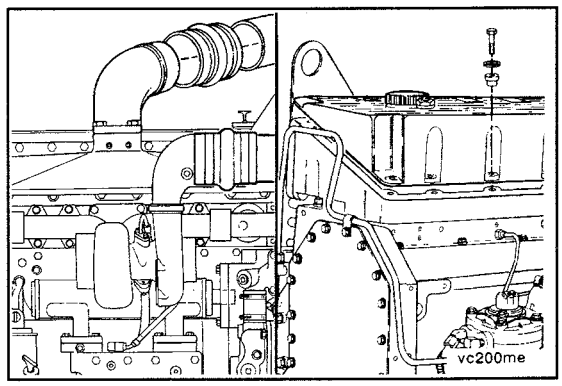


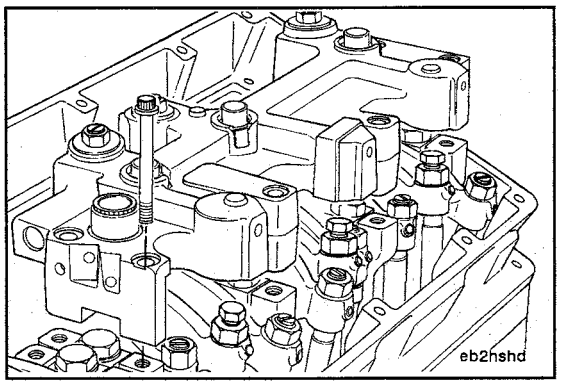
Camshaft (001-008)

Remove (001-008-002)

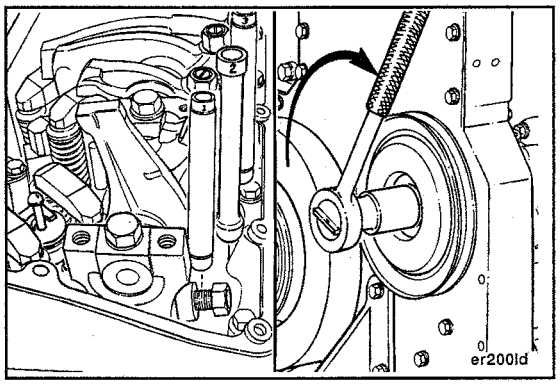
Remove the air piping from the intake manifold.

Remove the rocker lever cover. Refer to Procedure 003-011.

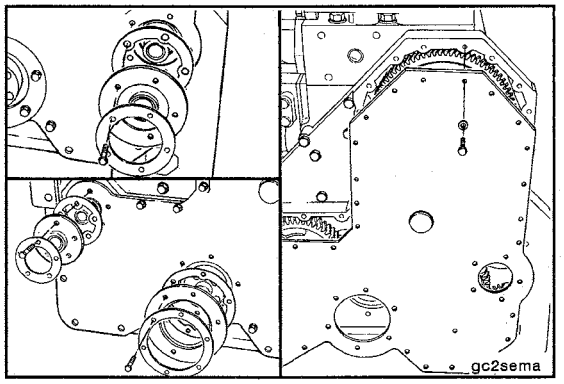




Remove the engine brakes, if equipped. Refer to Procedure 020-001.

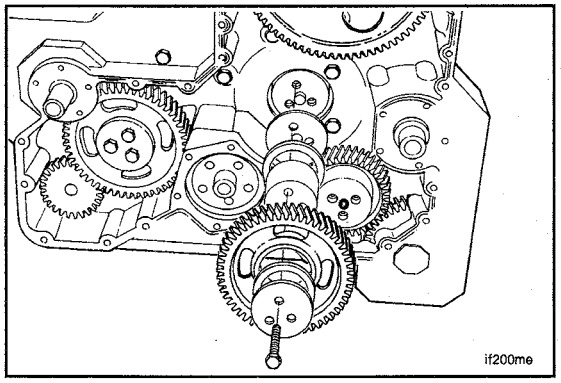


Remove the push tubes and push rods. Refer to Procedure 004-014.



Remove the gear cover. Refer to Procedure 001-031.

NOTE: It is possible to remove the camshaft without removing the cylinder head. The cam followers can be tied up and away from the camshaft with wire.

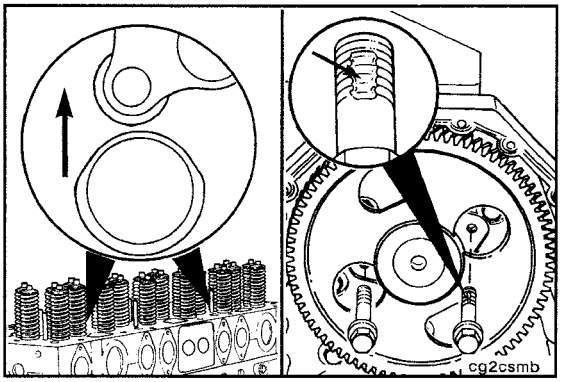


Remove the camshaft idler gear. Refer to Procedure 001-036.

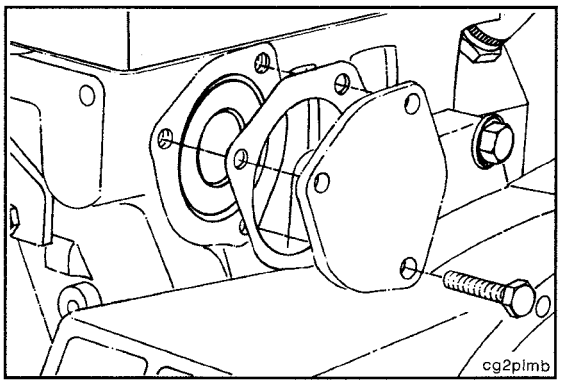
Raise the cam follower assemblies, and use a wire to tie the cam followers up away from the camshaft.

Rotate the camshaft to align the holes in the camshaft gear with the thrust plate capscrews.

Remove the thrust plate capscrews.

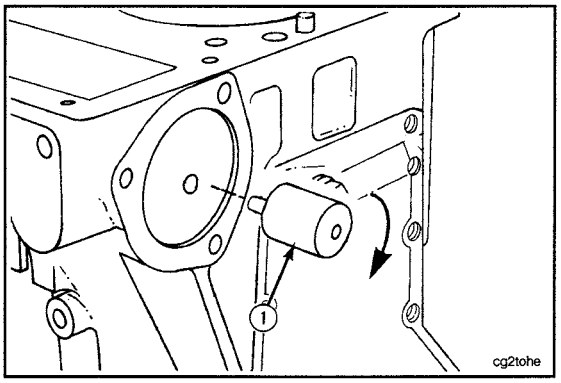


Remove the three capscrews and the camshaft rear cover plate.

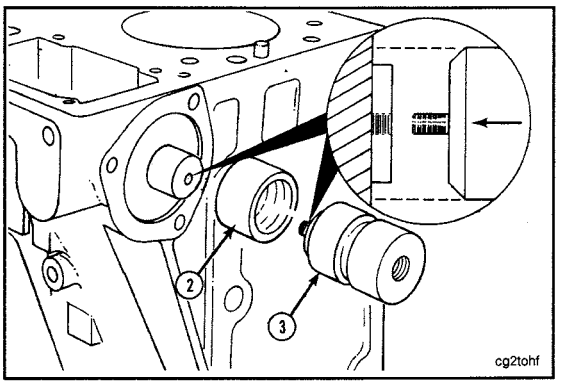


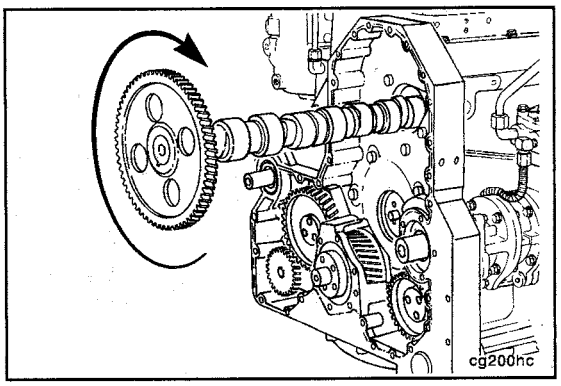
Install camshaft installation pilot, Part No. 3376388, as follows:

- Install the expander (1), Part No. 3376923, in the camshaft through the rear cover plate opening.
- Turn the screw inside the expander **clockwise** to expand the swell plug.



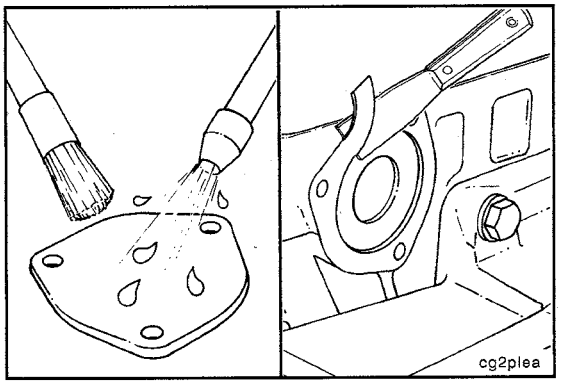
- Install the arbor sleeve (2) over the expander.
- Install the locating pilot extensions (3) to the expander.





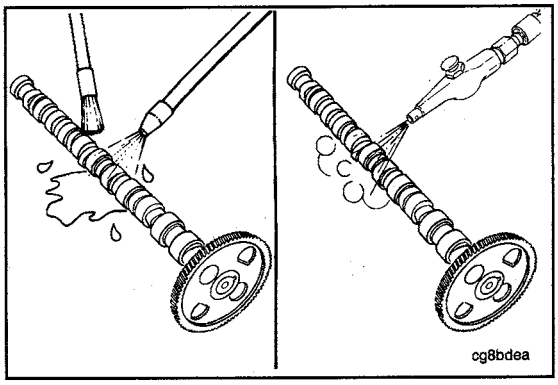
Use one hand to rotate slowly and pull the camshaft from the cylinder block and the other hand to balance the camshaft as it is removed.

Remove the camshaft pilot tool.



Clean (001-008-006)

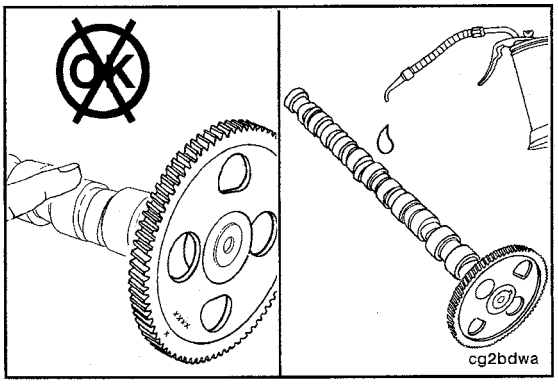
Clean the camshaft rear cover plate and the cylinder block mating surface.



⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, as well as, safety glasses or a face shield. Hot steam can cause serious personal injury.

Clean the camshaft with steam or solvent. Dry with compressed air.



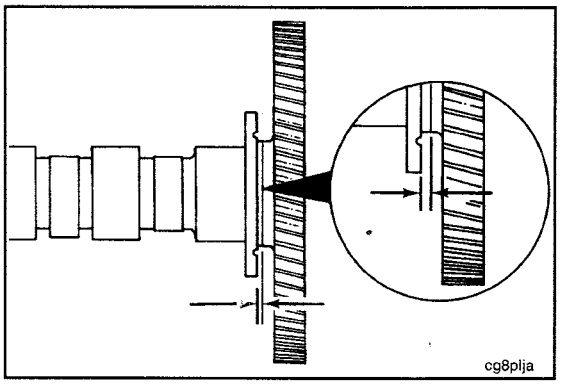
△ CAUTION △

After the camshaft has been steam cleaned, do not touch the machined surfaces with bare hands. This will cause rust to form, which will damage the camshaft. Lubricate the camshaft with clean 15W-40 oil before handling.

Inspect for Reuse (001-008-007)

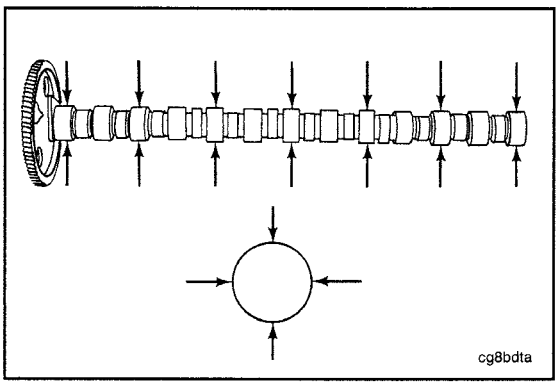
Measure the clearance between the gear hub and the thrust plate.

Camshaft Thrust Plate Clearance		
mm		in
0.13	MIN	0.005
0.33	MAX	0.013



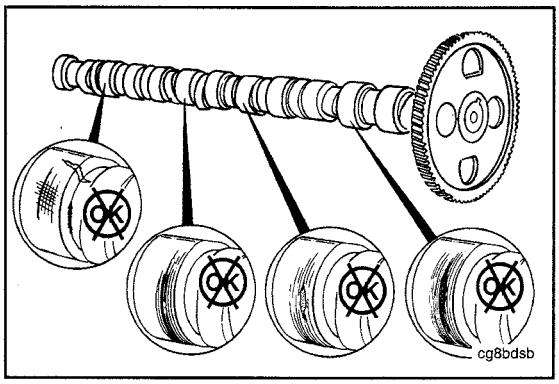
Measure the outside diameter of the seven camshaft bushing journals.

Camshaft Bushing Journal Outside Diameter		
mm		in
71.960	MIN	2.8331
72.013	MAX	2.8352

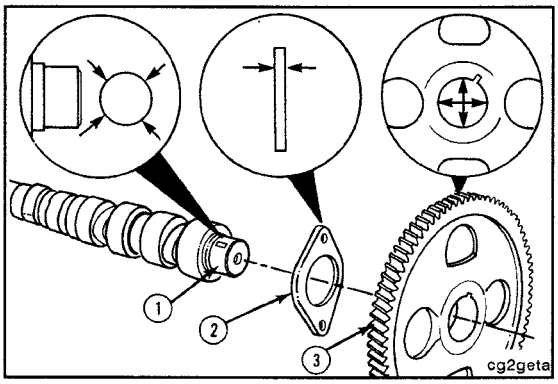


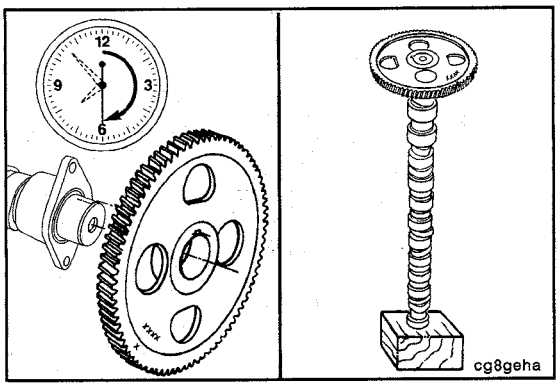
Inspect the camshaft lobes for cracks, scratches, or other damage.

Refer to Camshaft Reuse Guidelines for engines with crowned rollers, Bulletin No. 3666052, for camshaft reuse guidelines.



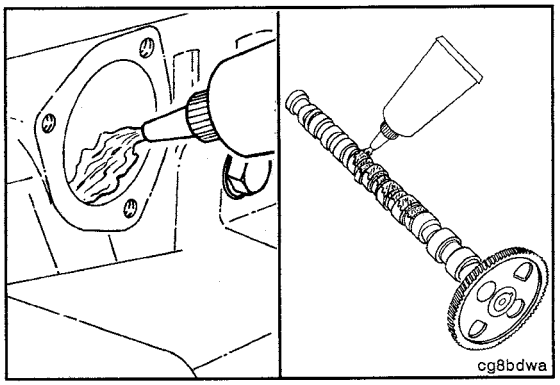
Remove the camshaft gear, and measure the camshaft nose (1), thrust plate (2), and gear (3). Refer to Procedure 001-013.



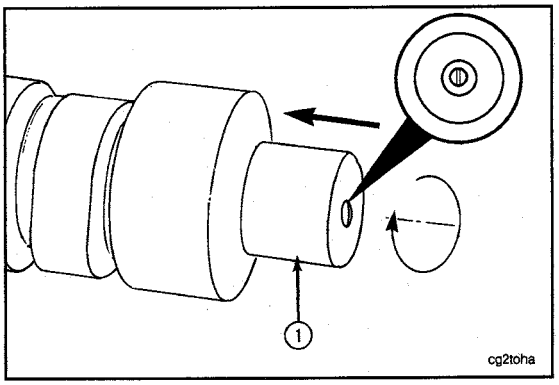


Install (001-008-026)

Install the camshaft gear on the camshaft. Refer to Procedure 001-013.

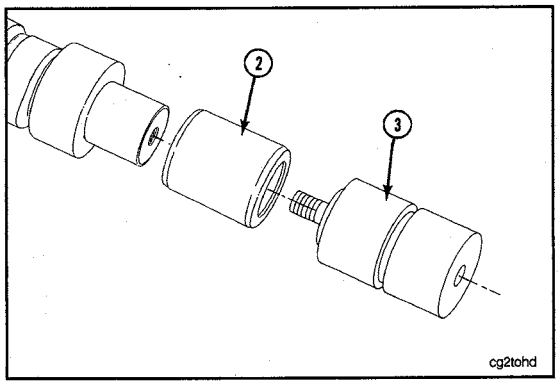


Use Lubriplate™ 105, or equivalent, to coat the camshaft bushings and camshaft.



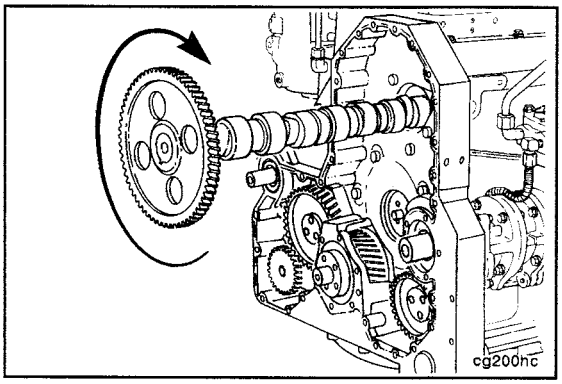
Install camshaft installation pilot, Part No. 3376388, as follows:

- Install expander (1), Part No. 3376923,
- Turn the screw inside the expander **clockwise** to expand the swell plug.



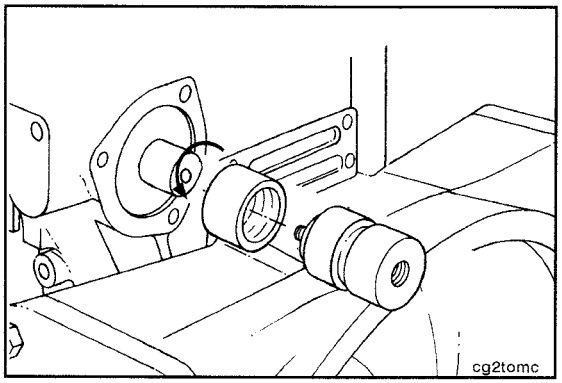
- Install the arbor sleeve (2) over the expander.
- Install the locating pilot extensions (3) to the expander.

Rotate the camshaft slowly as it is being installed in the cylinder block.



The camshaft installation pilot **must** be disassembled as it clears the number seven camshaft bushing to prevent interference with the rib across the top of die-cast flywheel housings.

Remove the camshaft pilot.

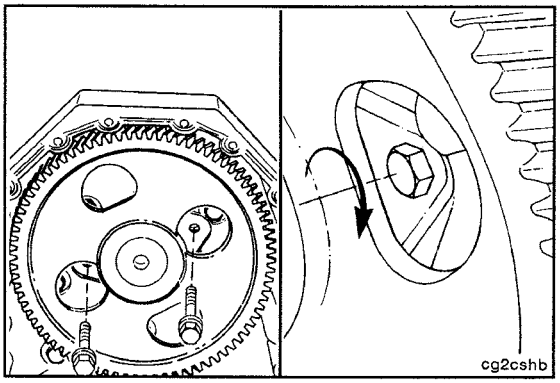


Rotate the camshaft to align the holes in the camshaft gear with the thrust plate capscrew holes in the cylinder block.

Align the capscrew holes in the thrust plate with the cylinder block capscrew holes.

Install the capscrews.

Torque Value: 47 N•m [35 ft-lb]



Use a new gasket to install the camshaft rear cover plate.

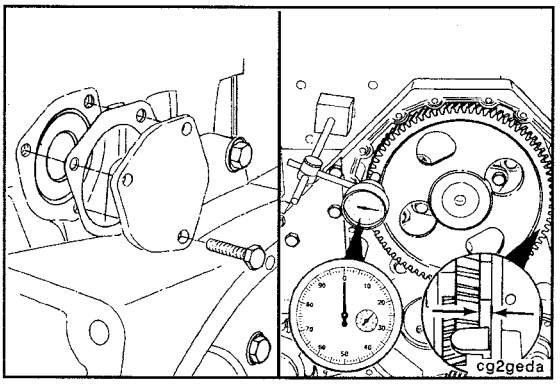
Tighten the three capscrews.

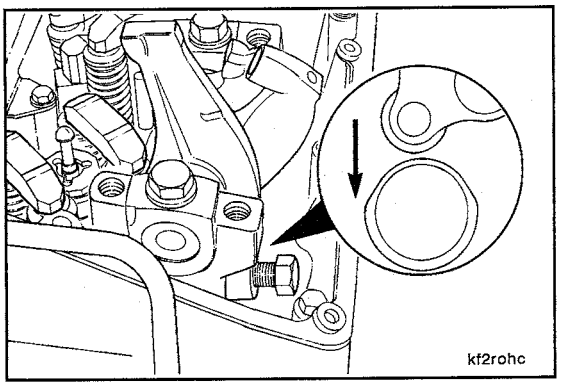
Torque Value: 47 N•m [35 ft-lb]

Measure the camshaft end clearance.

Camshaft End Clearance

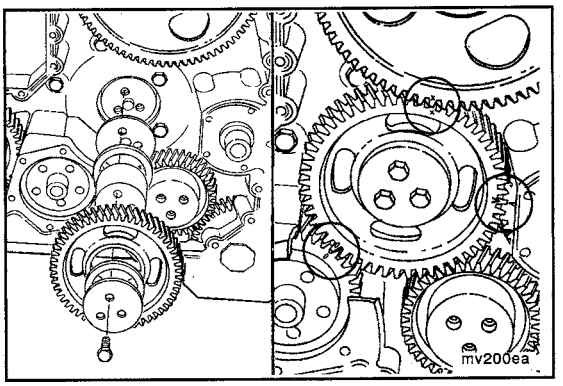
mm		in
0.13	MIN	0.005
0.33	MAX	0.013





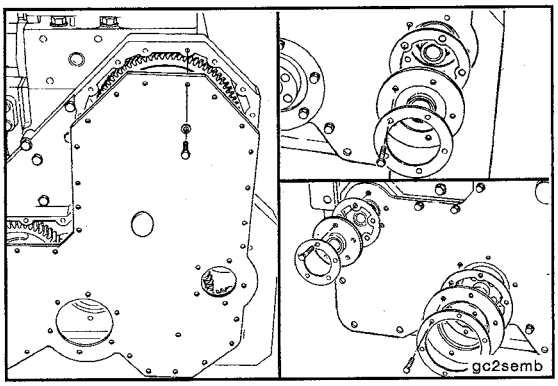
Do **not** drop the cam follower levers on the camshaft lobes.

Carefully lower the cam followers onto the camshaft.

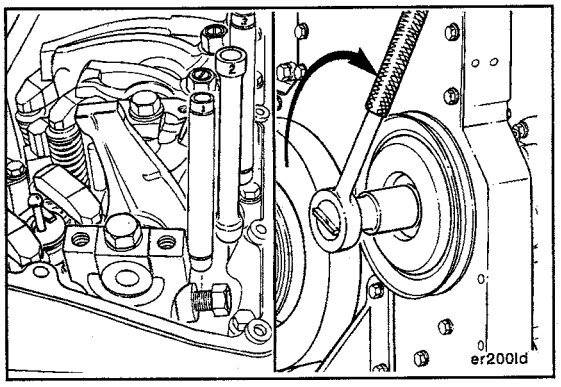


Install the camshaft idler gear. Refer to Procedure 001-036.

Check the engine timing. Refer to Procedure 006-025.

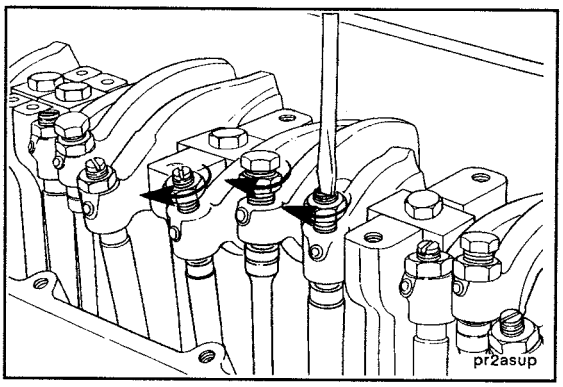


Install the gear cover. Refer to Procedure 001-031.

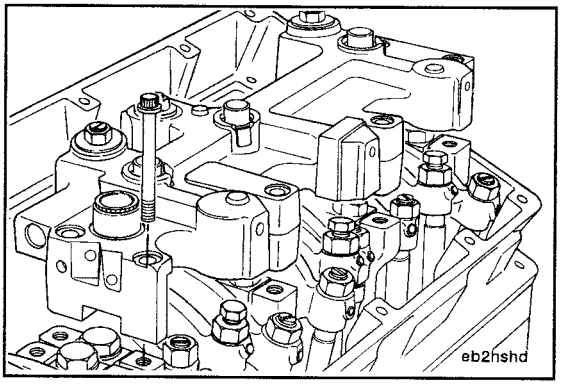


Install the push tubes and push rods. Refer to Procedure 004-014.

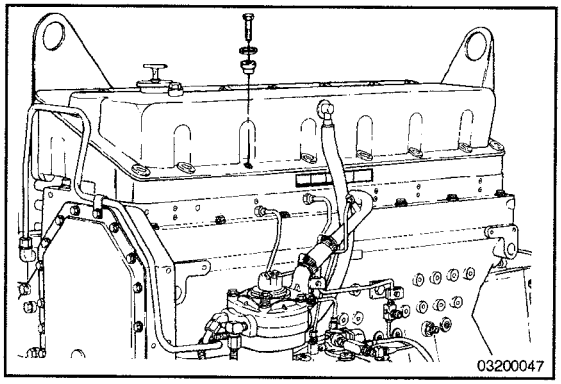
Adjust the valves and injectors. Refer to Procedure 003-004.



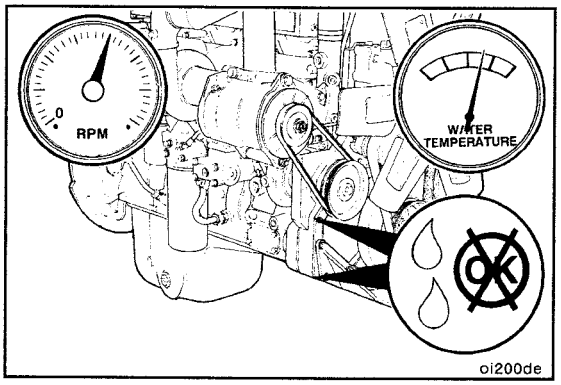
Install the engine brakes, if equipped. Refer to Procedure 020-001.

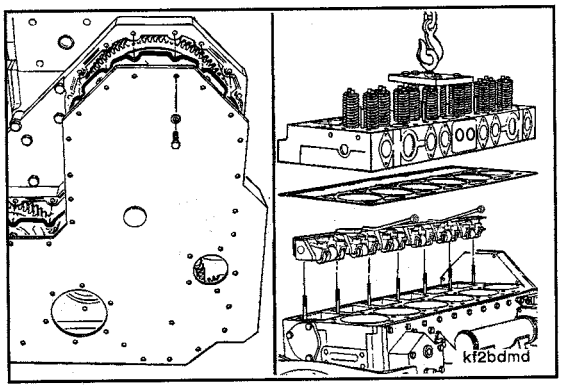


Install the rocker lever cover. Refer to Procedure 003-011.



Operate the engine to normal operating temperature and check for leaks.





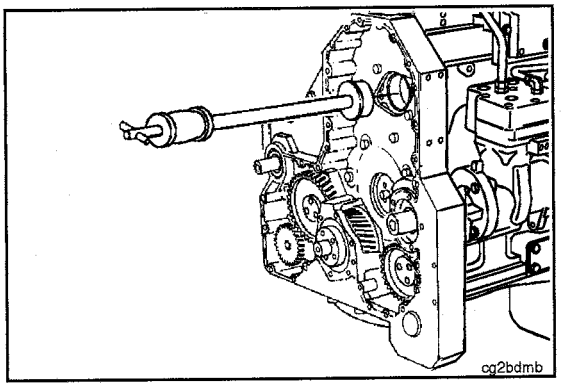
Camshaft Bushings (001-010)

Remove (001-010-002)

Remove the gear cover. Refer to Procedure 001-031.

Remove the cylinder head. Refer to Procedure 002-004.

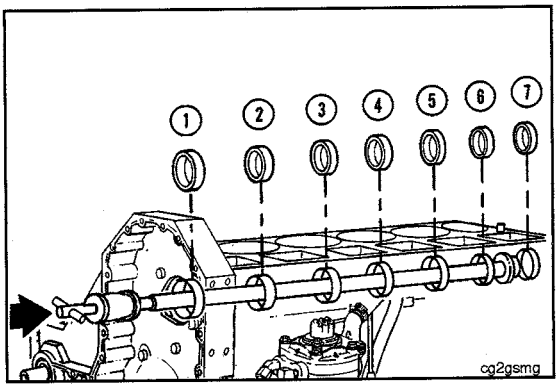
Remove the cam followers. Refer to Procedure 004-001.



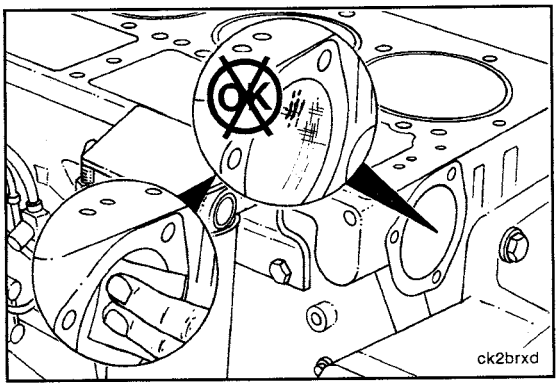
Remove the camshaft. Refer to Procedure 001-008.

Use Part No. 3376637, camshaft bushing driver and Part No. 3367636 Driver, or Part No. 3823642, hydraulic cam bushing tool, and Part No. 3823621 hydraulic actuator kit to remove the camshaft bushings.

Remove bushing number one first.



Remove the remaining six bushings in order from front to rear.



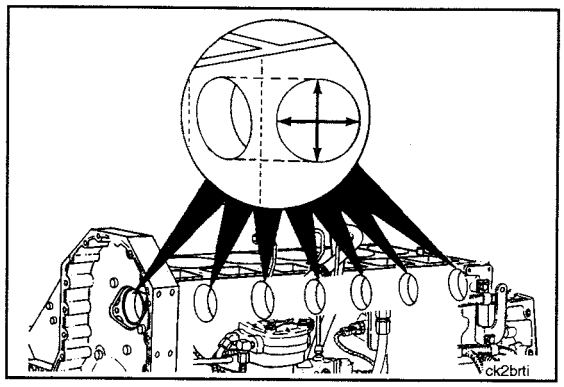
Clean (001-010-006)

Use Scotch-Brite® 7448, Part No. 3823258; or equivalent, to remove burrs and clean the bushing bores.

Inspect for Reuse (001-010-007)

Measure the cylinder block camshaft bore inside diameter.

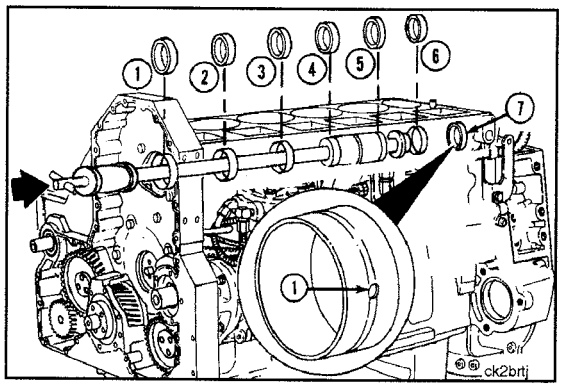
Cylinder Block Camshaft Bore I.D.		
mm		in
76.987	MIN	3.0310
77.040	MAX	3.0331



Install (001-010-026)

Starting with number seven bushing, install the camshaft bushings in order from rear to front.

NOTE: The oil hole (1) in the bushing **must** be at the three o'clock location when viewed from the front of the engine.

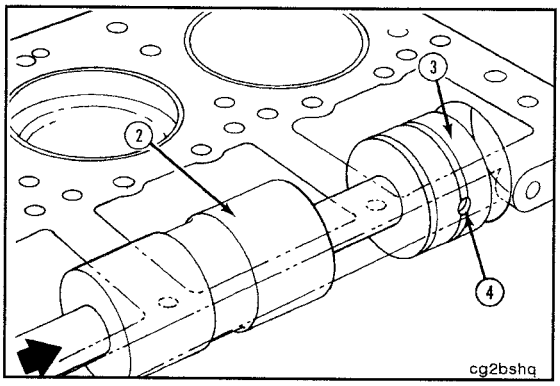


Number Seven Bushing - Installation

Install guide (2), Part No. 3376069, between the number six and number five bores.

Install a new bushing (3) on driver, Part No. 3376070, with the oil hole (4) at the **3 o'clock location** when viewed from the front of the engine.

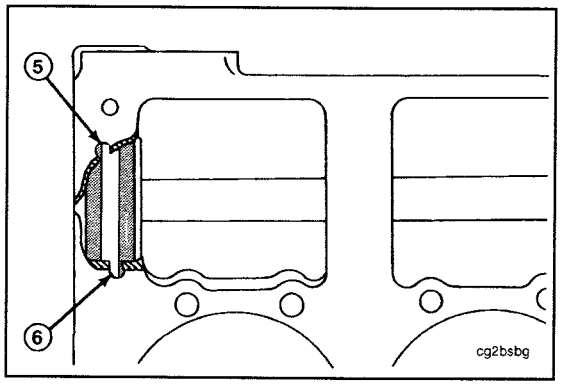
Drive the bushing into the bore.

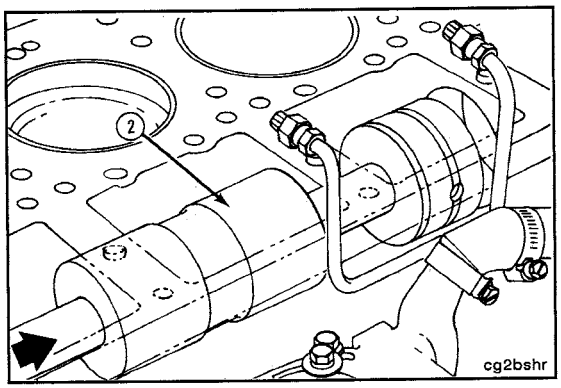


△ CAUTION △

The bushing oil groove must be visible in both cylinder block oil drillings (5 and 6) to prevent engine damage. The oil drillings are not in alignment with each other.

Inspect the bushing oil groove alignment with the two oil drillings in the block as the bushing is installed.





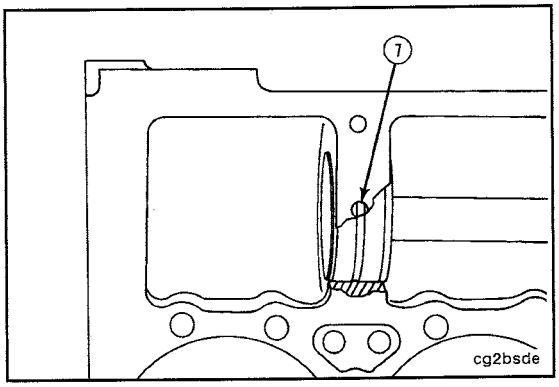
Number Six Through Number Two Bushings - Installation

Use the same procedure to install the number six through number two bushings.

Install the guide (2) in the correct location.

Install the bushing on the driver with the oil hole at the 3 o'clock location when viewed from the front of the engine.

Drive in the bushing.

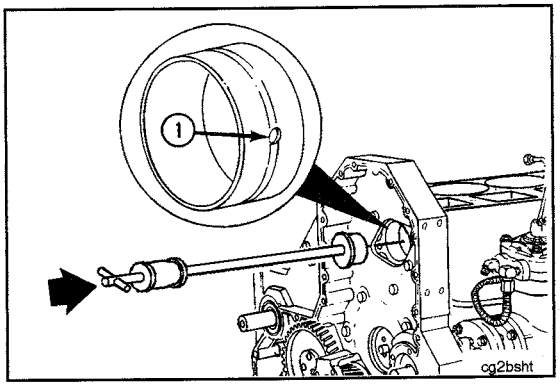


Remove the cam follower studs. Refer to Procedure 004-001.

△ CAUTION △

The oil groove must be visible through the cam follower stud holes (7). If the oil groove is not aligned, engine damage will occur.

Inspect the location of the camshaft bushing oil groove.

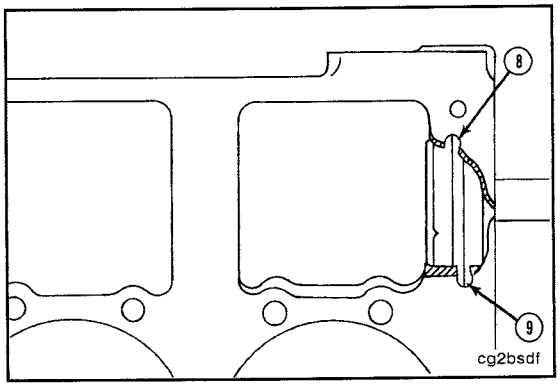


Number One Bushing - Installation

Install a new bushing on driver, Part No 3376070, with the oil hole (1) at the 3 o'clock location when viewed from the front of the engine.

NOTE: The guide is **not** used to install this bushing.

Drive the bushing into the bore.

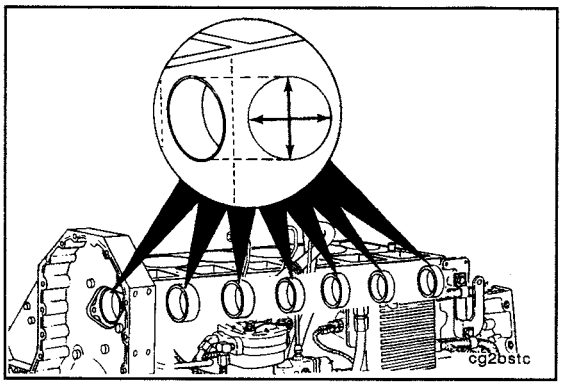


△ CAUTION △

The bushing oil groove must be visible in both block oil drillings (8 and 9) to prevent engine damage. The block oil drillings are not in alignment with each other.

Measure the camshaft bushing-installed inside diameter.

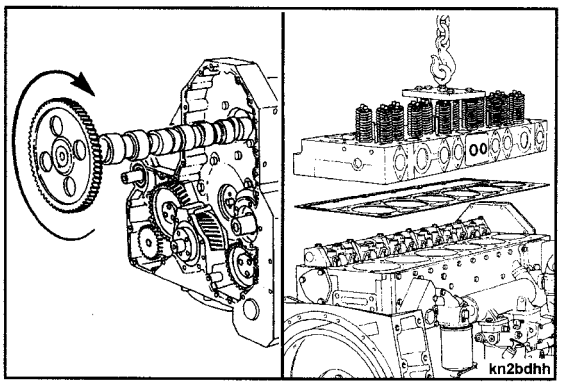
Camshaft Bushing I.D. Installed		
mm		in
72.078	MIN	2.8377
72.142	MAX	2.8402



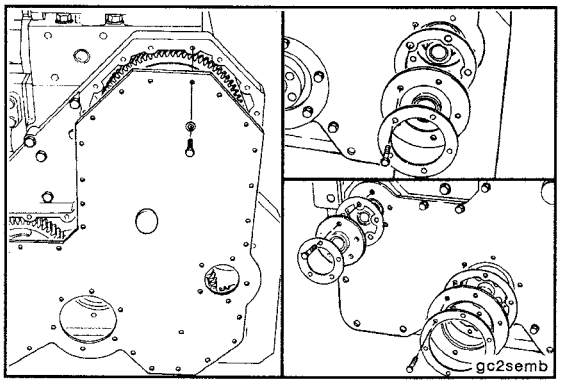
Install the camshaft. Refer to Procedure 001-008.

Install the cam follower studs and cam followers. Refer to Procedure 004-001.

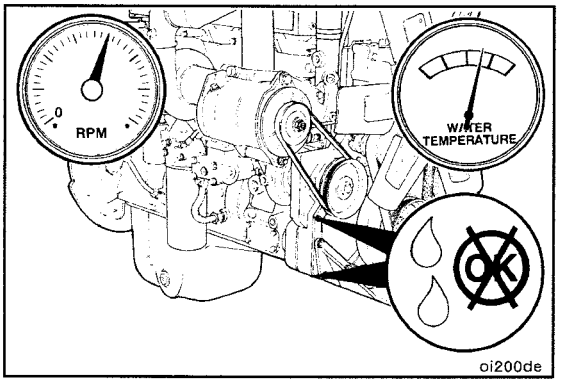
Install the cylinder head. Refer to Procedure 002-004.

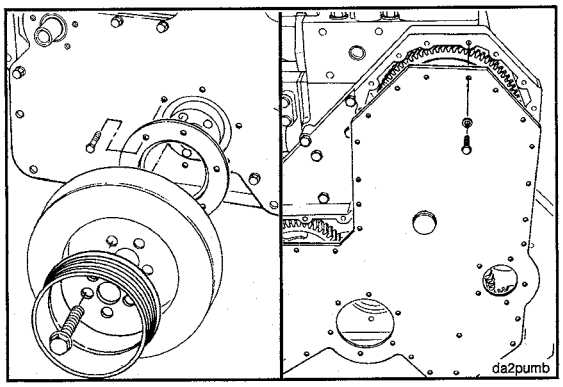


Install the gear cover. Refer to Procedure 001-031.



Operate the engine to normal operating temperature and check for leaks.

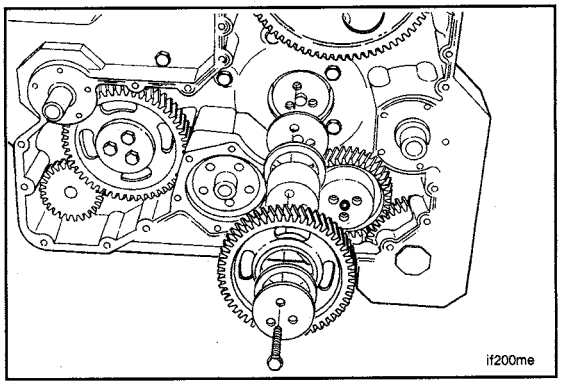




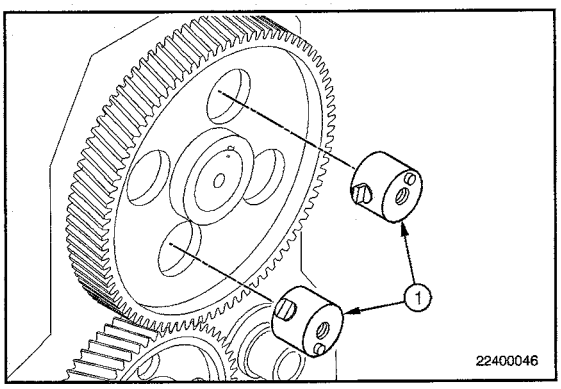
Camshaft Gear (Camshaft Installed) (001-012)

Remove (001-012-002)

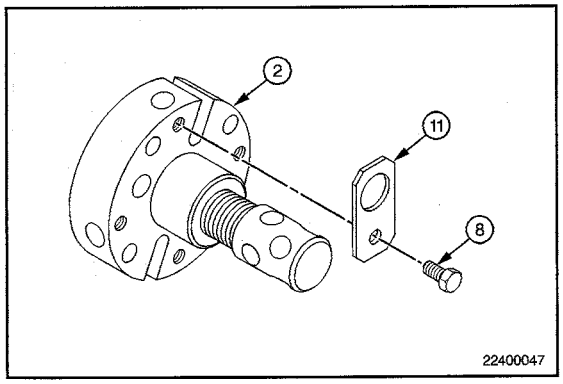
Remove the gear cover. Refer to Procedure 001-031.



Remove the camshaft idler gear. Refer to Procedure 001-036.

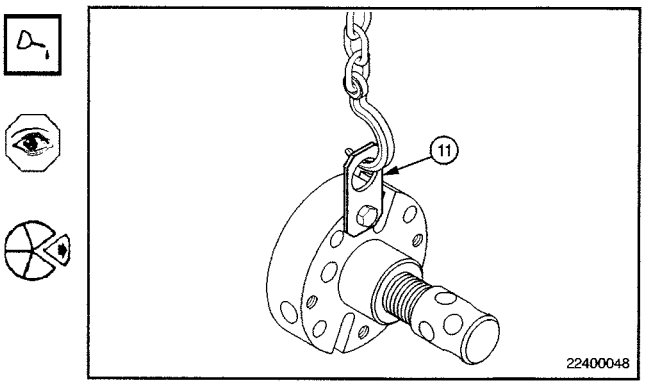


Place two puller adapter assemblies (1) in opposite lightening holes in cam gear.



Install lifting plate (11) on the holder plate (2) with one screw (8). Tighten screw securely.

Attach a lifting device to the lifting plate (11).



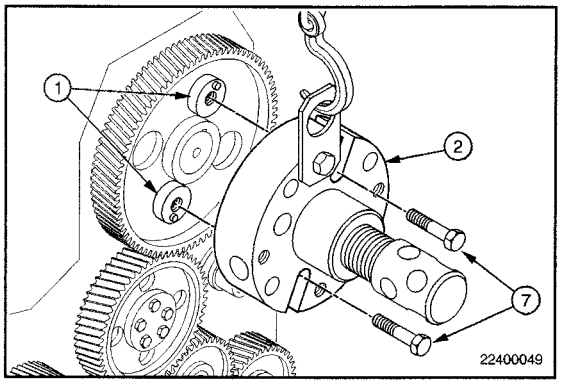
⚠ WARNING ⚠

The puller assemble is heavy. Use a lifting device when securing it to the cam gear.

NOTE: Make sure the forcing screw pilot is engaged with the center of the camshaft and the puller adapter assembly studs are properly seated in the holder plate assembly.

Using the lifting device, position the holder plate (2) against the cam gear and install two screws (7) through the holder plate (2) into the puller adapters (1).

Tighten screws securely.

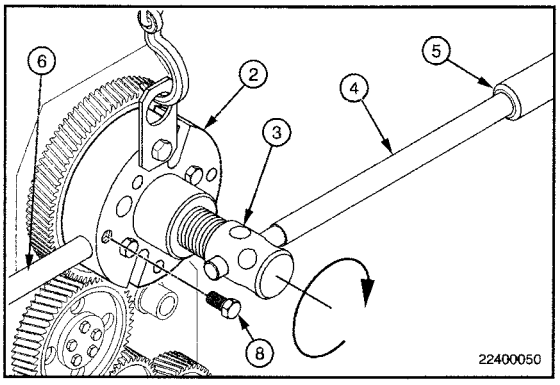


⚠ WARNING ⚠

Cam gear and puller assembly may fall when released and cause serious injury to personnel.

NOTE: Do not attempt to alter the puller assembly for use with any kind of impact wrench. The threads on the puller assembly may gall and seize.

Using the lever bar (4), extension bar (5), and torque reaction lever (6), turn the forcing screw (3) clockwise to pull cam gear from the camshaft.



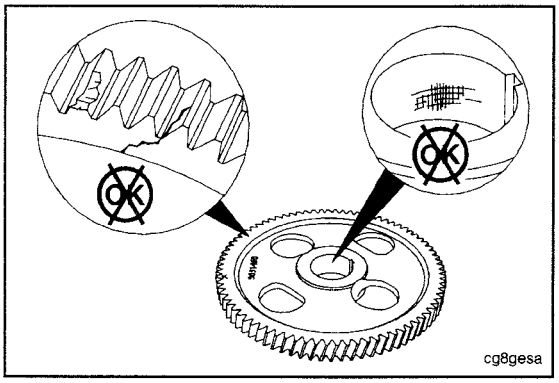
Inspect for Reuse (001-012-007)

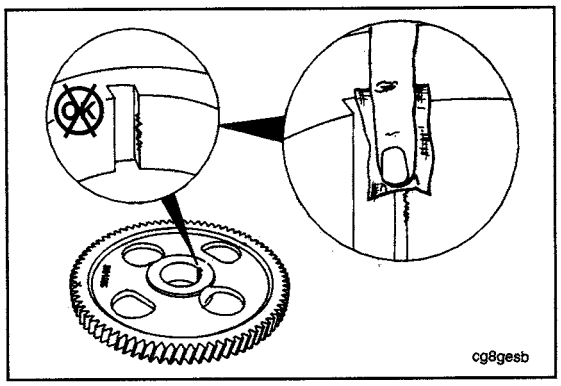
Inspect the camshaft gear for cracks and chipped or broken teeth.

Inspect the bore of the gear for frets or burrs.

Remove any burrs with Scotch-Brite™ 7448, Part No. 3823258; a fine honing stone, or equivalent.

If the frets, burrs, or raised material can **not** be removed, replace the gear.

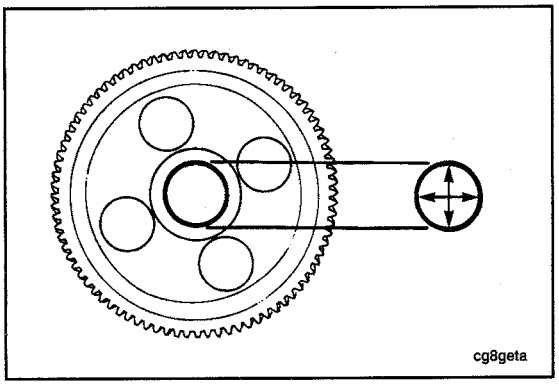




Inspect the gear keyway for burrs.

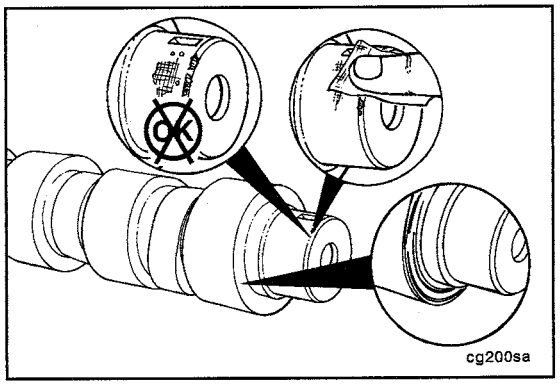
Remove burrs with Scotch-Brite™ 7448, Part No. 3823258; a fine honing stone, or equivalent.

If the keyway is damaged or the burrs can **not** be removed, the gear **must** be replaced.



Measure the camshaft gear bore inside diameter.

Camshaft Gear Bore I.D.		
mm		in
46.912	MIN	1.8469
46.938	MAX	1.8479

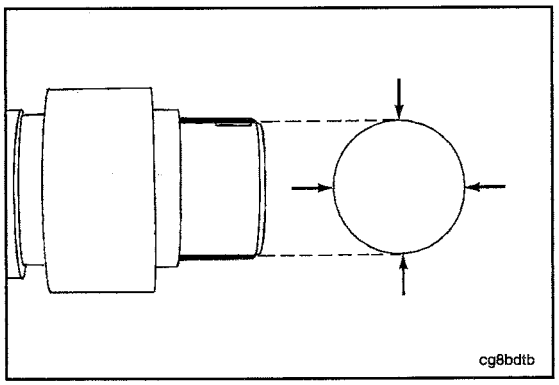


Inspect the camshaft nose for frets or burrs.

Remove any burrs with Scotch-Brite™ 7448, Part No. 3823258; a fine honing stone, or equivalent.

If frets or burrs can **not** be removed, replace the camshaft.

Inspect the thrust surface of the camshaft for grooves or heavy wear.

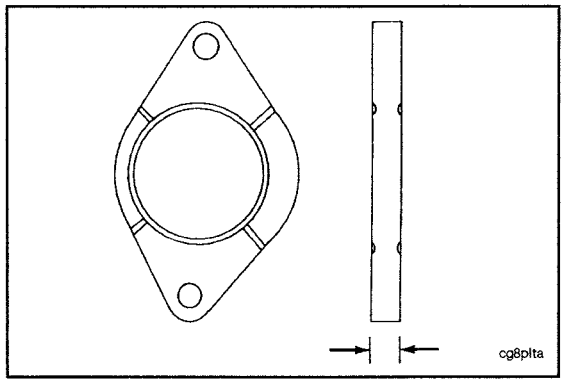


Measure the camshaft gear journal outside diameter.

Camshaft Gear Journal O.D.		
mm		in
46.987	MIN	1.8499
47.013	MAX	1.8509

Measure the camshaft thrust plate thickness.

Camshaft Thrust Plate Thickness		
mm		in
8.96	MIN	0.353
9.04	MAX	0.356

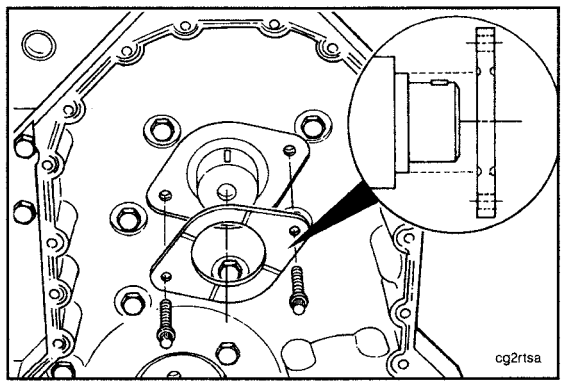


Install (001-012-026)

Install the thrust plate on the camshaft.

Install the capscrews and tighten.

Torque Value: 47 N•m [35 ft-lb]

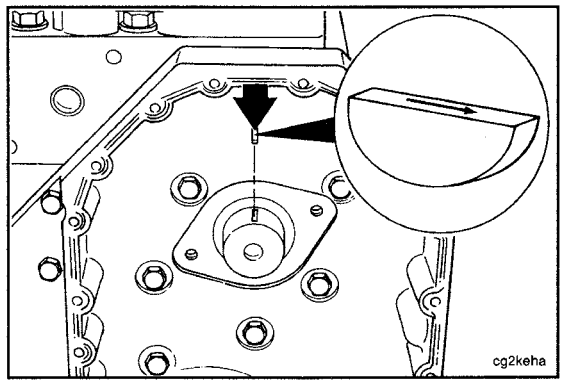


NOTE: Gear housing clearance makes key installation more difficult. Use care in seating the key.

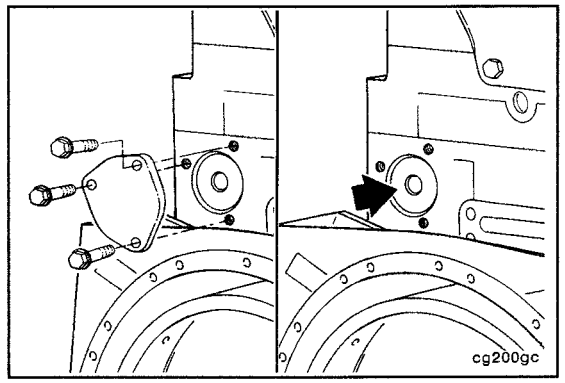
Be sure the gear mounting surface is clean and free of oil, dirt, or debris.

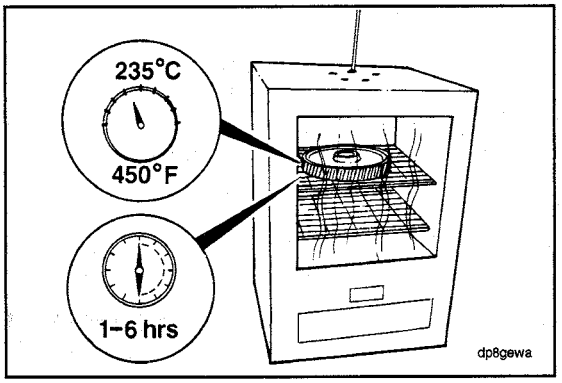
If the same camshaft gear is used again, use the same part number key as the one that was removed. Be sure the arrow on the key is pointing in the same direction as when it was removed.

Use a leather hammer to install the camshaft gear key.



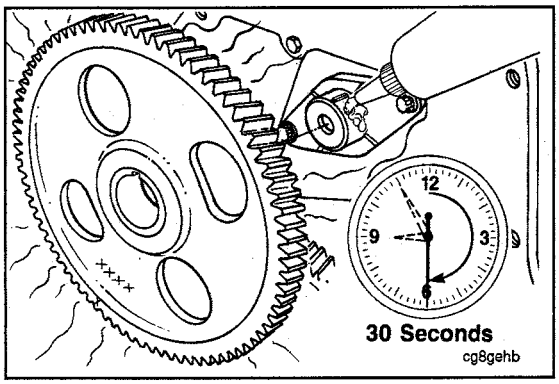
It can be necessary to remove the camshaft rear cover plate and apply pressure to the end of the camshaft to hold it in the forward position while the gear is being installed. Refer to Procedure 001-008.





Heat the gear in an oven for a minimum of 1 hour, but **not** longer than 6 hours.

Temperature: 235 °C [450 °F]



⚠ WARNING ⚠

Use insulated gloves, Part No. 3823730, and/or hot clamp pliers, Part No. 3823732, when handling heated parts. Hot parts can cause serious personal injury.

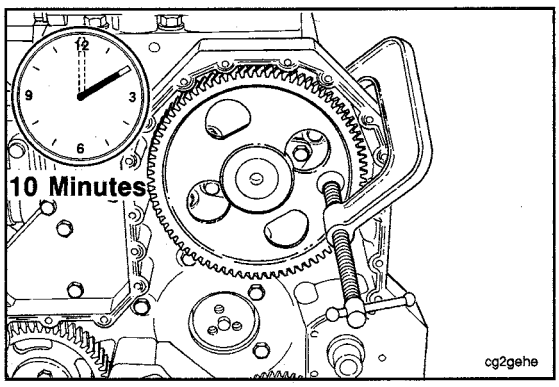
△ CAUTION △

The timing marks and gear part number must be facing away from the camshaft when the gear is installed to prevent engine damage.

Use Lubriplate™ 105, or equivalent, to coat the camshaft nose before installing the camshaft gear.

Remove the gear from the oven. Install the gear on the camshaft within 30 seconds after being removed from the oven.

Align the gear keyway with the key in the camshaft, and install the gear on the camshaft.



Install a "C-clamp" around the gear housing and the camshaft gear to hold the gear in position as it cools.

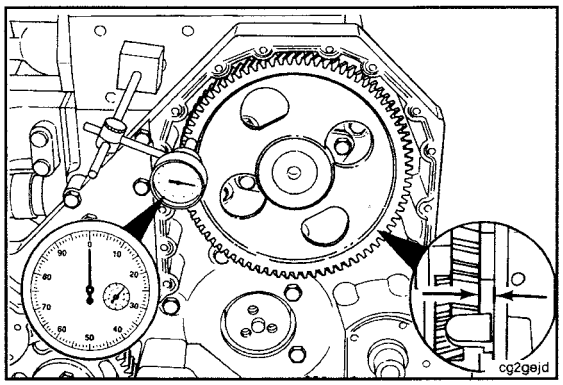
Remove the "C-clamp" after the gear has cooled to room temperature (approximately 10 minutes).

Use a dial indicator to check the end clearance of the gear.

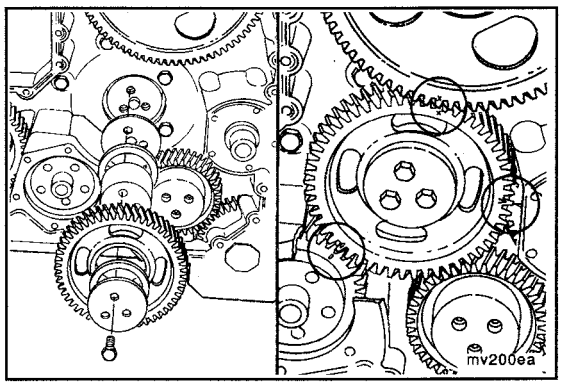
Push the camshaft to the rear, and set the gauge at zero.

Pull the gear out, and measure the end clearance.

Camshaft Gear End Clearance		
mm		in
0.13	MIN	0.005
0.33	MAX	0.013



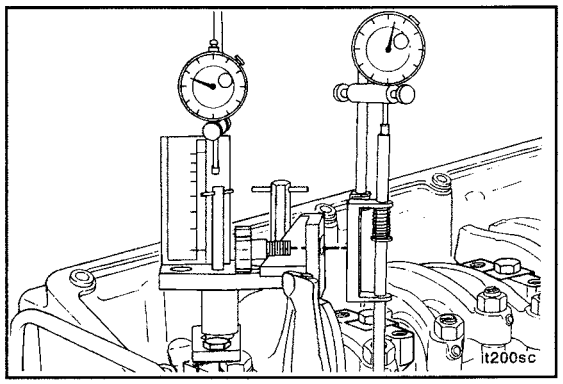
Install the camshaft idler gear. Refer to Procedure 001-036.



⚠ CAUTION ⚠

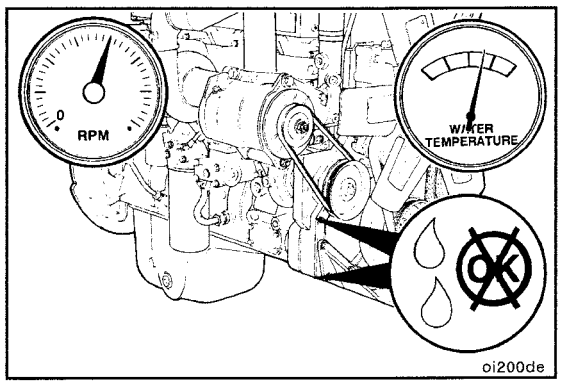
Failure to check the engine timing can cause severe engine damage.

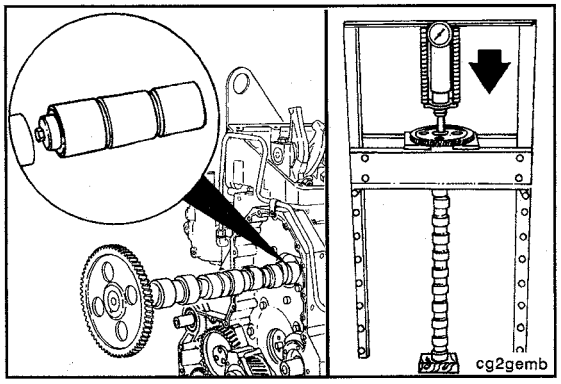
Check the engine timing. Refer to Procedure 006-025.



Install the gear cover. Refer to Procedure 001-031.

Operate the engine to normal operating temperature and check for leaks.





Camshaft Gear (Camshaft Removed) (001-013)

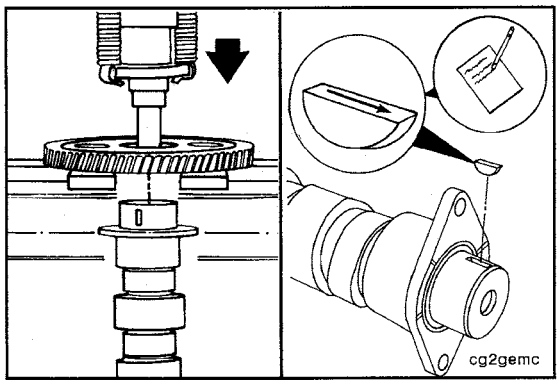
Remove (001-013-002)

Remove the camshaft. Refer to Procedure 001-008.

⚠ CAUTION ⚠

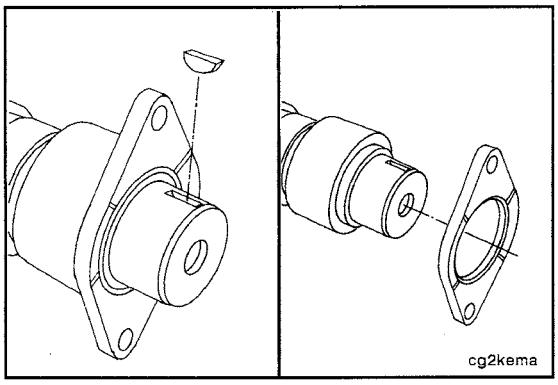
Support the camshaft gear on the center hub when pressing it off the camshaft. Failure to do so can result in damage to the gear.

Install the camshaft and gear assembly in a hydraulic press.



Press the camshaft from the gear.

NOTE: If the camshaft key is marked with an arrow, record the direction the arrow is pointed.



Remove the camshaft key.

Remove the thrust plate.

Camshaft Keys

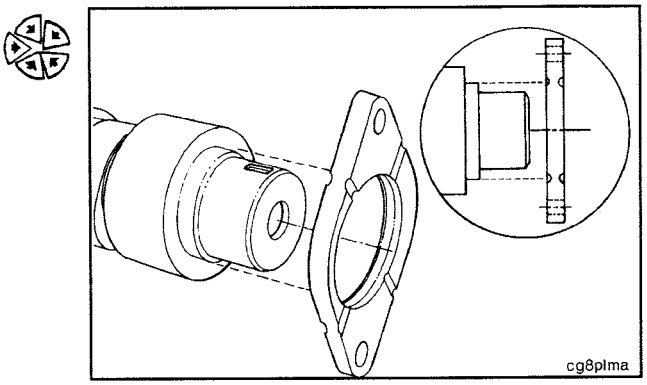
Key Part No.	Degree of Offset (To the Camshaft)	Change in Push Rod Travel mm	Change in Push Rod Travel in.
3009953	0.00	0.000	0.0000
3030893 3009948	0.25 0.50	0.051 0.102	0.0020 0.0040
3030894 3009949	0.75 1.00	0.152 0.203	0.0060 0.0080
3030895 3009950	1.25 1.50	0.254 0.305	0.0100 0.0120
3030896 3009951	1.75 2.00	0.356 0.406	0.0140 0.0160
3030897 3030898	2.25 2.50	0.457 0.508	0.0180 0.0200

lt200nb

Install (001-013-026)

The accompanying chart lists different camshaft key part numbers, the degree of offset, and the approximate injector timing change from nominal.

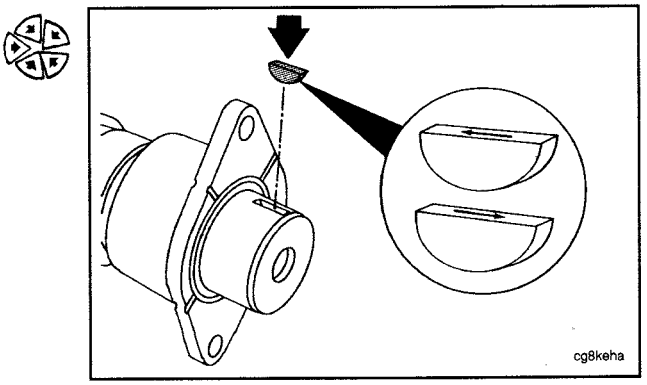
Install the thrust plate on the camshaft.



Be sure the gear mounting surface is clean and free of oil, dirt, or debris.

Use a leather hammer to install the camshaft gear key.

NOTE: If the same camshaft and gear are used again, use the same part number key as the one that was removed. Be sure the arrow on the key is pointing in the same direction as when it was removed. If a different camshaft and gear are used, install a straight key.



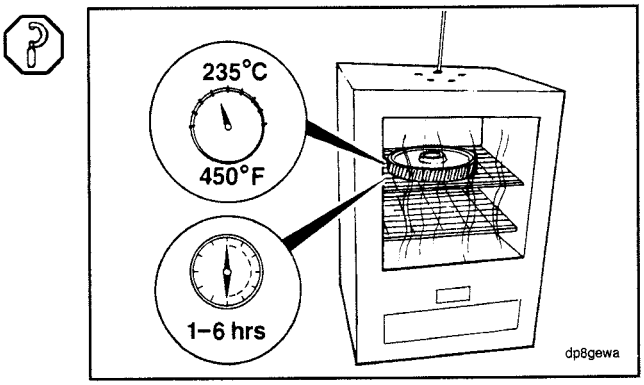
⚠ WARNING ⚠

Use insulated gloves, Part No. 3823730, and/or hot clamp pliers, Part No. 3823732, when handling heated parts. Hot parts can cause serious personal injury.

Heat the gear in an oven for a minimum of 1 hour, but no longer than 6 hours.

Temperature 235 °C [450 °F]

Use Lubriplate™ 105, or equivalent, to coat the camshaft nose before installing the camshaft gear.



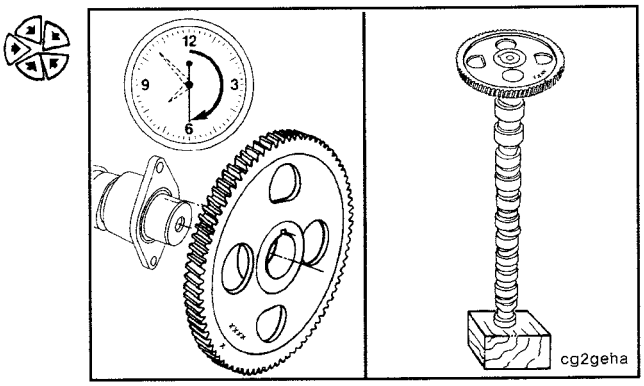
△ CAUTION △

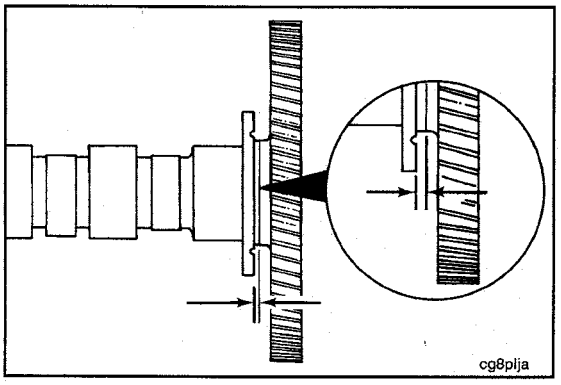
The timing marks and gear part number must be facing away from the camshaft when the gear is installed to prevent engine damage.

The gear **must** be installed within 30 seconds after being removed from the oven.

Remove the gear from the oven. Align the keyway in the gear with the key in the camshaft, and install the gear on the camshaft.

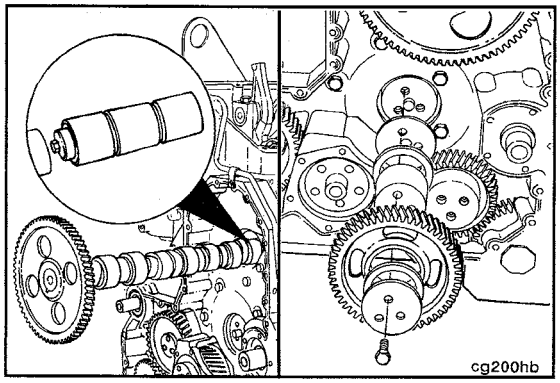
Keep the camshaft in a vertical position with the gear up until the gear has cooled.





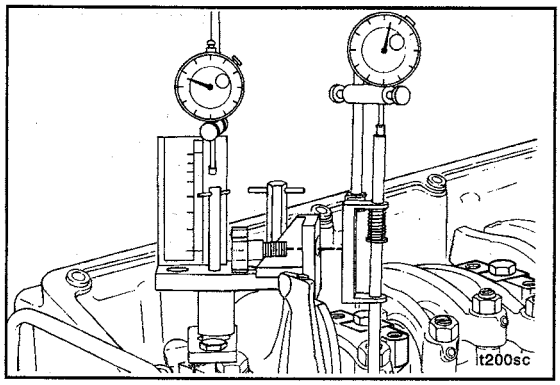
Measure the clearance between the gear hub and the thrust plate.

Thrust Plate Clearance		
mm		in
0.13	MIN	0.005
0.33	MAX	0.013



Install the camshaft. Refer to Procedure 001-008.

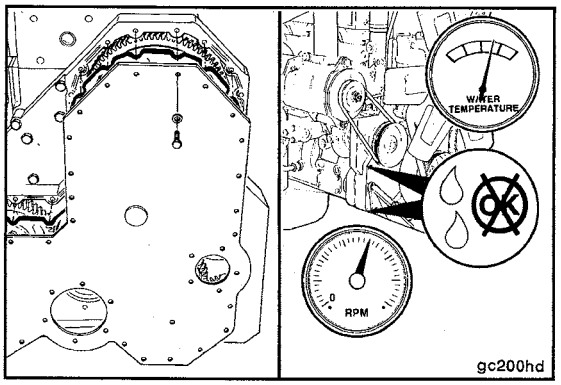
Install the camshaft idler gear. Refer to Procedure 001-036.



⚠ CAUTION ⚠

Failure to check engine timing can cause severe engine damage.

Check the engine timing. Refer to Procedure 006-025.



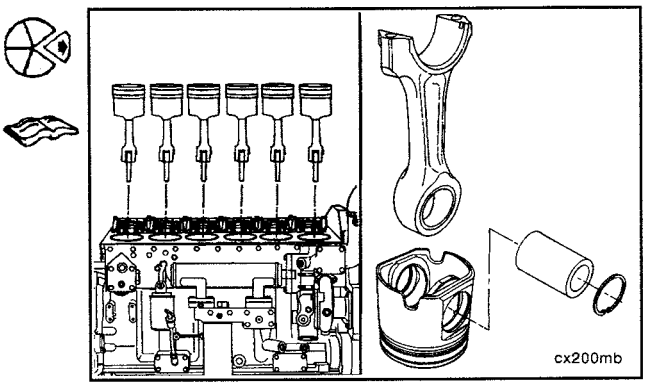
Install the gear cover. Refer to Procedure 001-031.

Operate the engine to normal operating temperature and check for leaks.

Connecting Rod (001-014)

Remove (001-014-002)

The piston and connecting rod **must** be removed as an assembly on M Series engines. Refer to Procedure 001-054 for removal instructions.

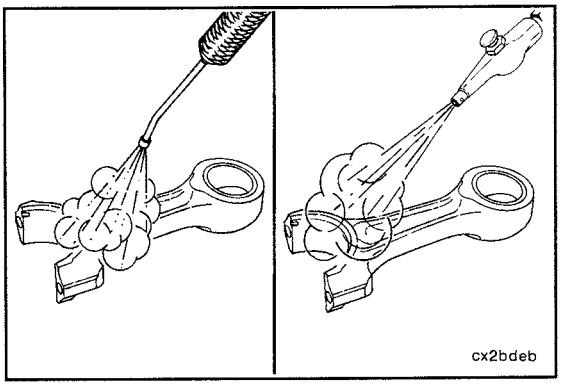


Clean (001-014-006)

⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, as well as, safety glasses or a face shield. Hot steam can cause serious personal injury.

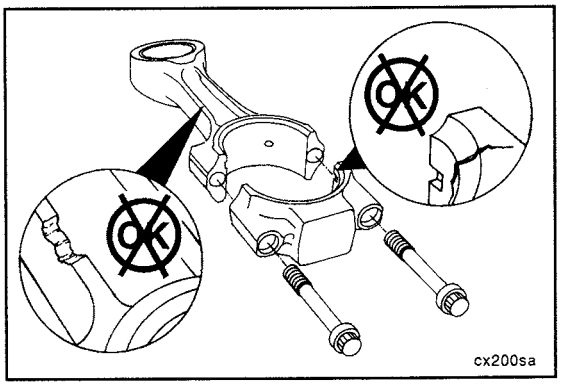
Use steam or solvent to clean the connecting rods. Dry with compressed air.



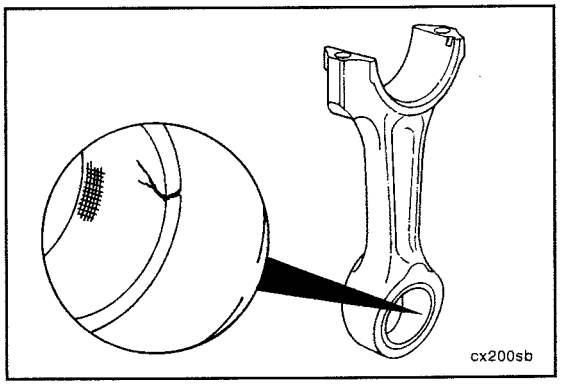
Inspect for Reuse (001-014-007)

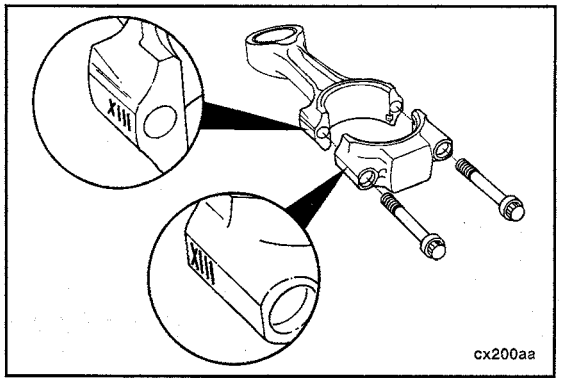
Inspect the connecting rods and caps for damage.

Replace the connecting rod if the "I-beam" is nicked or damaged.



Inspect the connecting rod pin bore bushing for damage.



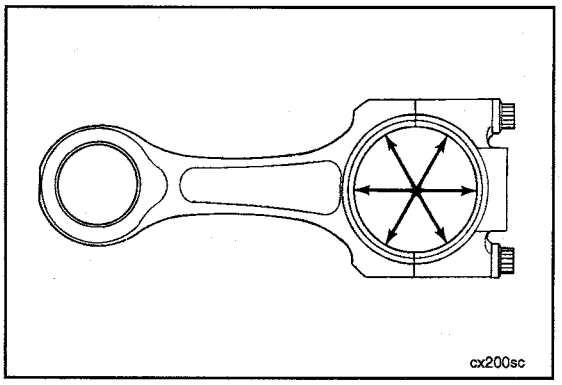


Install the connecting rod caps and capscrews.

NOTE: The connecting rod cap number **must** match the number on the connecting rod and be installed with the numbers aligned.

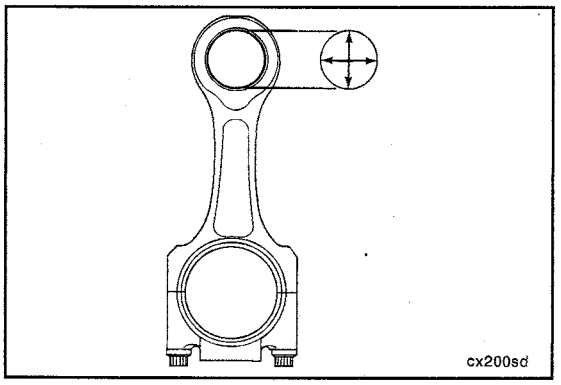
Tighten the capscrews in alternating sequence to the following torque values:

Torque Value:	Step 1	68 N•m	[50 ft-lb]
	2	142 N•m	[105 ft-lb]
	3	210 N•m	[155 ft-lb]
	4	Loosen completely	
	5	Repeat steps 1 through 3	



Measure the connecting rod crankshaft bore inside diameter.

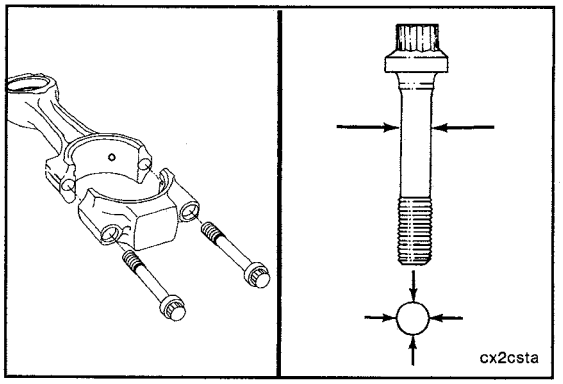
Connecting Rod Crankshaft Bore I.D.		
mm		**in**
83.975	MIN	3.3061
84.025	MAX	3.3080



Measure the piston pin bushing inside diameter.

Piston Pin Bushing I.D.		
mm		**in**
54.054	MIN	2.1281
54.099	MAX	2.1299

NOTE: Refer to the M11 Shop Manual, Bulletin No. 3666075, to measure the bend and twist of the connecting rods.



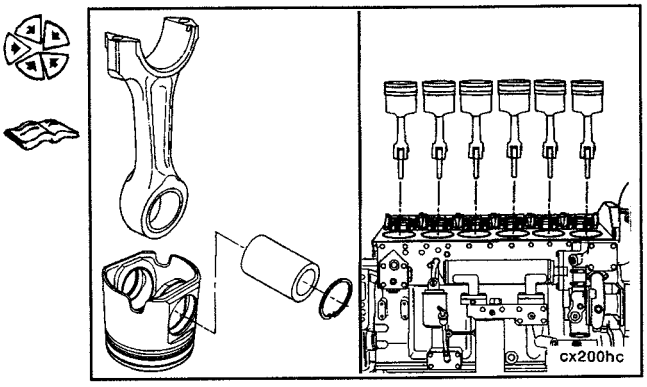
Remove the capscrews and rod caps.

Measure the connecting rod capscrew outside diameter.

Connecting Rod Capscrew O.D.		
mm		**in**
12.60	MIN	0.496
12.80	MAX	0.504

Install (001-014-026)

The piston and connecting rod **must** be installed as an assembly on M Series engines. Refer to Procedure 001-054 for installation instructions.



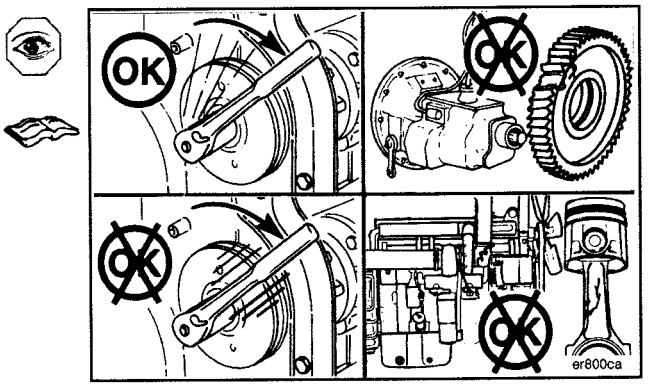
Crankshaft (001-016)

Rotation Check (001-016-052)

Use **only** the accessory driveshaft to rotate the crankshaft.

Rotate the crankshaft **clockwise** through two complete revolutions.

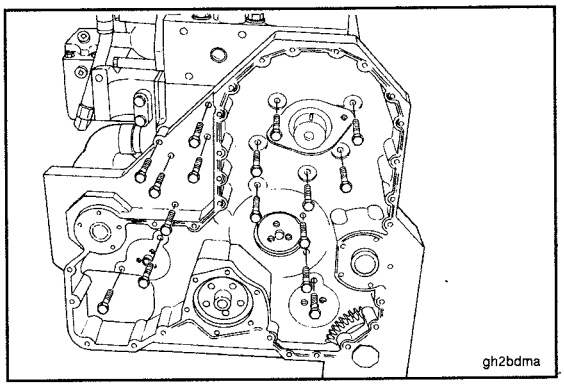
If the engine does **not** turn freely, the equipment can have a malfunction. Refer to the manufacturer's instructions. The engine can have internal problems. Refer to the correct procedure for inspection and replacement of internal engine components.



Crankshaft Gear, Front (Crankshaft Installed) (001-018)

Remove (001-018-002)

Remove the gear housing. Refer to Procedure 001-033.

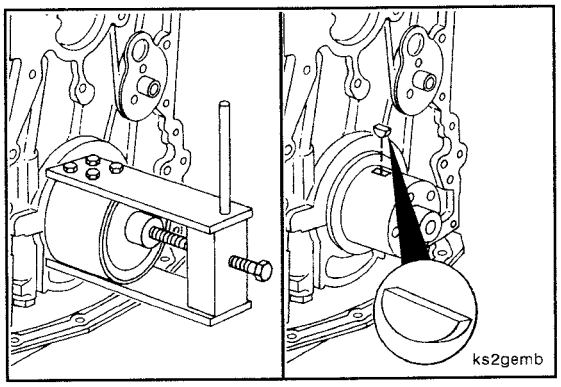


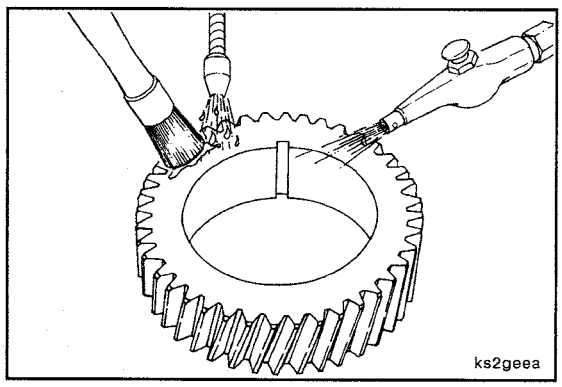
Install crankshaft gear puller, Part No. 3375834, and jaw, Part No. 3375839, on the gear.

Turn the pressure screw **clockwise** to remove the gear.

Remove the crankshaft gear key.

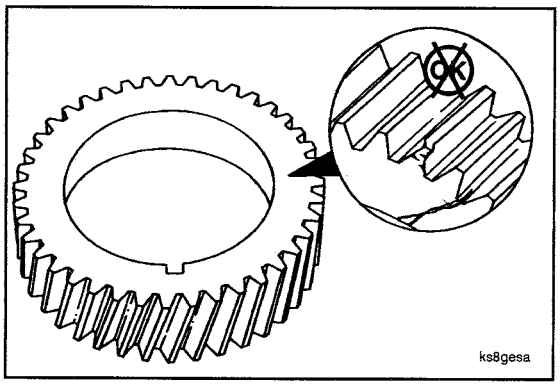
Do **not** damage the crankshaft when removing the key.





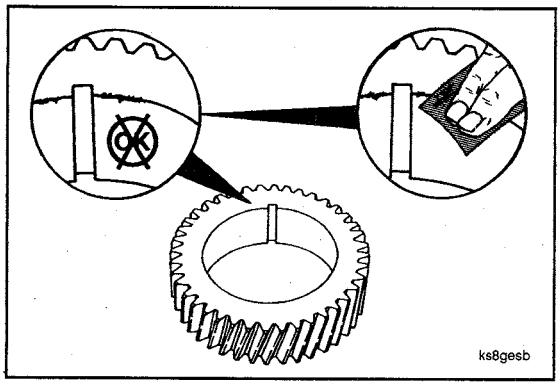
Clean (001-018-006)

Clean the gear with solvent. Dry with compressed air.

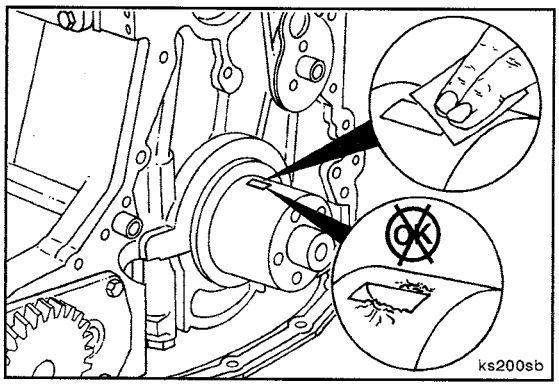


Inspect for Reuse (001-018-007)

Inspect the crankshaft gear for cracks and broken or chipped teeth.



Remove any burrs with Scotch-Brite™ 7448, Part No. 3823258, or equivalent.

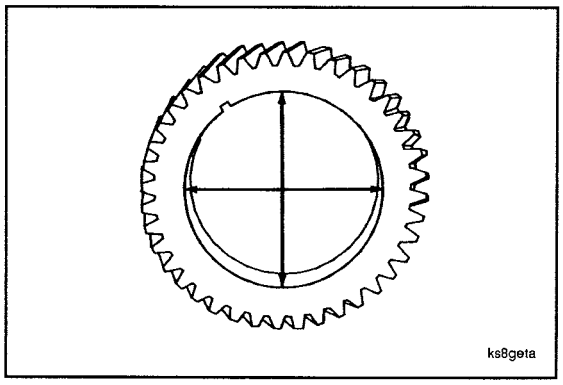


Inspect the crankshaft gear journal for burrs or damage.

Remove any burrs with Scotch-Brite™ 7448, Part No. 3823258, or equivalent.

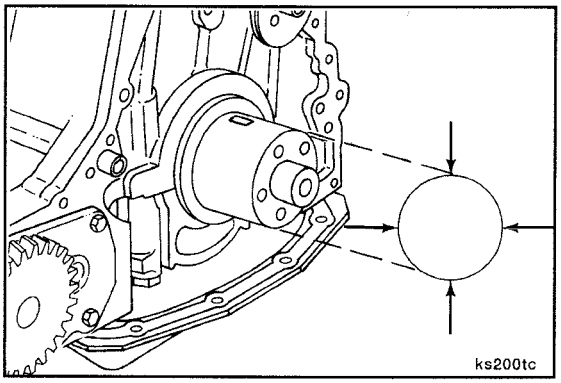
Measure the crankshaft gear bore inside diameter.

Crankshaft Gear Bore Inside Diameter		
mm		in
85.910	MIN	3.3823
85.935	MAX	3.3833



Measure the crankshaft gear journal outside diameter.

Crankshaft Gear Journal Outside Diameter		
mm		in
85.975	MIN	3.3848
86.000	MAX	3.3858



Install (001-018-026)

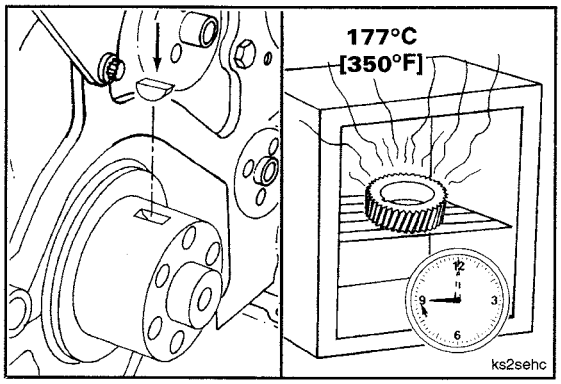
Use a leather hammer to install a new key in the crankshaft keyway.

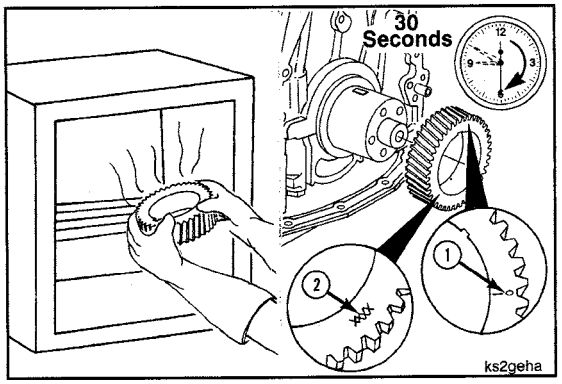
⚠ CAUTION ⚠

Do not exceed the specified time or temperature when heating the crankshaft gear. The gear and teeth can be damaged.

Heat the gear in an oven for a minimum of 1.5 hours, but **not** more than 6 hours.

Temperature: 177 °C [350 °F]





⚠ WARNING ⚠

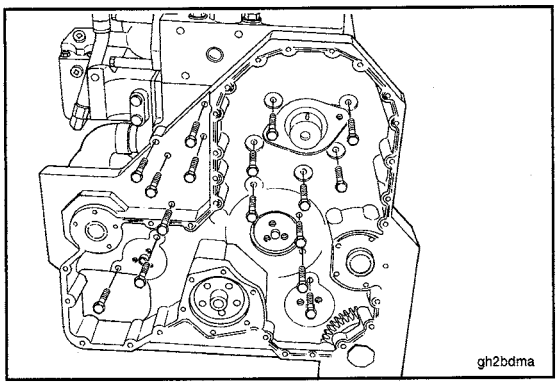
Use insulated gloves, Part No. 3823730, and/or hot clamp pliers, Part No. 3823732, when handling heated parts. Hot parts can cause serious personal injury.

△ CAUTION △

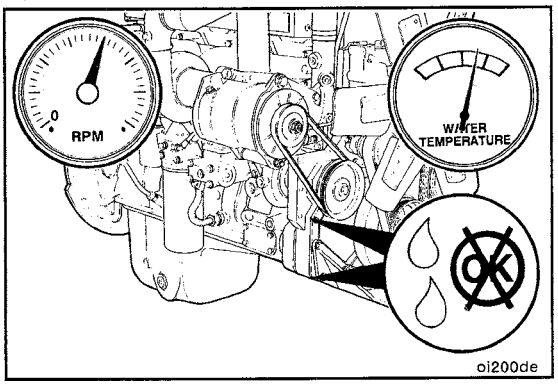
The timing mark (1) and part number (2) on the gear must be facing away from the crankshaft after the gear is installed. Engine damage can result if the gear is installed backwards.

Use Lubriplate™ 105, or equivalent, to lubricate the outside diameter of the crankshaft gear journal.

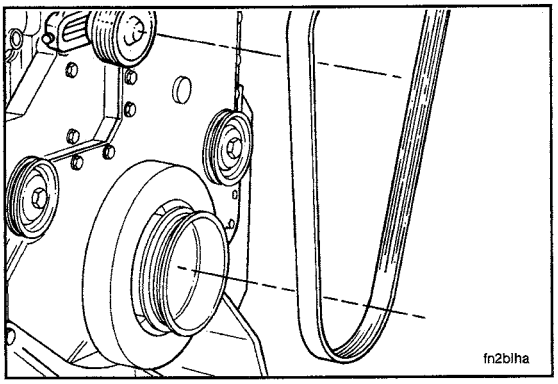
Remove the gear from the oven. Align the keyway of the gear with the key in the crankshaft, and install the gear within 30 seconds.



Install the gear housing. Refer to Procedure 001-033.



Operate the engine to normal operating temperature and check for leaks.



Crankshaft Pulley (001-022)

Remove (001-022-002)

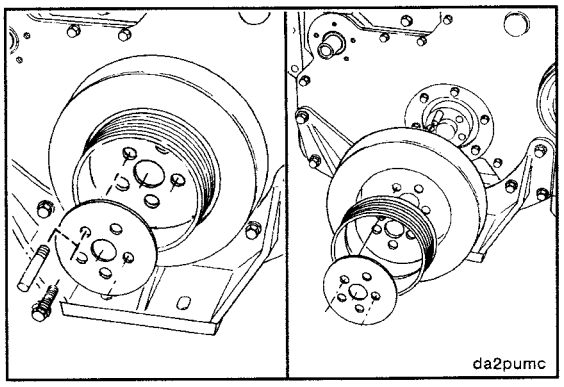
Remove the fan drive belt. Refer to Procedure 008-002.

Remove two of the vibration damper and crankshaft pulley retaining capscrews.

Install two guide studs, Part No. 3376696, in the holes.

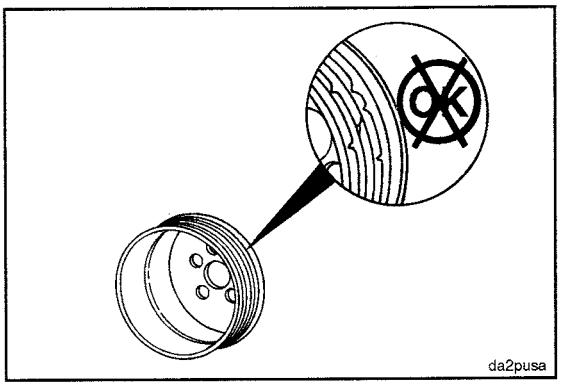
Remove the remaining three capscrews, clamping plate, pulley, and damper.

NOTE: Do **not** use a hammer or a screwdriver to remove the viscous damper. These tools can damage the damper.



Inspect for Reuse (001-022-007)

Inspect the pulley for cracks, excessive wear in the belt grooves, or other damage.

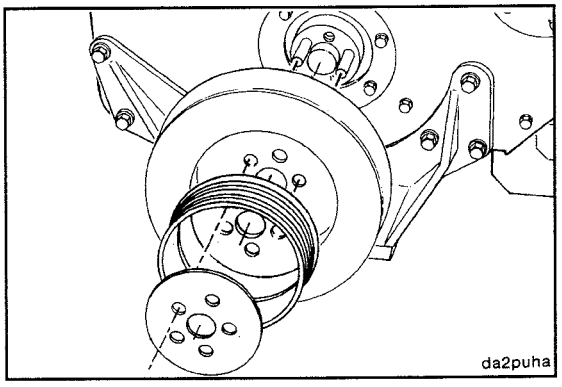


Install (001-022-026)

Make sure the mounting surfaces of the crankshaft nose, the vibration damper, and the pulley are clean, dry, and free of burrs.

Install two guide studs, Part No. 3376696, in the crankshaft nose.

Install the vibration damper, pulley, and clamping plate on the guide studs.



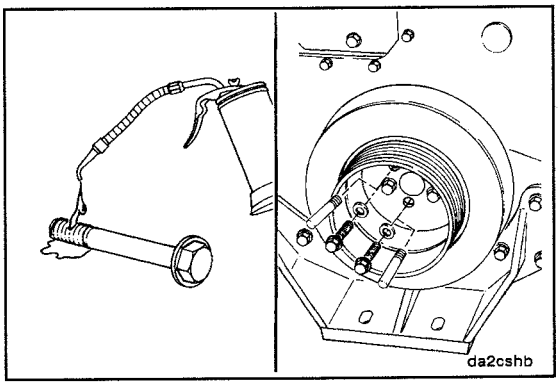
Use clean 15W-40 oil to lubricate the capscrew threads.

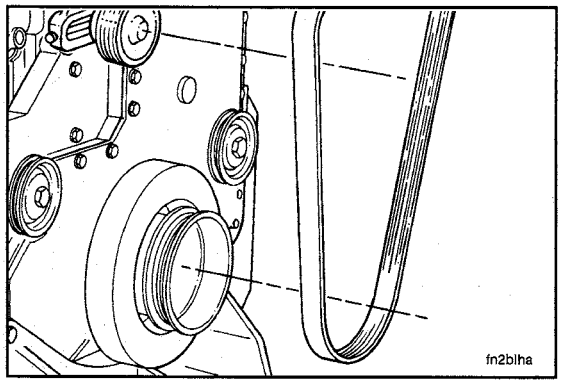
Install three of the five capscrews.

Remove the two guide studs, and install the two remaining capscrews.

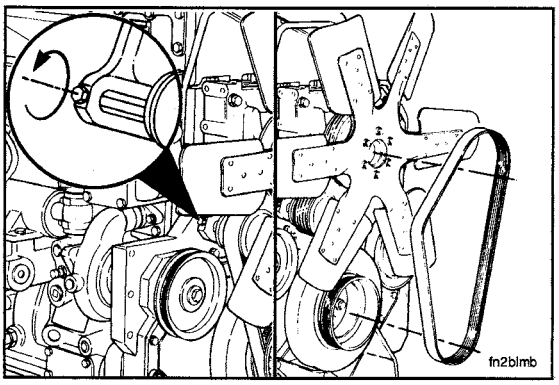
Tighten the capscrews in a star pattern.

Torque Value: 203 N•m [150 ft-lb]





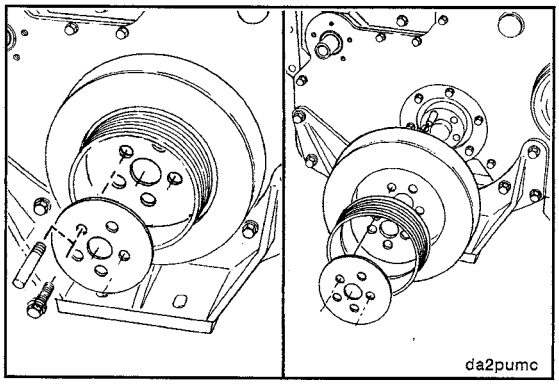
Install and adjust the fan drive belt. Refer to Procedure 008-002.



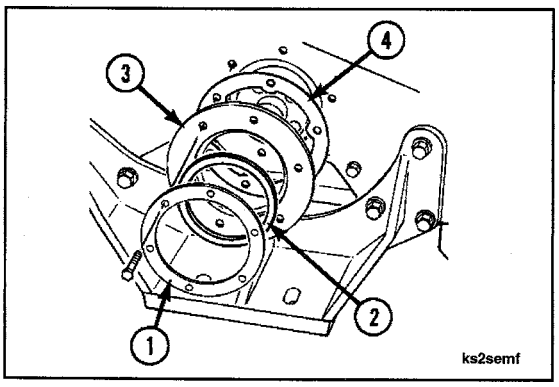
Crankshaft Seal, Front (001-023)

Remove (001-023-002)

Remove the fan drive belt. Refer to Procedure 008-002.



Remove the clamping plate, crankshaft pulley, and vibration damper. Refer to Procedure 001-052.

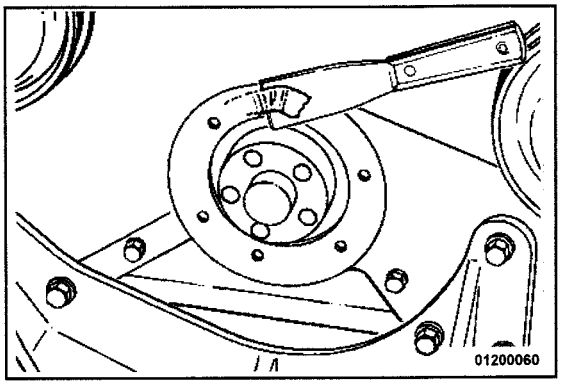


Remove the six capscrews, the clamping ring (1), the oil seal (3), and dust seal (2) together.

Remove the gasket (4).

Clean (001-023-006)

Clean the front crankshaft oil seal gasket surface of the gear cover.

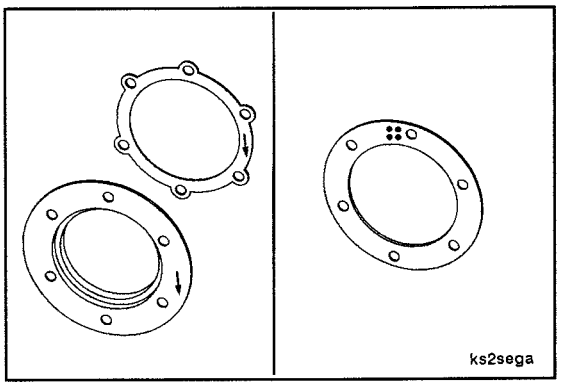


Install (001-023-026)

The capscrew hole spacing on the oil seal is **not** symmetrical.

The gear cover, oil seal, and carrier gasket are each marked with an arrow located at approximately the three-o'clock location.

The clamping ring is marked with four punch marks, which can be found at approximately the eleven-thirty location.

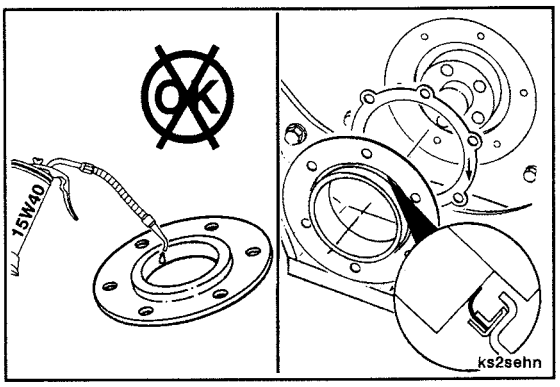


Do **not** use any kind of lubricant to install the seal. The oil seal **must** be installed with the lip of the seal and the crankshaft clean and dry.

The yellow dust lip of the seal **must** be facing out.

Align the arrow markings on the seal and gasket to the arrow markings on the gear cover.

Use the installation sleeve provided with the new seal kit to install the new seal and gasket.

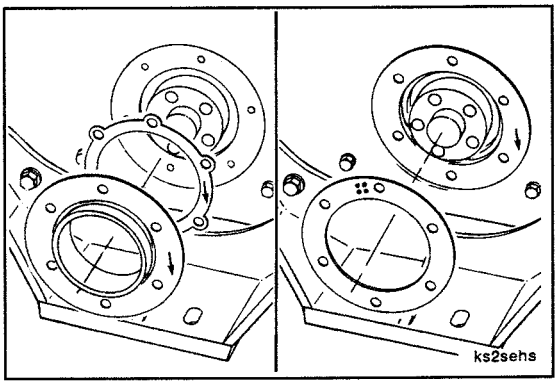


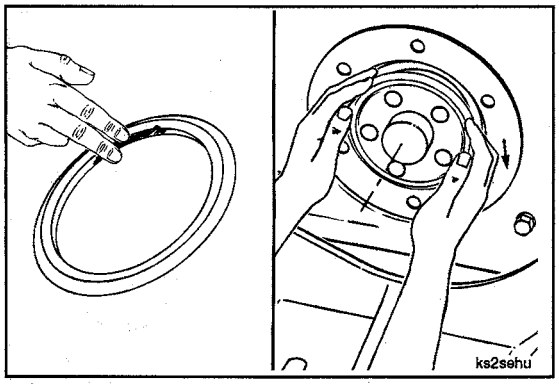
Orientate the four punch marks on the clamping ring at the 11:30 o'clock location.

Apply a coating of thread sealant, Part No. 3823494, to the six mounting capscrews.

Install the six seal capscrews (M8-1.25 x 20) and washers. Tighten the capscrews in a star pattern in two steps.

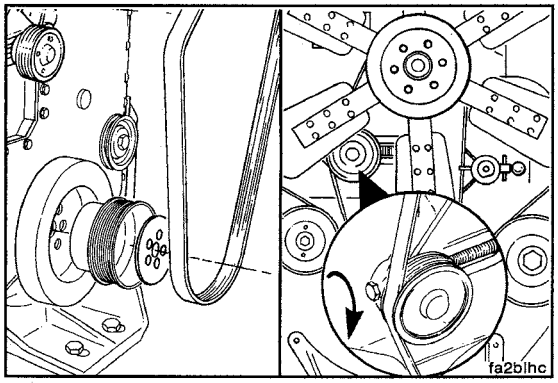
Torque Value: Step 1 7 N•m [60 in-lb]
2 20 N•m [180 in-lb]





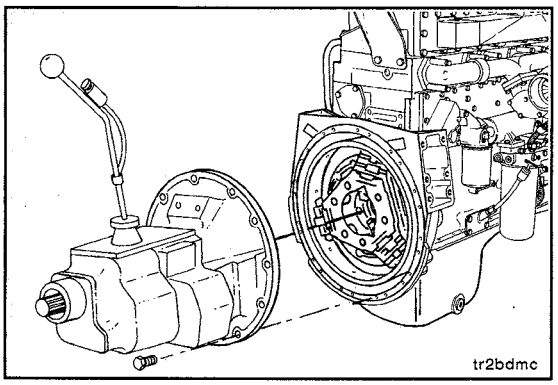
Place a light film of oil or antifreeze on the inside diameter of a new dust seal.

Install the dust seal with the larger outside diameter facing toward the engine. Push the dust seal back on the shaft until the entire seal contacts the oil seal case.



Install the vibration damper, crankshaft pulley, and clamping plate. Refer to Procedure 001-052.

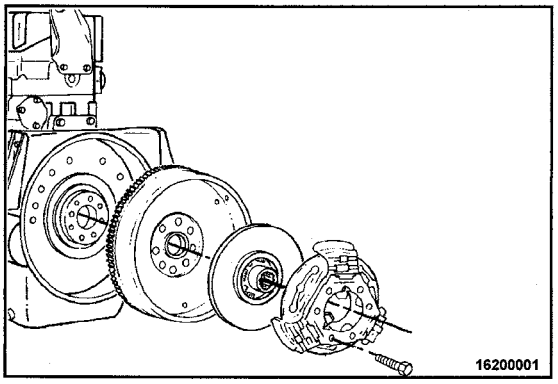
Install and adjust the fan drive belt. Refer to Procedure 008-002.



Crankshaft Seal, Rear (001-024)

Remove (001-024-002)

Disconnect the driveline, and remove the transmission, if equipped. Refer to the manufacturer's instructions.



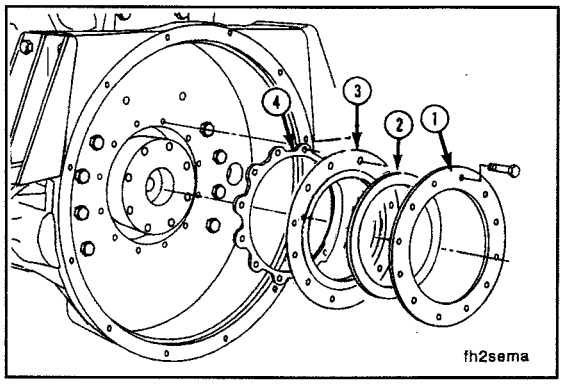
Remove the clutch and flywheel, if equipped. Refer to Procedure 016-005.

NOTE: On REPTO units, it is necessary to remove the crankshaft gear mounting capscrews before removing the oil seal.

Remove the 12 capscrews and clamping ring (1).

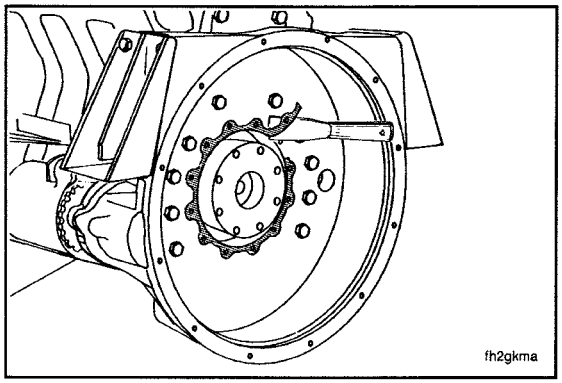
Use a heal bar to remove the oil seal (3) and dust seal (2) together.

Remove the gasket (4).



Clean (001-024-006)

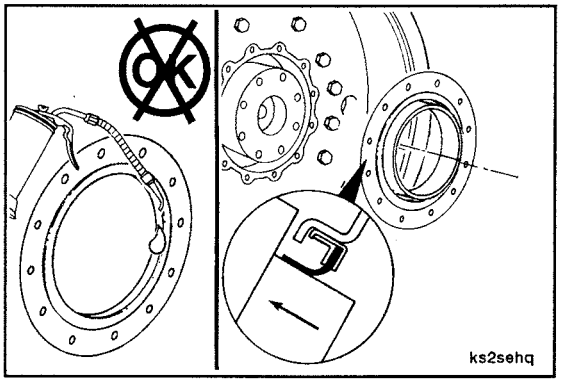
Clean the gasket surface of the flywheel housing.



Install (001-024-026)

Do **not** use any kind of lubricant to install the seal. The oil seal **must** be installed with the lip of the seal and the crankshaft clean and dry.

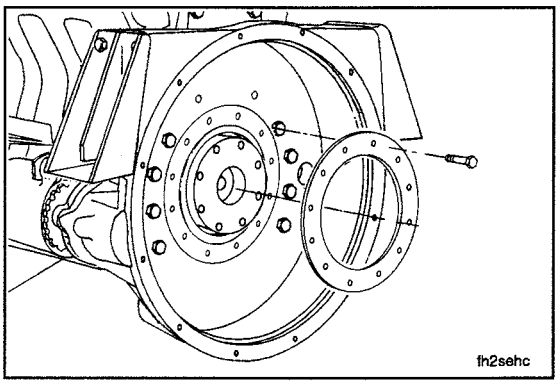
Use the installation sleeve provided with the new seal to install the seal on the crankshaft.

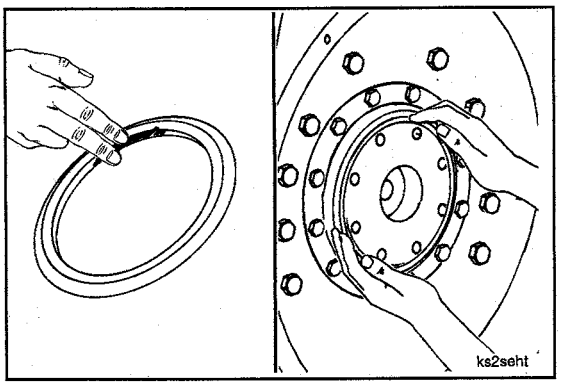


Install the clamping ring using the 12 capscrews (M8-1.25 x 20).

Tighten the capscrews in a star pattern in two steps.

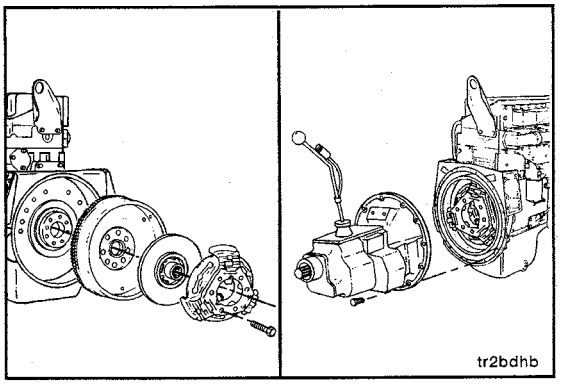
Torque Value: Step 1 7 N•m [60 in-lb]
2 20 N•m [180 in-lb]





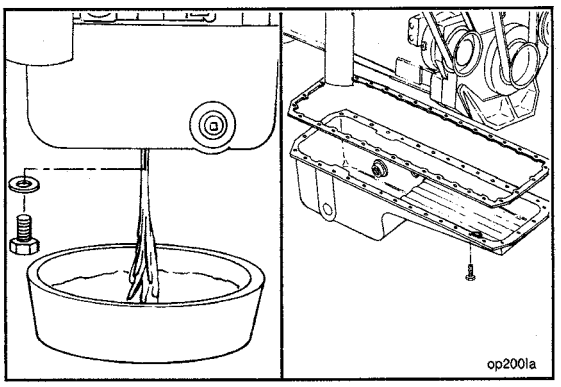
Place a light film of oil or antifreeze on the inside diameter of the dust seal.

Install the dust seal on the crankshaft with the larger outside diameter facing toward the engine. Push the dust seal back by hand on the crankshaft until the entire dust seal contacts the oil seal case.



Install the flywheel and clutch, if equipped. Refer to Procedure 016-005.

Install the transmission, and connect the driveline. Refer to the manufacturer's instructions.

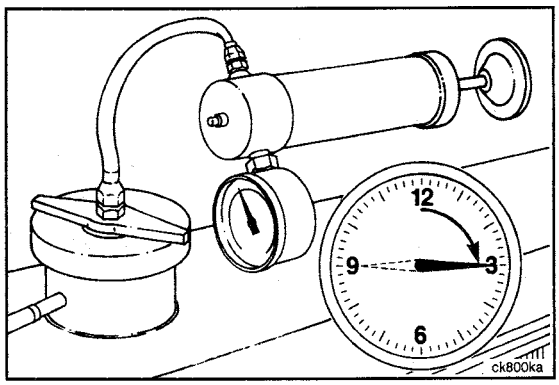


Cylinder Block and Liner Seats (001-027)

Leak Test (001-027-014)

Drain the engine lubricating oil. Refer to Procedure 007-025.

Remove the lubricating oil pan. Refer to Procedure 007-025.



Pressurize the engine cooling system. Refer to Procedure 008-018.

NOTE: Apply the air pressure 15 minutes before inspecting the cylinder liner seats. Be sure the system is holding air pressure before beginning inspection.

Air Pressure: 138 kPa [20 psi]

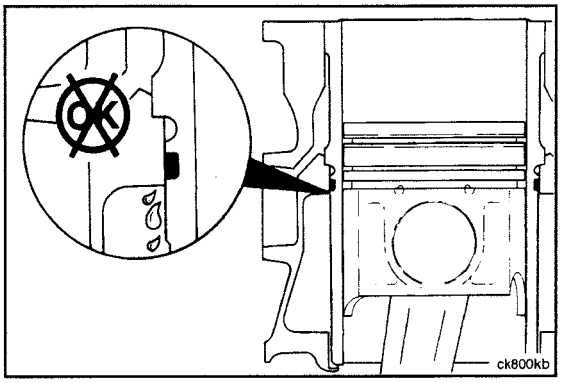
Inspect the outside diameter of the cylinder liners and the area below the cylinder liner seats in the cylinder block for coolant leaks.

If a leak is found:

- Remove the cylinder liner(s). Inspect the sealing ring and cylinder liner. Refer to Procedure 001-028.

If a leak is found in the cylinder liner seat:

- Remove the cylinder liners. Refer to Procedure 001-028. Inspect the cylinder block liner counterbore area. Refer to the M11 Shop Manual, Bulletin No. 3666075. If fretting or wear is found, the cylinder block liner counterbore can be repaired. Refer to the L10 and M11 Alternative Repair Manual, Bulletin No. 3810310.

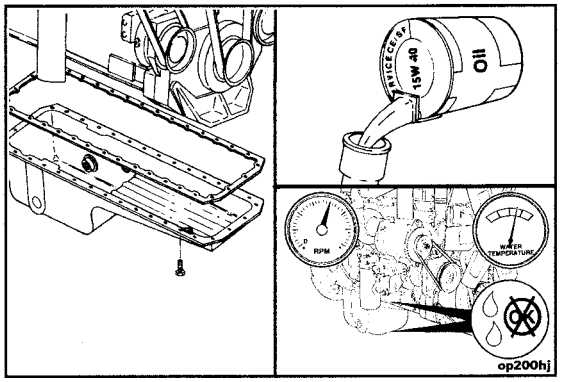


Install a new gasket and the lubricating oil pan. Refer to Procedure 007-025. Tighten the oil pan drain plug.

Torque Value: 88 N•m [65 ft-lb]

Fill the engine with clean 15W-40 oil. Refer to Procedure 007-025.

Operate engine until it reaches a temperature of 80°C [180°F] and check for coolant or lubricating oil leaks.



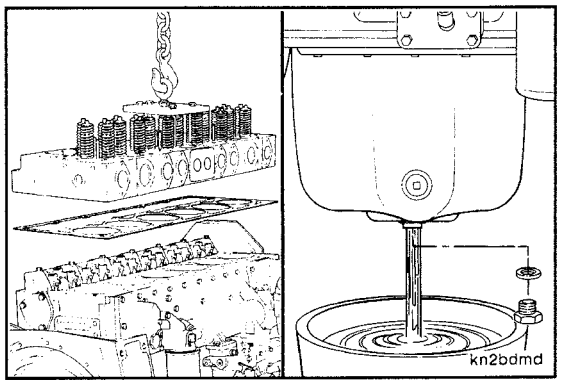
Cylinder Liner (001-028)

Remove (001-028-002)

NOTE: Cummins Engine Company, Inc. does **not** recommend removing the cylinder liners to repair an oil consumption problem unless the cylinder liners are damaged and **must** be replaced.

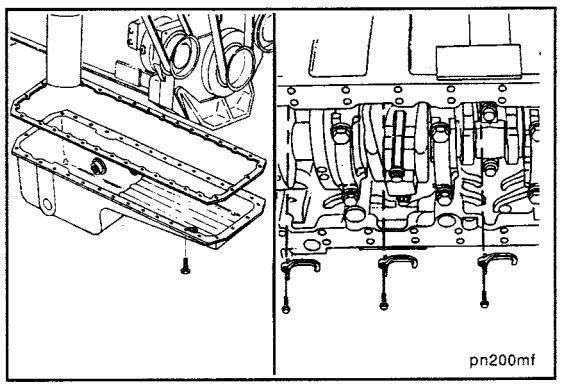
Remove the cylinder head. Refer to Procedure 002-004.

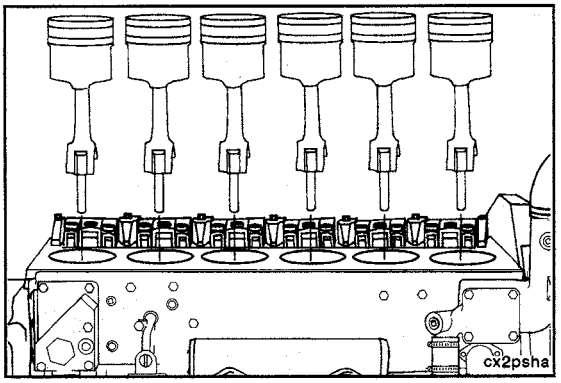
Drain the lubricating oil pan. Refer to Procedure 007-025.



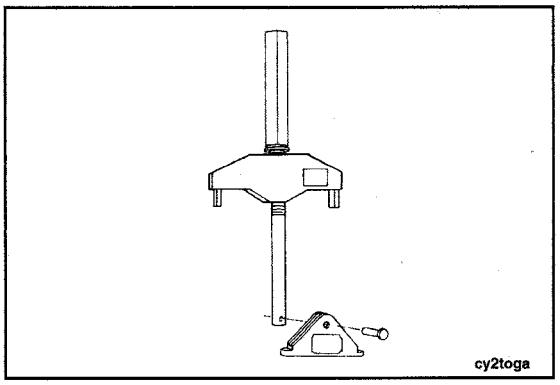
Remove the lubricating oil pan. Refer to Procedure 007-025.

Remove the piston cooling nozzles. Refer to Procedure 001-046.

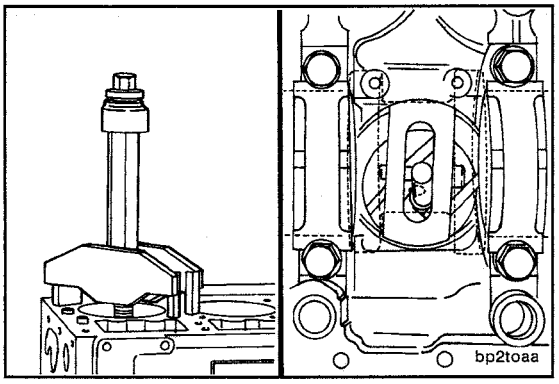




Remove the pistons and connecting rods. Refer to Procedure 001-054.



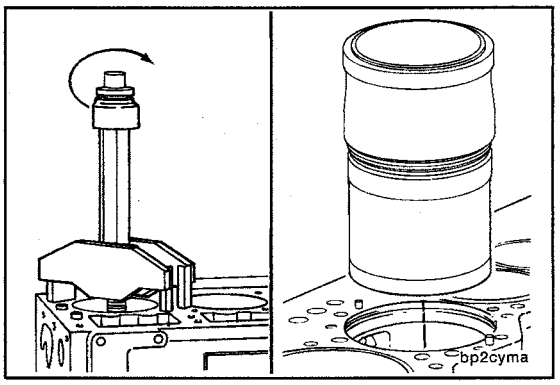
The cylinder liners can be removed by using universal liner puller, Part No. 3375629.



⚠ CAUTION ⚠

The liner puller must be installed and used as described to avoid damage to the cylinder block. The puller plate must be parallel to the main bearing saddles and must not overlap the liner outside diameter.

Insert the liner puller in the top of the cylinder block.

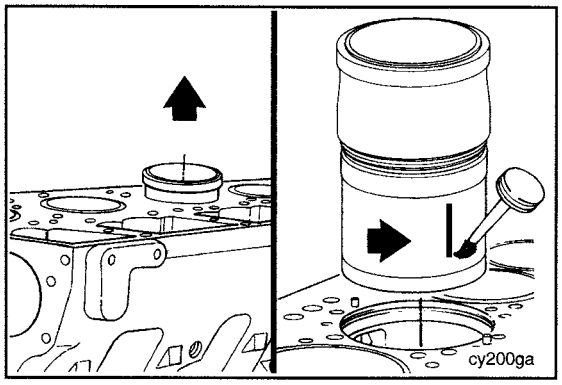


The liner puller **must** be centered on the top of the cylinder block.

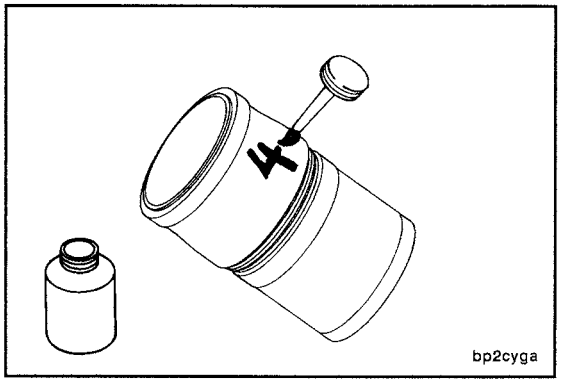
Turn the puller jackscrew **clockwise** to loosen the liner from the cylinder block.

Use both hands to remove the liner.

When the liner is removed from the cylinder block, use Dykem®, or equivalent, to place a mark on the camshaft side of the liner to show liner orientation.



Use Dykem®, or equivalent, to mark the cylinder number on each liner.



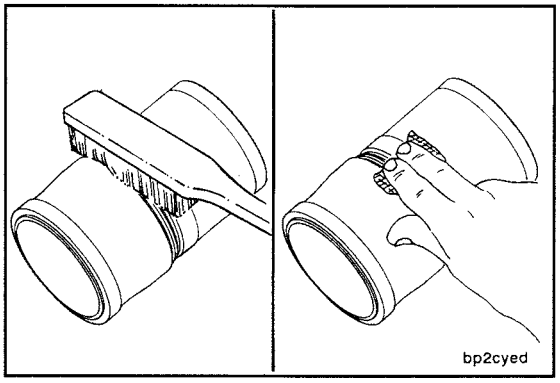
Clean (001-028-006)

⚠ CAUTION ⚠

Do not use any abrasives in the ring travel area of the liner. The liner can be damaged.

Use a soft wire brush to clean the flange seating area.

Use a fine fibrous abrasive pad such as Scotch-Brite™ 7448, Part No. 3823258, or equivalent, to remove the remaining scale and rust.



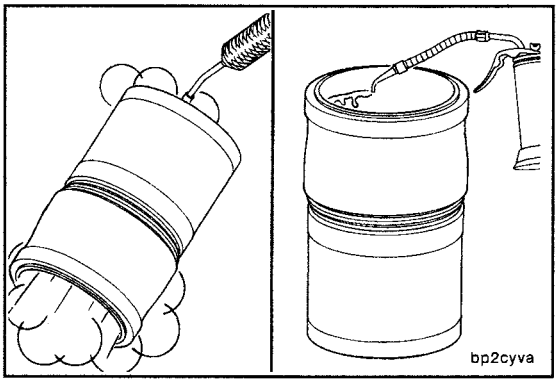
⚠ WARNING ⚠

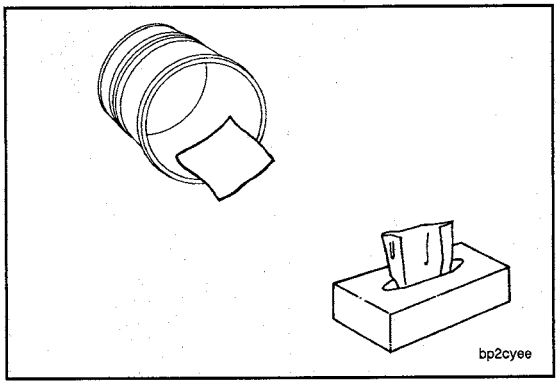
When using a steam cleaner, wear protective clothing, as well as, safety glasses or a face shield. Hot steam will cause serious personal injury.

Use solvent or steam to clean the liners, and dry with compressed air.

Use clean 15W-40 oil to lubricate the inside diameter of the liners.

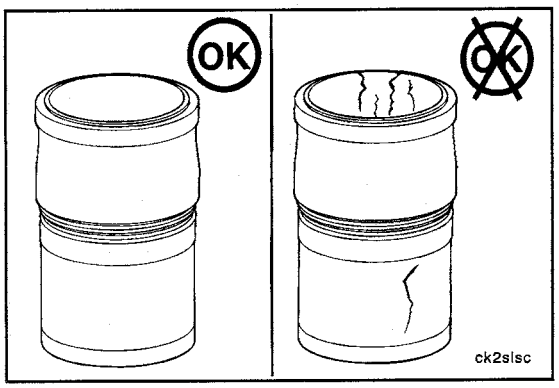
Allow the oil to soak in the liner for 5 to 10 minutes.





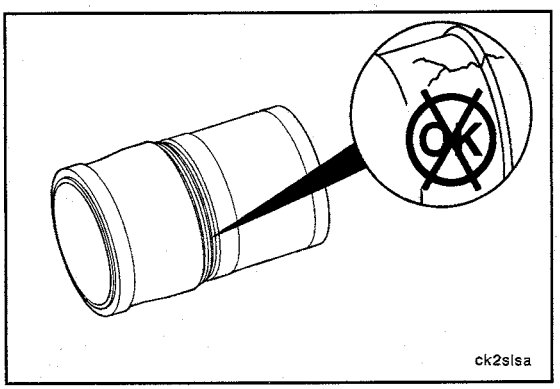
Use lint-free paper towels to wipe the oil from the inside of the liners.

Continue to lubricate the inside of the liners and wipe clean until the paper towel shows no gray or black residue.



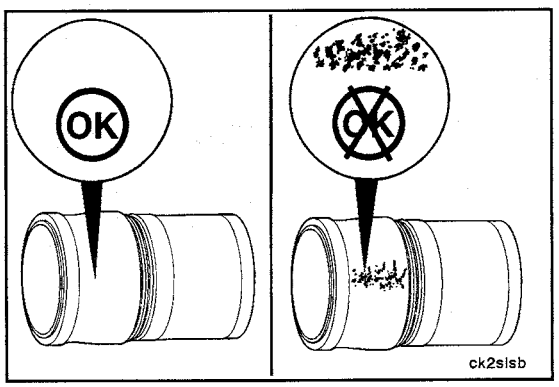
Inspect for Reuse (001-028-007)

Inspect the liners for cracks on the inside and outside diameters.



Inspect for cracks under the liner flange.

NOTE: Cracks can also be detected using either magnetic inspection or the dye method. Refer to M11 Shop Manual, Bulletin No. 3666075.



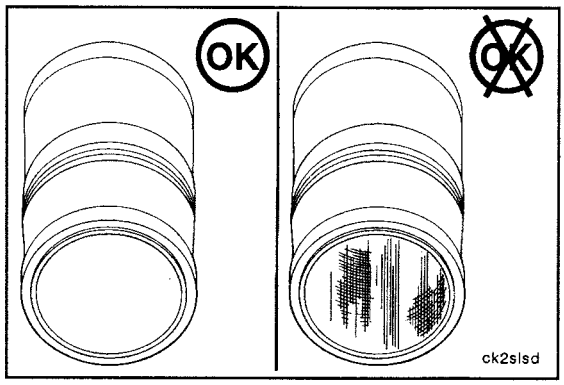
Inspect the outside diameter for excessive corrosion or pitting. Liners with pitting generally can **not** be reused. However, if the pitting is light and can be removed with fine emery cloth, the liner can be reused.

Pits **must not** be more than 1.60-mm [0.060-in] deep.

Inspect the inside diameter for vertical scratches deep enough to be felt with a fingernail.

If a fingernail catches in the scratch, the liner **must** be replaced.

Inspect the inside diameter for scuffing or scoring.

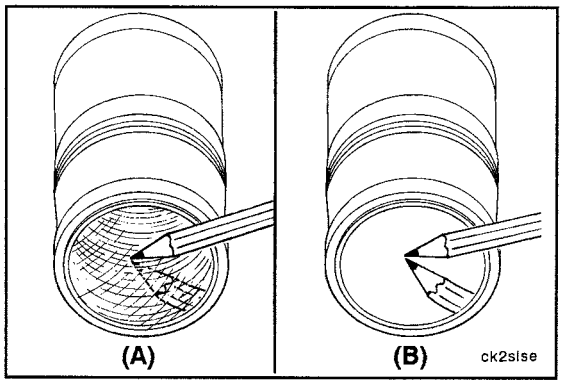


Inspect the inside diameter for liner bore polishing.

NOTE: M Series cylinder liners are **not** lubricated.

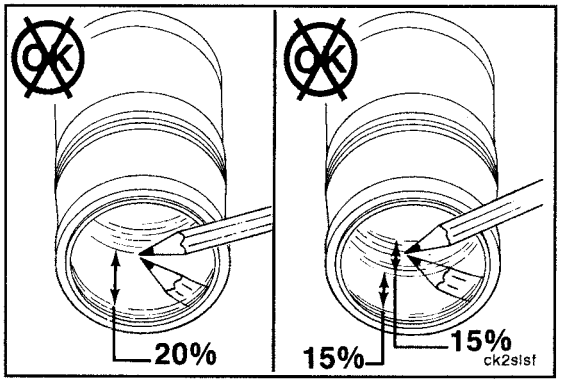
A **moderate polish (A)** produces a bright mirror finish in the worn area with traces of the original hone marks or an indication of an etch pattern.

A **heavy polish (B)** produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.



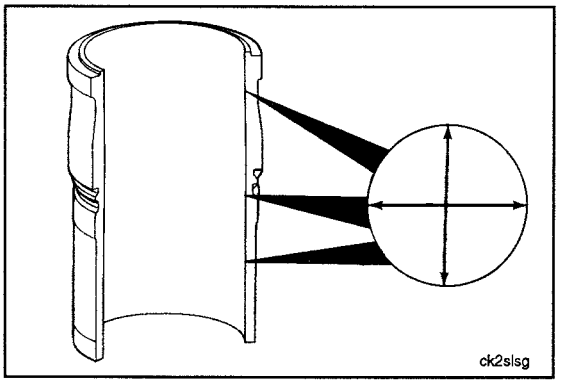
Replace the liner if:

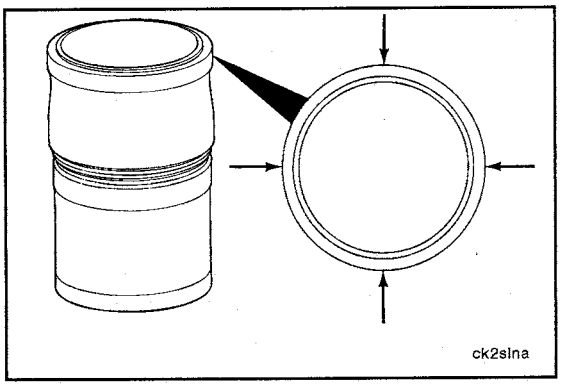
- A heavy polish is present over 20 percent of the piston ring travel area.
- 30 percent of the piston ring travel area has both moderate and heavy polish and one-half (15 percent) is heavy polish.



Use a dial bore gauge to measure the liner's inside diameter in four places 90-degrees apart at the top and bottom of the piston travel area.

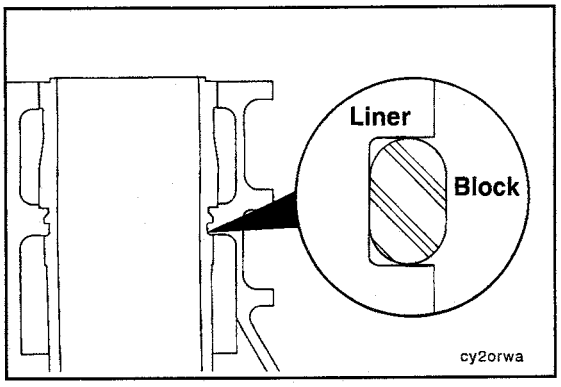
Cylinder Liner I.D.		
mm		in
125.000	MIN	4.9213
125.095	MAX	4.9250





Measure the liner top press fit area outside diameter.

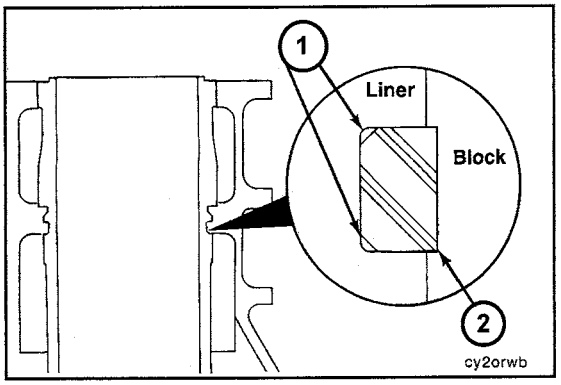
Cylinder Liner Top Press Fit O.D.		
mm		in
145.938	MIN	5.7456
145.976	MAX	5.7471



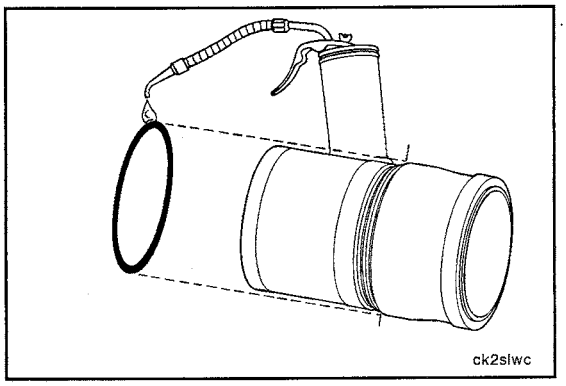
Install (001-028-026)

The current o-ring has been produced by two distinctly different manufacturing processes. Following are those two methods and the installation procedures:

- The molded o-ring has a symmetrical cross section. The edges are rounded. It does **not** require specific care in orientation of the o-ring other than normal prevention of rolling the o-ring.



- The lathe-cut o-ring has a straight outside with sharp corners. The inside has two 45-degree chamfers (1), so there are no sharp corners next to the liner. This o-ring **must** be installed with the straight side (2) facing the block, and the chamfered side next to the liner. If the o-ring is **not** installed this way, liner bore distortion can occur.



Make sure the cylinder block and all parts are clean before assembly.

△ CAUTION △

The liners must be installed within 30 seconds after being lubricated with oil. If the liners are not installed within this time limit, the o-rings will swell and be damaged when the liner is installed.

Use clean 15W-40 oil to coat the liner o-ring seals.

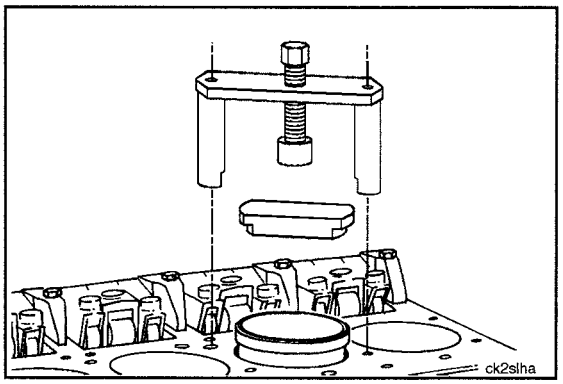
Install the o-ring seal on the liner.

Install the liner into the cylinder block.

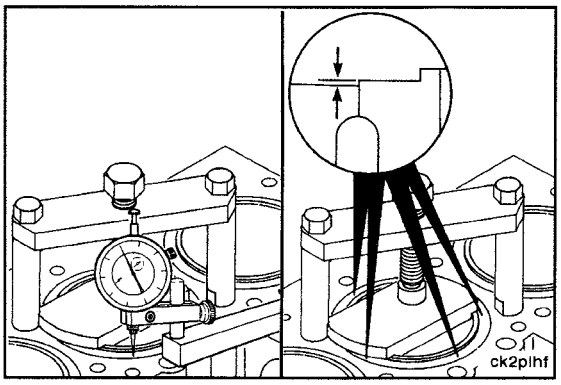
When acceptable reused liners are installed, rotate the liner 90 degrees from their original position in the engine. The thrust and anti-thrust surfaces **must** face the front and back of the cylinder block.

Use cylinder liner driver, Part No. 3824272, and a leather mallet to drive the liner into the cylinder block bore.

If the liner does **not** seat properly, remove the liner. Inspect the counterbore seat and liner for nicks, burrs, or dirt. Install the liner again.

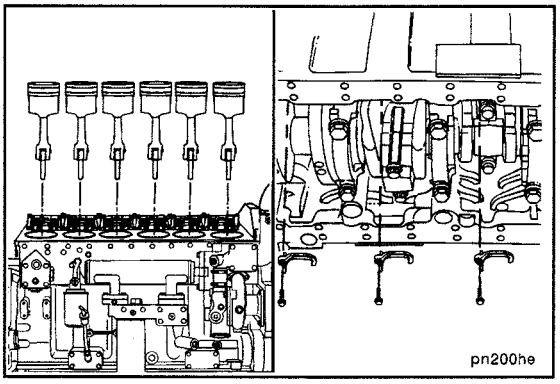


The cylinder liner protrusion **must** be checked before installing the pistons and connecting rods. Refer to Procedure 001-064 for measuring the cylinder liner protrusion.



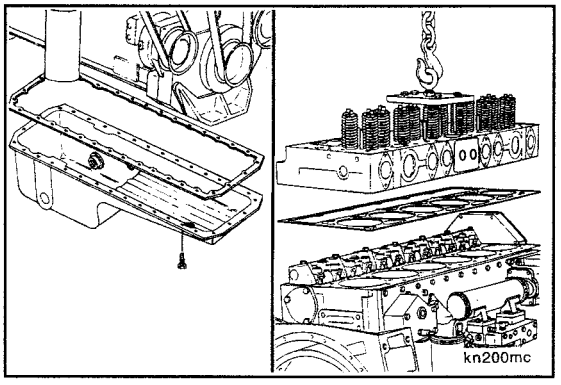
Install the pistons and connecting rods. Refer to Procedure 001-054.

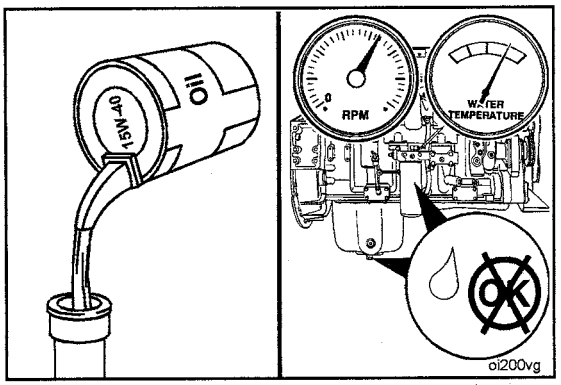
Install the piston cooling nozzles. Refer to Procedure 001-046.



Install the lubricating oil pan. Refer to Procedure 007-025.

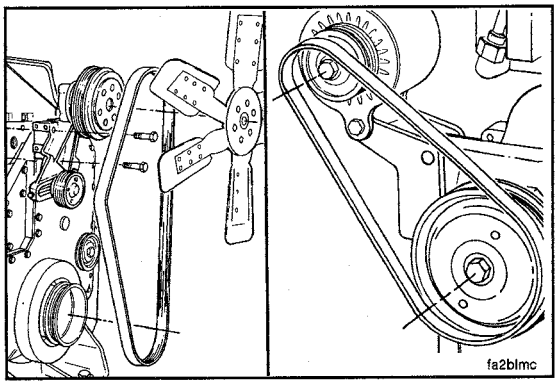
Install the cylinder head. Refer to Procedure 002-004.





Fill the engine with lubricating oil. Refer to Procedure 007-025.

Operate the engine to normal operating temperature and check for leaks.



Gear Cover, Front (001-031)

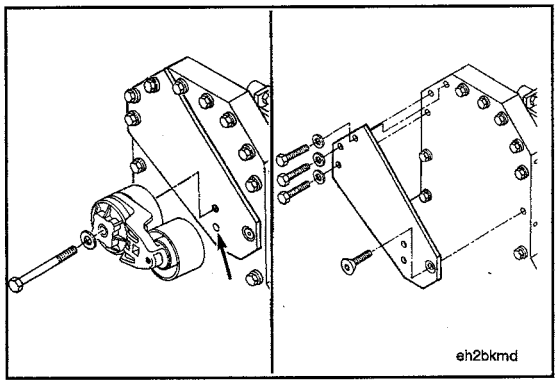
Remove (001-031-002)

Remove the fan drive belt. Refer to Procedure 008-002.

Remove the alternator drive belt. Refer to Procedure 013-005.

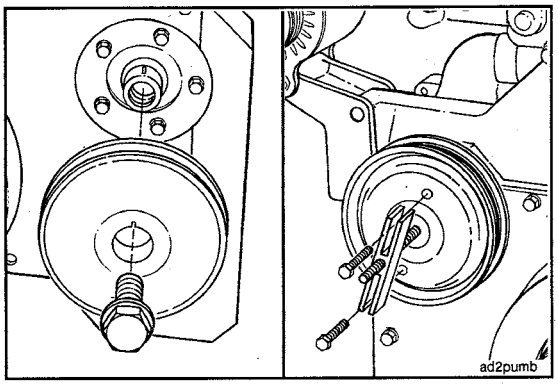
NOTE: If the engine is equipped with an automatic belt tensioner, refer to Procedure 013-021 to remove the alternator belt.

Remove the fan and fan hub support. Refer to Procedure 008-036.



If the engine is equipped with an automatic belt tensioner, remove the belt tensioner arm from the tensioner bracket.

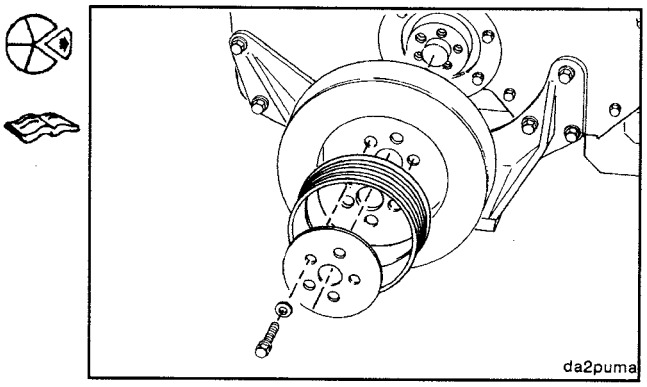
Remove the four mounting capscrews and the tensioner bracket from the gear cover.



Remove the accessory drive pulley. Refer to Procedure 009-004.

Remove the alternator drive pulley. Refer to Procedure 009-010.

Remove the clamping plate, crankshaft pulley, and vibration damper. Refer to Procedure 001-052.

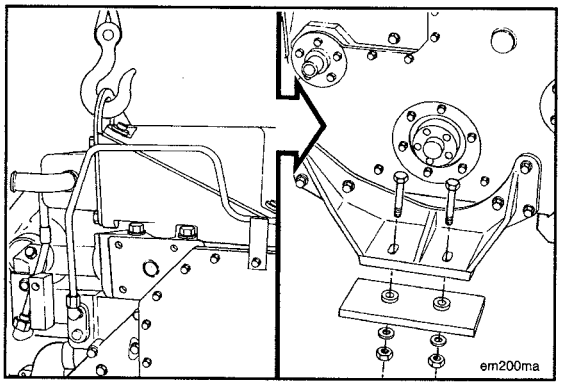


⚠ WARNING ⚠

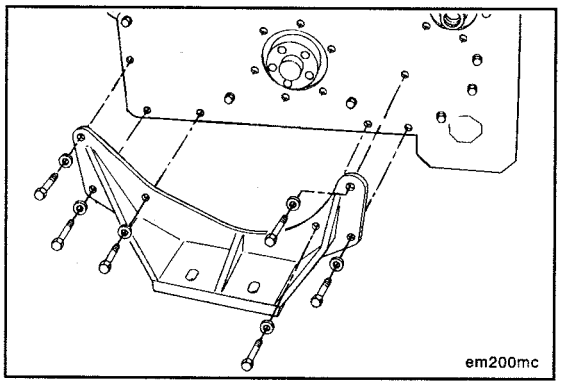
The lifting equipment must be designed to support the engine safely while the front engine support is removed from the engine. Failure to do so will result in equipment damage or personal injury.

Use an overhead hoist or hydraulic arm to support the engine.

Remove the capscrews that hold the front engine support to the cross member of the equipment.

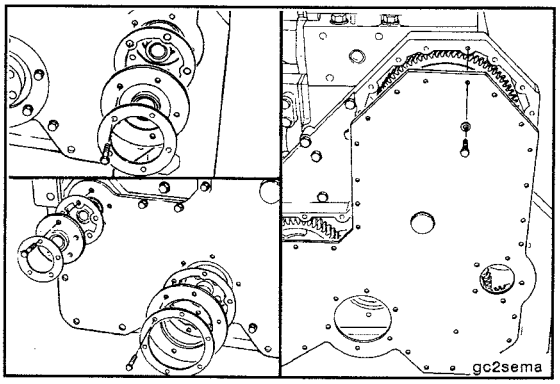


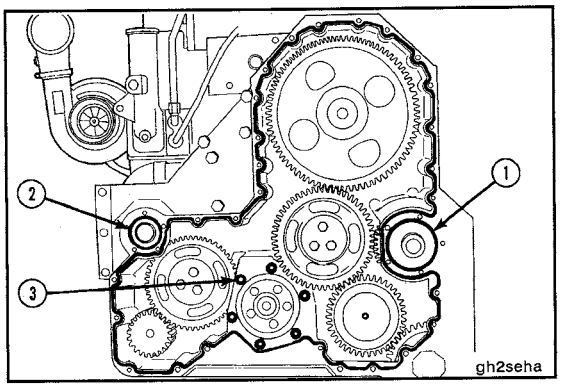
Remove the capscrews and the front engine support.



Remove the oil seals from the gear cover. Refer to Procedures 001-001, 001-003, and 001-023.

Remove the remaining capscrews and the gear cover.

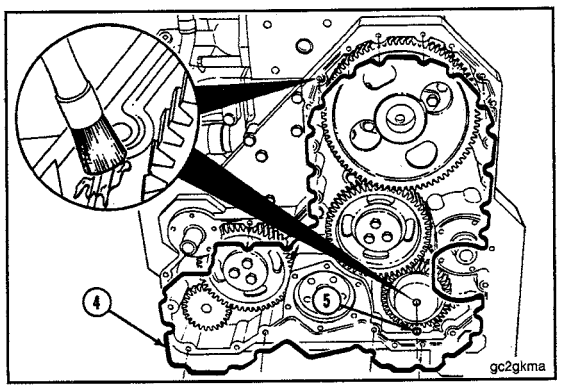




Clean (001-031-006)

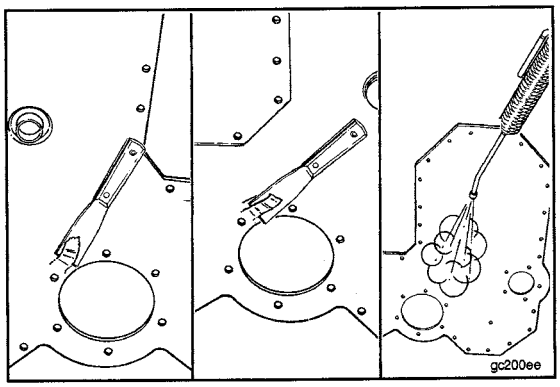
Remove the seal rings at the accessory drive mounting (1) and the water pump mounting (2), and clean the grooves.

Remove the six o-ring seals at the crankshaft seal mounting (3), and clean the grooves.



Remove the seal (4) from the front of the gear housing, and clean the groove.

Remove the o-ring at the front of the hydraulic drive idler retainer, and clean the groove.



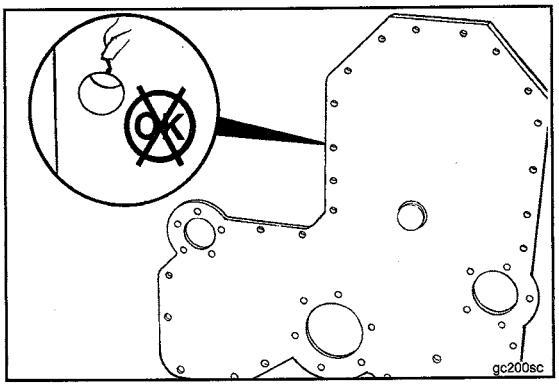
⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

Clean the sealing surface on the rear face of the gear cover.

Clean the oil seal carrier gasket surfaces.

Use steam or solvent to clean the gear cover. Dry with compressed air.

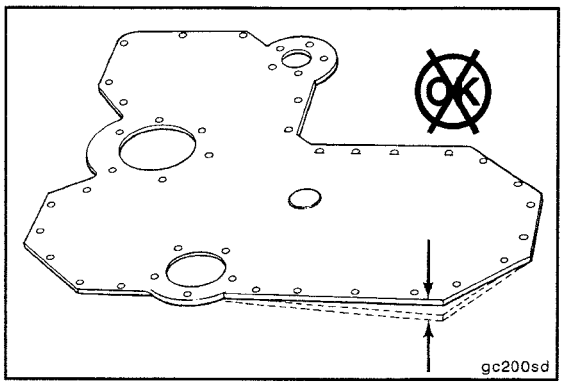


Inspect for Reuse (001-031-007)

Inspect the gear cover for cracks or damage.

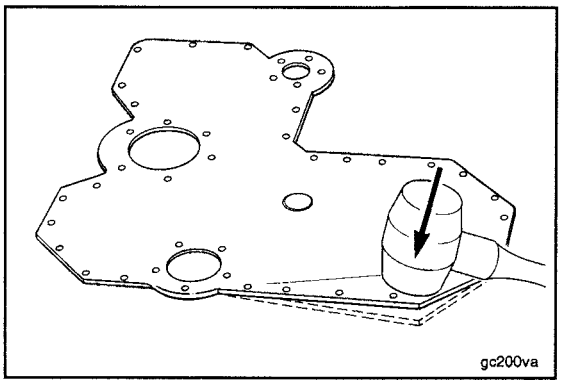
If the cover is cracked, it **must** be replaced.

Put the gear cover on a flat surface, and inspect the gear cover for flatness.



It is an acceptable practice to use a mallet to straighten a gear cover with minor bends.

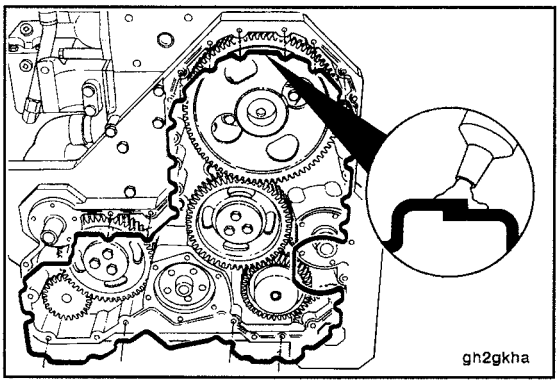
Lay the gear cover on a flat surface, and hit the cover in the bent area.



Install (001-031-026)

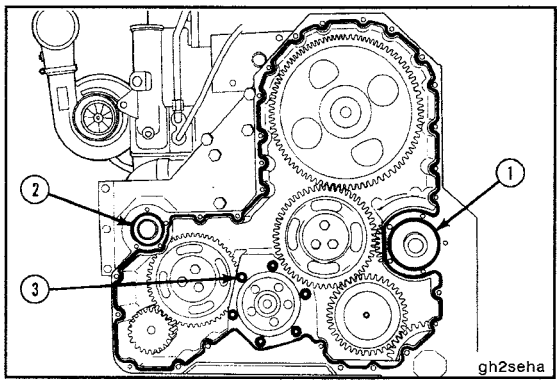
Insert a new seal into the groove on the front of the gear housing.

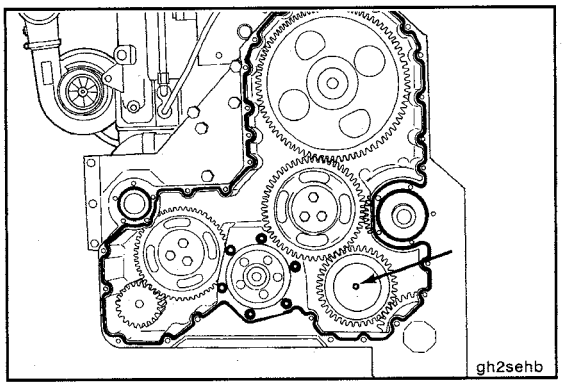
Apply silicone sealant, Part No. 3823494, to the seal overlap joint at the top of the gear housing.



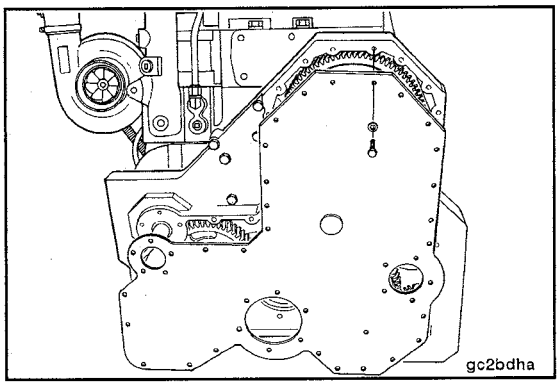
Install a new seal ring at the accessory drive mounting (1) and water pump mounting (2) locations.

Install six new capscrew o-rings at the crankshaft seal mounting capscrew locations (3).





Install a new o-ring at the front of the hydraulic drive idler retainer mounting spacer. Make sure the spacer is in place.



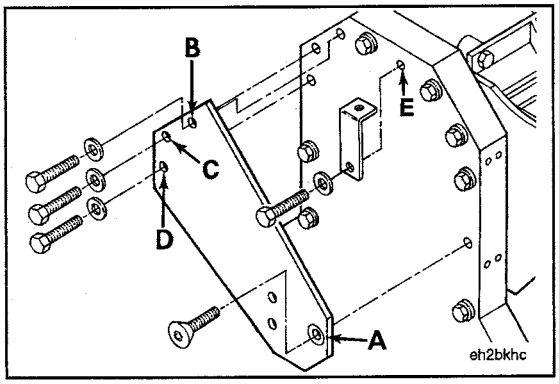
Install the gear cover and mounting capscrews.

NOTE: Do **not** install the front engine support capscrews at this time.

Tighten the capscrews.

Torque Value: 6 N•m [55 in-lb]

NOTE: This is **not** the final torque value.

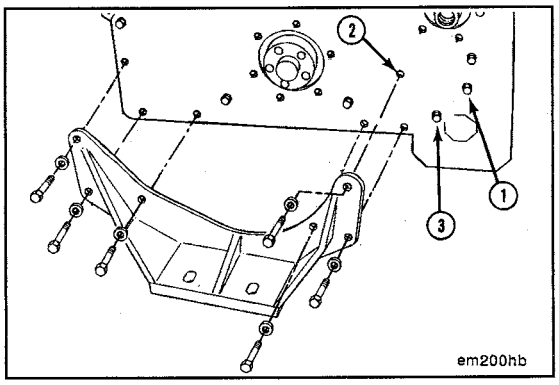


If the engine is equipped with an automatic belt tensioner, install the belt tensioner bracket with the countersunk hole (A) facing away from the gear cover. Use a flat head (M8 x 25) at location (A).

Use three capscrews (M8 x 30) and plain washers at (B, C, and D). Tighten the capscrews.

Torque Value: 6 N•m [55 in-lb]

NOTE: This is **not** the final torque value.



Apply a coating of thread sealant, Part No. 3823494, to the three capscrews at locations (1, 2, and 3).

Install and tighten all the front engine support and mounting capscrews to the following torque:

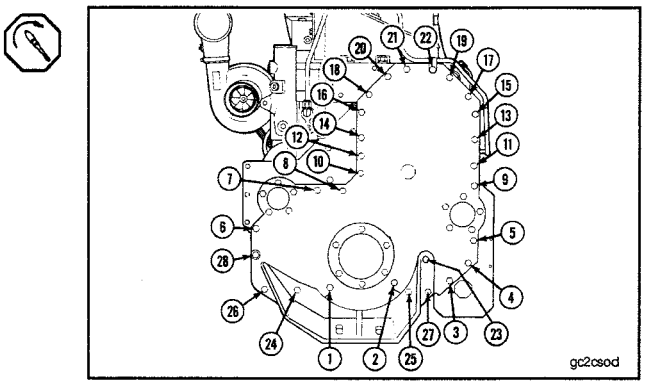
Torque Value: 6 N•m [55 in-lb]

NOTE: This is **not** the final torque value.

Tighten the gear cover capscrews in the sequence shown.

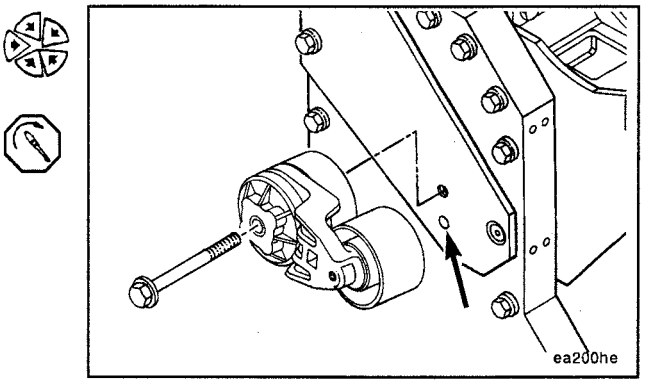
Torque Value:

Capscrews 1 through 22:	20 N•m	[15 ft-lb]
Capscrews 23 through 28:	68 N•m	[50 ft-lb]



Install the automatic belt tensioner with a (M10-1.50 x 70) capscrew. Align the cast locator pin on the tensioner with the hole in the bracket before tightening.

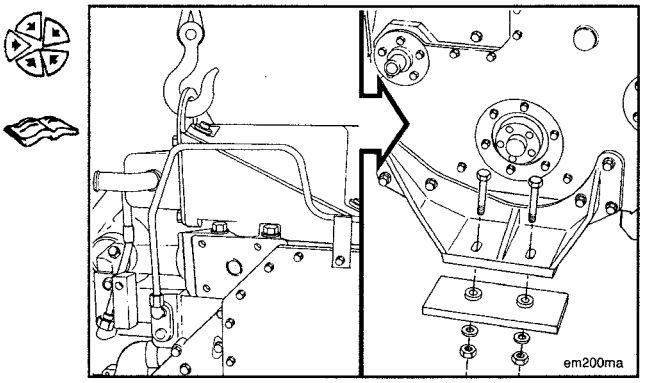
Torque Value: 43 N•m [32 ft-lb]



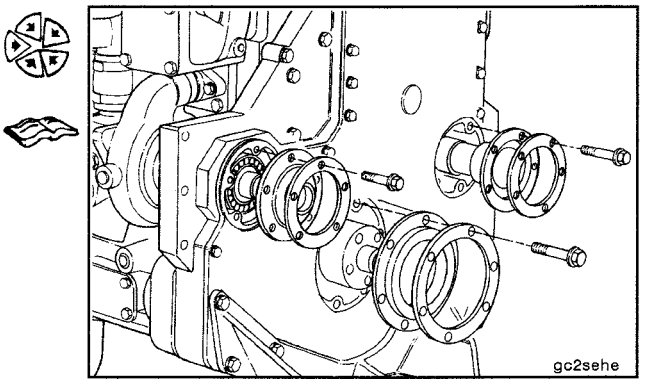
Lower the engine onto the crossmember.

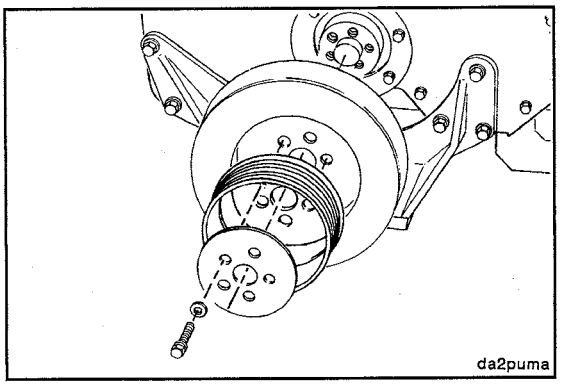
Install the front support to crossmember.

Install the capscrews and tighten. Refer to the manufacturer's specifications for the correct torque value.

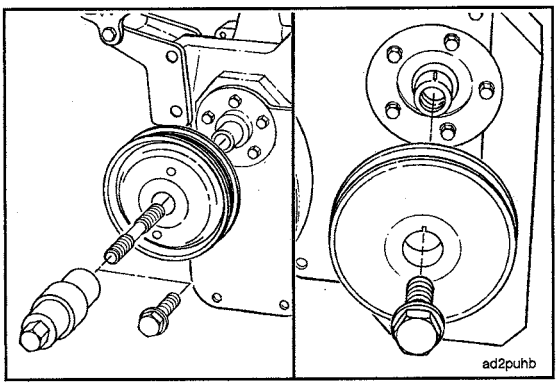


Install the gear cover oil seals. Refer to Procedures 001-001, 001-003, and 001-023.



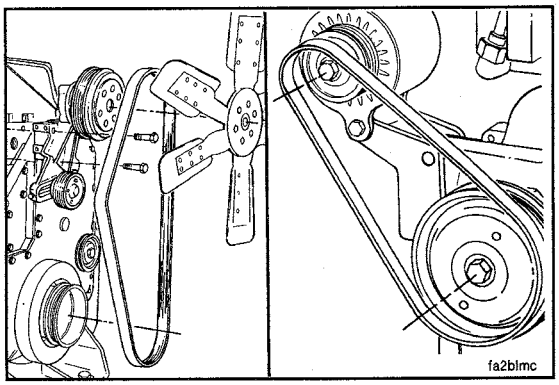


Install the vibration damper, crankshaft pulley, and clamping plate. Refer to Procedure 001-052.



Install the alternator drive pulley. Refer to Procedure 009-010.

Install the accessory drive pulley. Refer to Procedure 009-004.

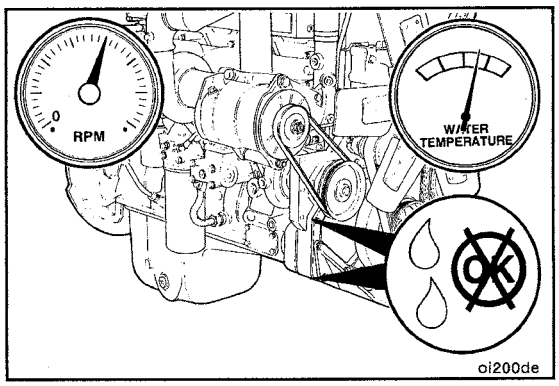


Install the fan hub support and fan. Refer to Procedure 008-036.

Install and adjust the fan drive belt. Refer to Procedure 008-002.

Install and adjust the alternator drive belt. Refer to Procedure 013-005.

NOTE: If the engine is equipped with an automatic belt tensioner, refer to Procedure 013-021 to install the alternator belt.

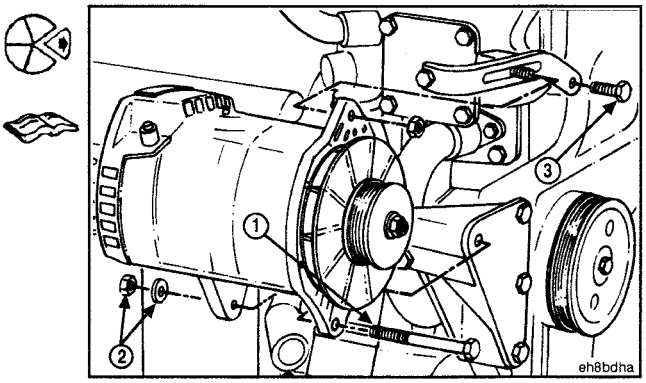


Operate the engine to normal operating temperature and check for leaks.

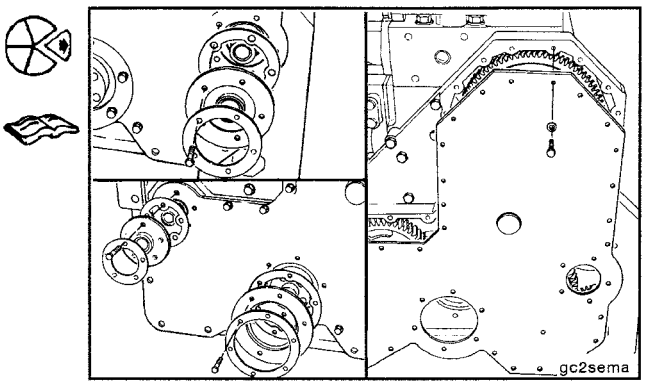
Gear Housing, Front (001-033)

Remove (001-033-002)

Remove the alternator and alternator bracket. Refer to Procedure 013-001.

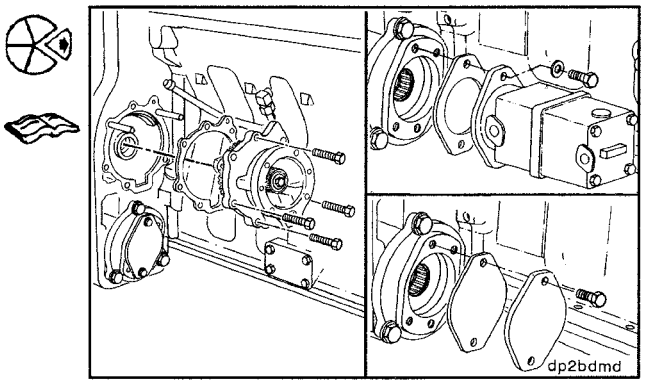


Remove the gear cover. Refer to Procedure 001-031.

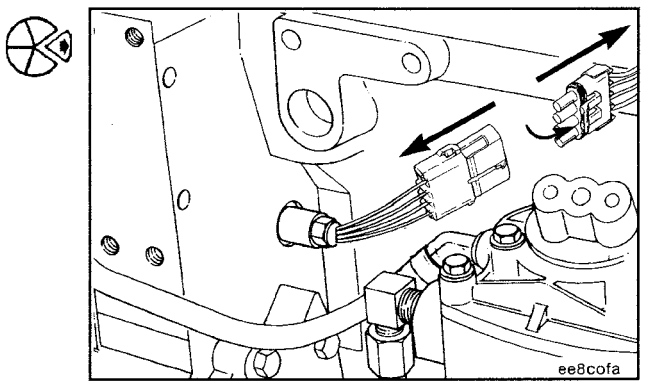


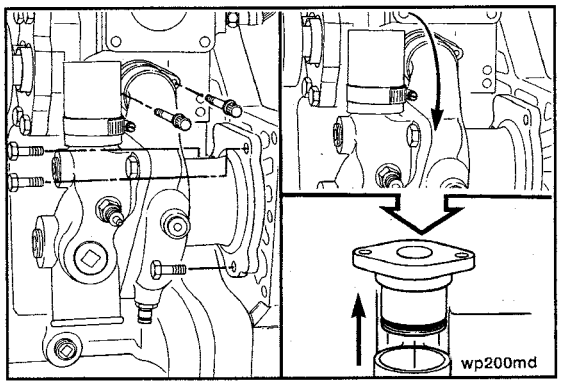
Remove the accessory drive. Refer to Procedure 009-001.

Remove the hydraulic pump, if equipped. Refer to Procedure 009-016.

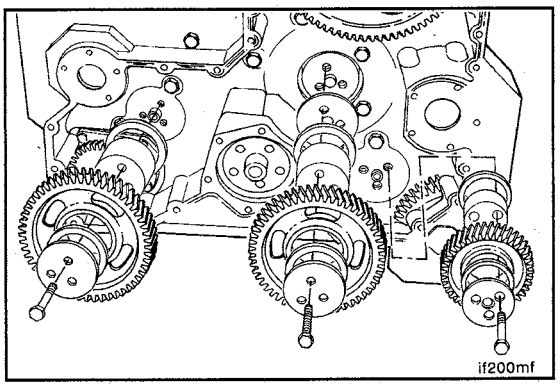


Disconnect the engine position wire connector, and remove the engine position sensor from the backside of the housing.

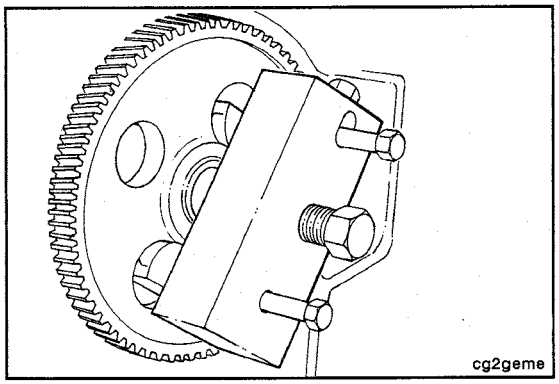




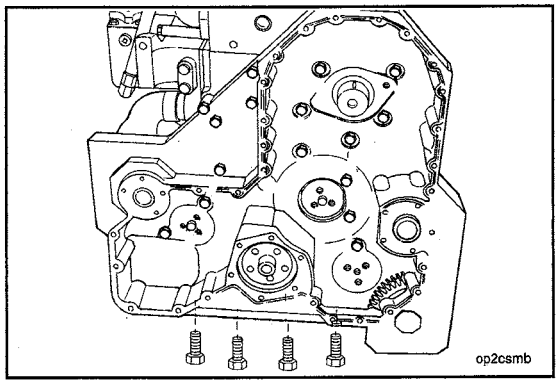
Remove the water pump. Refer to Procedure 008-062.



Remove the idler gears. Refer to Procedures 001-036, 001-039, and 001-040.



Remove the camshaft gear or the camshaft and gear assembly. Refer to Procedure 001-012 or 001-008, respectively.

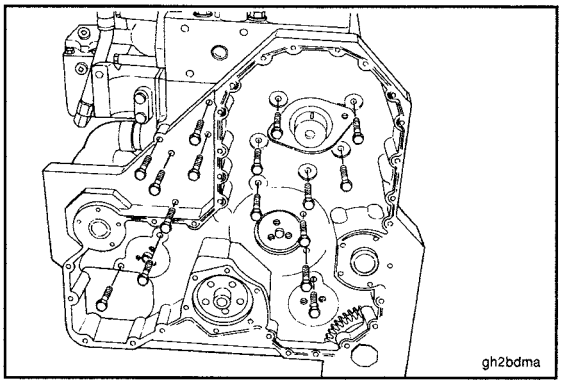


Remove the four oil pan-to-gear housing capscrews.

Remove the capscrews that secure the gear housing to the cylinder block.

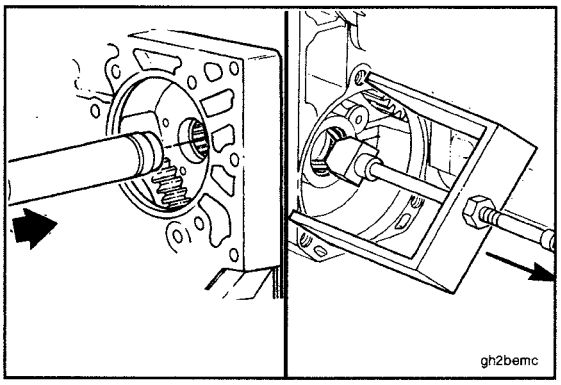
NOTE: Be careful **not** to damage the oil pan gasket when removing the gear housing. If the gasket is damaged, the oil pan **must** be removed and the gasket replaced.

Remove the gear housing from the cylinder block.



Use bearing driver kit, Part No. 3824117, to remove the water pump drive needle bearing.

Use bearing puller kit, Part No. 3823774, to remove the hydraulic drive needle bearing.

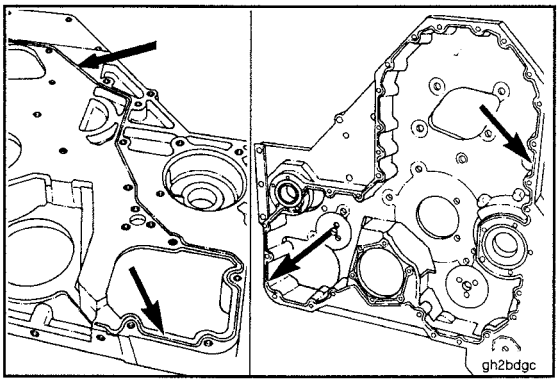


Clean (001-033-006)

Remove the RTV sealant from the rear surface of the gear housing.

Remove the seal in the grooves on the front surface of the gear housing.

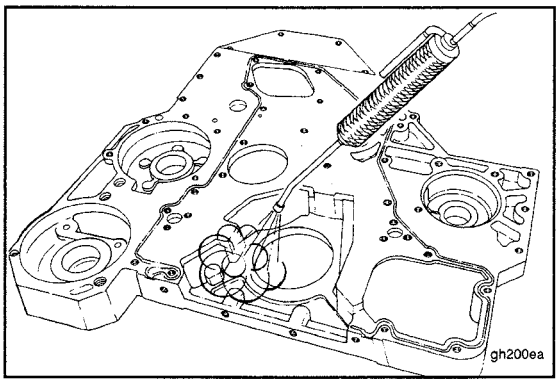
Use a wire brush, rounded blade or screwdriver, to clean the grooves on both sides.

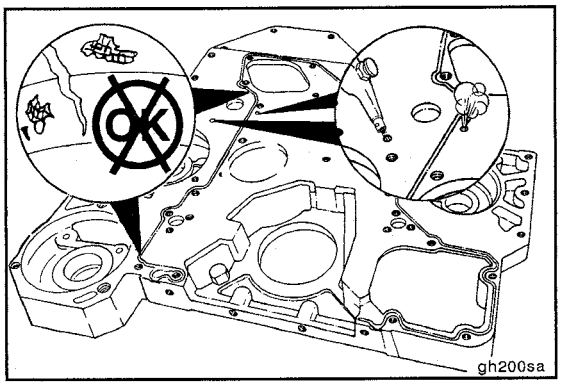


⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

Use steam or solvent to clean the gear housing and dry with compressed air.





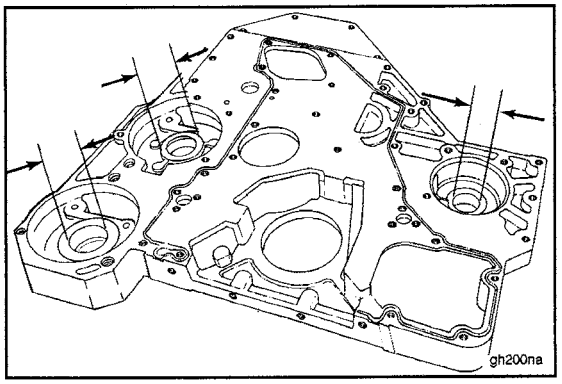
Inspect for Reuse (001-033-007)

Inspect the gear housing for cracks or other damage.

Inspect the seal grooves on both sides of the housing for debris or damage.

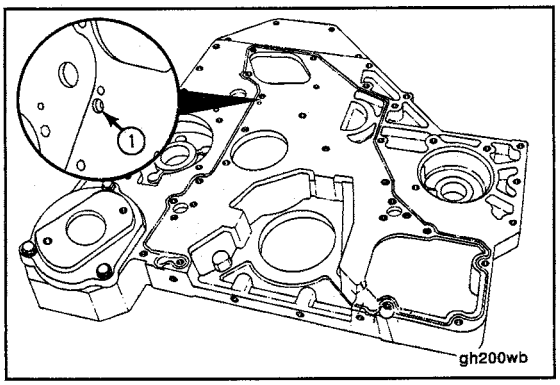
Inspect the o-ring groove at the accessory drive oil jumper gallery for cracks or damage.

Use compressed air to make sure the oil jumper gallery to the accessory drive is free of any obstructions.



Measure the inside diameter of the bearing bores at the accessory drive, water pump drive, and hydraulic drive.

Gear Housing Bearing Bore I.D.			
	mm		in
Hydraulic Drive	41.967	MIN	1.6522
	41.992	MAX	1.6532
Water Pump	36.967	MIN	1.4553
	36.992	MAX	1.4564
Accessory Drive	45.100	MIN	1.7756
	45.125	MAX	1.7766



Install (001-033-026)

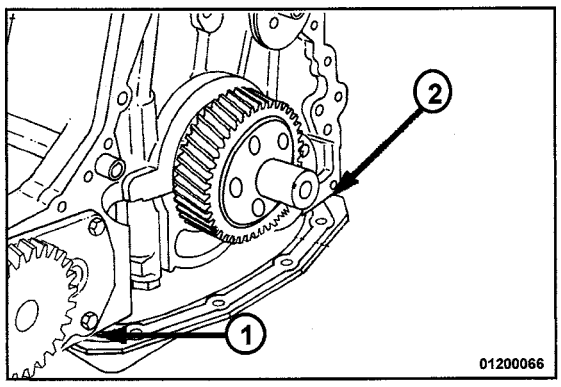
△ CAUTION △

Avoid the use of excessive amounts of sealant, which could result in blocked oil passages in the engine.

Install a new o-ring, Part No. 3883150, into the rear of the gear housing at the oil jumper gallery (1) for the accessory drive support. Be sure to keep sealant from the hole.

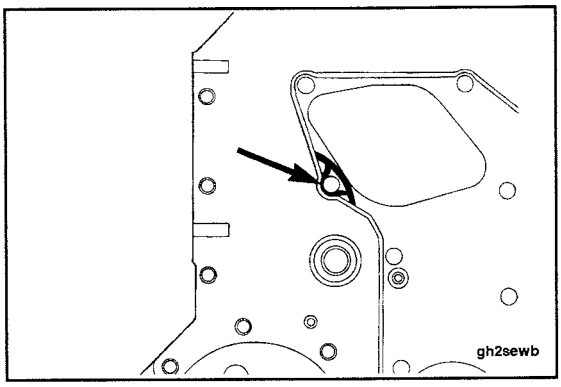
NOTE: Sealant requires assembly in 10 minutes or less. It is best to apply the sealant and then immediately assemble the parts.

Apply a bead of sealant, Part No. 3823494, to the groove in the rear of the gear housing. Completely fill the groove so that approximately 1/16 to 1/8 inch of the bead is raised above the block mounting surface of the gear housing.



Apply a 2-mm [1/6-in] bead of sealant, Part No. 3823494, to the oil pan and cylinder block gear housing joint.

Apply additional sealant in the area by the camshaft opening as shown in the graphic.



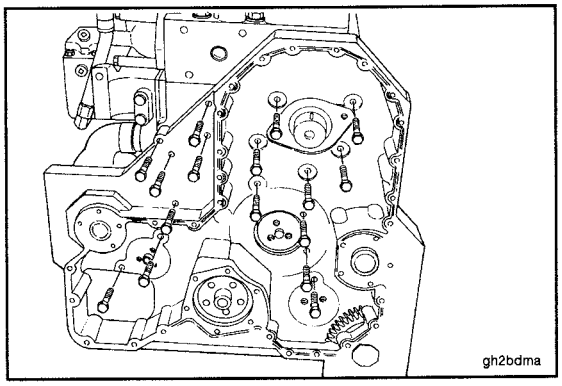
Install two guide pins, Part No. 3376488, in the gear housing end of the cylinder block.

NOTE: Use care **not** to damage the oil pan gasket while installing the gear housing.

Install the gear housing and ten capscrews (M10-1.50 x 25) in the inner part of the gear housing.

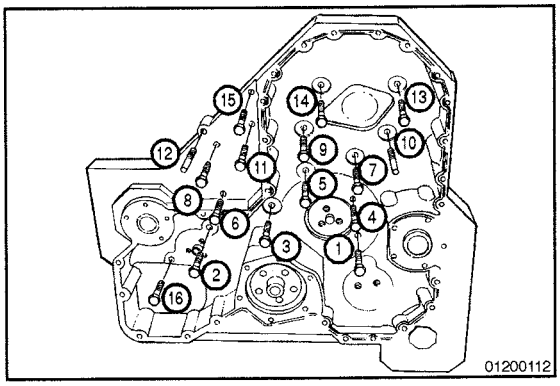
Install five capscrews (M10-1.50 x 50) on the outer surface of the housing.

Remove the guide pins, and install the two remaining capscrews (M10-1.50 x 25).



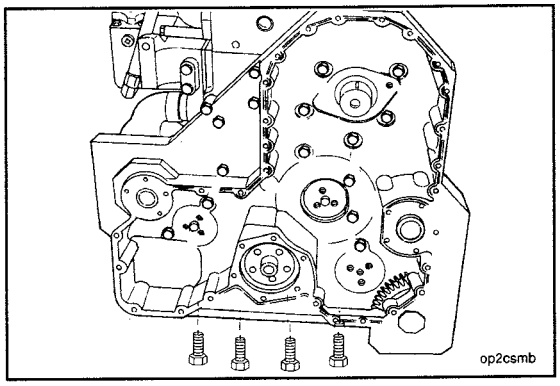
Tighten the capscrews in the sequence shown.

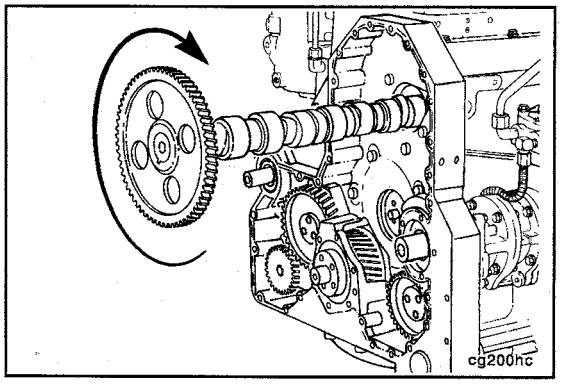
Torque Value: Step 1 20 N•m [15 ft-lb]
2 68 N•m [50 ft-lb]



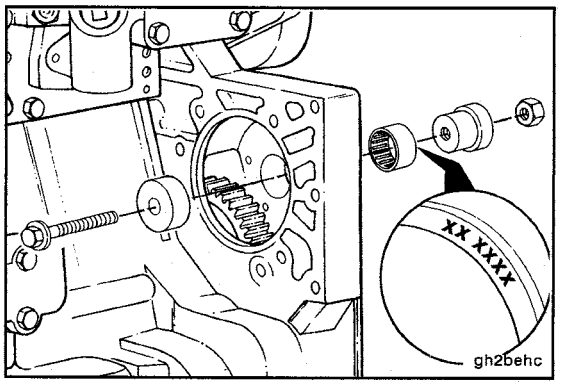
Install the four oil pan to gear housing capscrews.

Torque Value: 47 N•m [35 ft-lb]





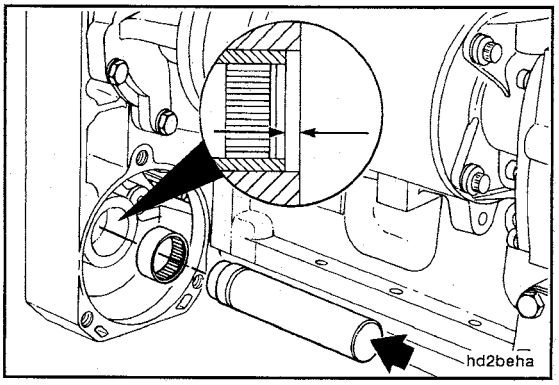
Install the camshaft gear, or camshaft and gear assembly. Refer to Procedure 001-012 or 001-008, respectively.



Use bearing driver kit, Part No. 3824117, to install a new needle bearing in the water pump drive bore of the gear housing.

NOTE: The bearing **must** be installed with the part number side of the bearing against the installation tool to prevent damage to the bearing during the installation.

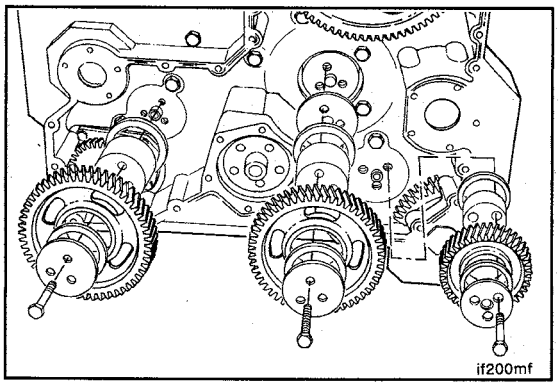
Install the bearing from the front side of the gear housing until the bearing is flush with the front edge of the housing bore.



Use bearing installation tool, Part No. 3823776, included in bearing puller kit, Part No. 3823774, to install a new needle bearing in the hydraulic drive bore of the gear housing.

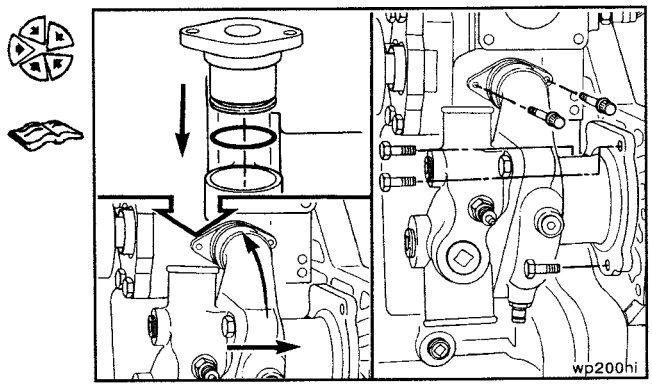
Tap the bearing gently until it comes in contact with the shoulder in the housing.

The bearing **must** be 0.25 to 0.76 mm [0.010 to 0.030 in] past the outside edge of the gear housing bore surface.



Install the idler gears. Refer to Procedures 001-036, 001-039, and 001-040.

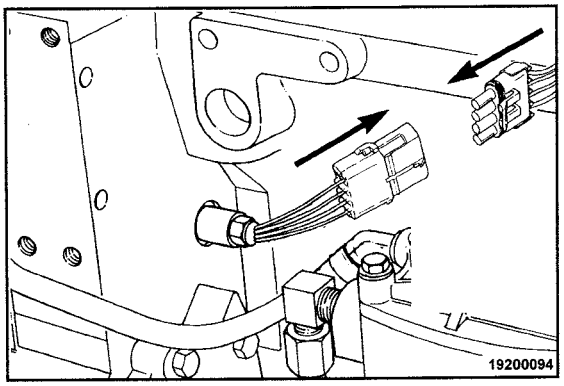
Install the water pump. Refer to Procedure 008-062.



Install the engine position sensor in the backside of the gear housing.

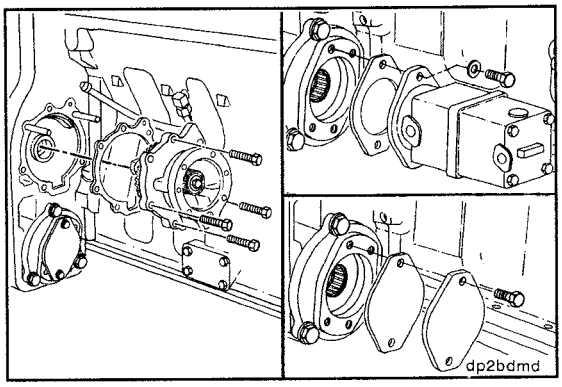
Torque Value: 34 N•m [25 ft-lb]

Connect the sensor to the engine wiring harness.



Install the accessory drive. Refer to Procedure 009-001.

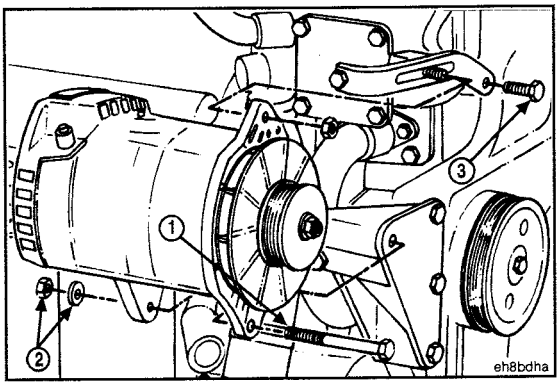
Install the hydraulic drive, if equipped. Refer to Procedure 009-016.

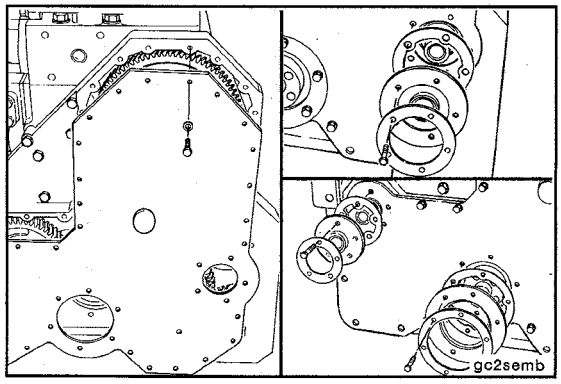


Install the alternator bracket with two M10-1.50 x 30 capscrews.

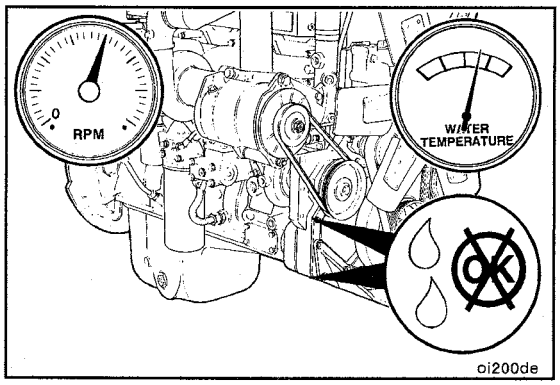
Torque Value: 47 N•m [35 ft-lb]

Install the alternator. Refer to Procedure 013-001.

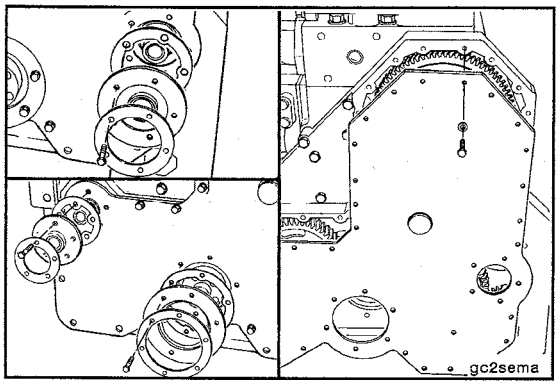




Install the gear cover. Refer to Procedure 001-031.



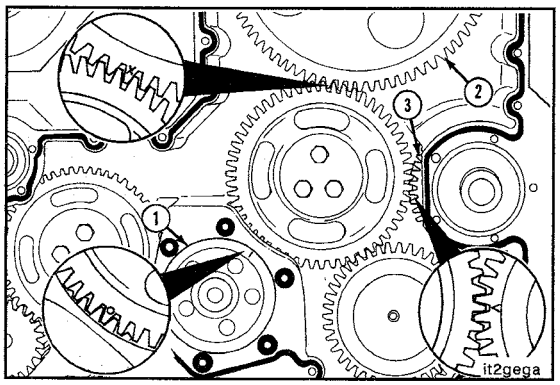
Operate the engine to normal operating temperature and check for leaks.



Idler Gear, Camshaft (001-036)

Remove (001-036-002)

Remove the gear cover. Refer to Procedure 001-031.

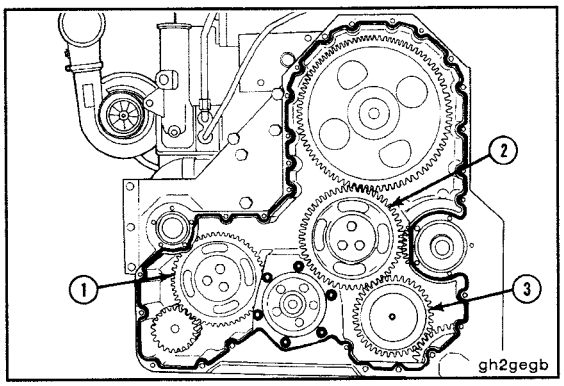


Before removing the idler gear, use the accessory driveshaft to rotate the crankshaft until the timing marks on the crankshaft gear (1), camshaft gear (2), and accessory drive gear (3) are completely engaged in the camshaft idler gear.

NOTE: Due to the camshaft idler gear having more gear teeth than the crankshaft gear, the camshaft idler gear timing marks will **not** align with the crankshaft, camshaft, and accessory drive gears timing marks on every engine revolution.

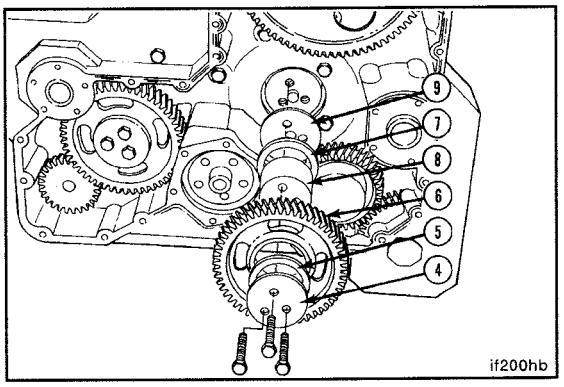
Three idler gear assemblies are used:

- Water pump idler gear (1)
- Camshaft idler gear (2)
- Hydraulic pump idler gear (3).

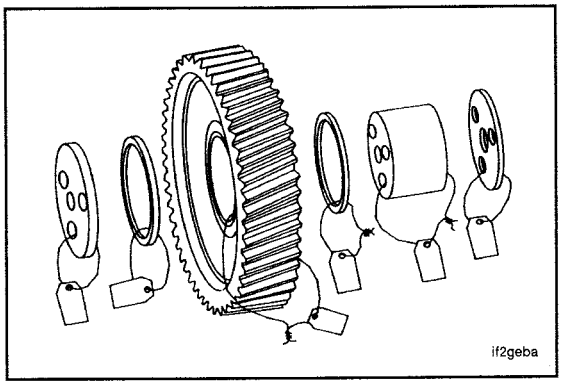


To remove the camshaft idler gear assembly, remove:

- The three capscrews
- Cover plate (4)
- Front thrust bearing (5)
- Idler gear (6)
- Rear thrust bearing (7)
- Idler gear shaft (8)
- Wear plate (9).

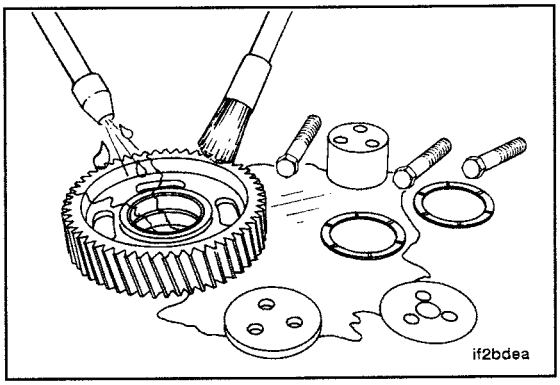


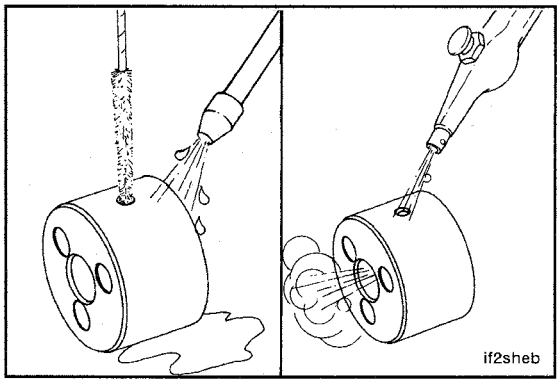
Mark or tag the individual pieces of the idler gear assembly and attach them together.



Clean (001-036-006)

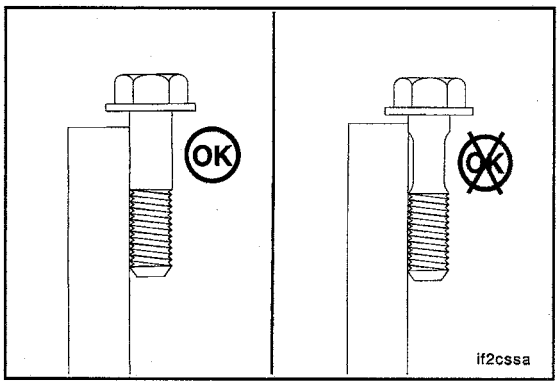
Clean the parts with solvent. Dry with compressed air.





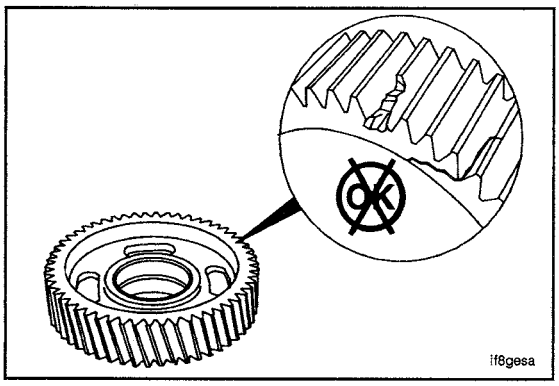
Use a bristle brush to clean the oil drillings in the idler gear shaft.

Blow out the oil drillings with compressed air.

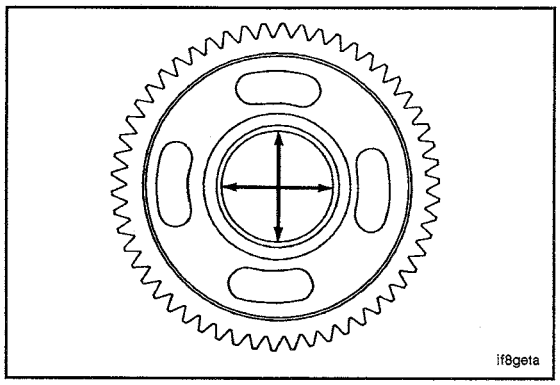


Inspect for Reuse (001-036-007)

Use a straightedge to inspect the retaining capscrews for necking. If necking is observed, do **not** reuse the capscrews. They **must** be replaced.



Inspect the idler gear for chipped, broken, or cracked teeth.

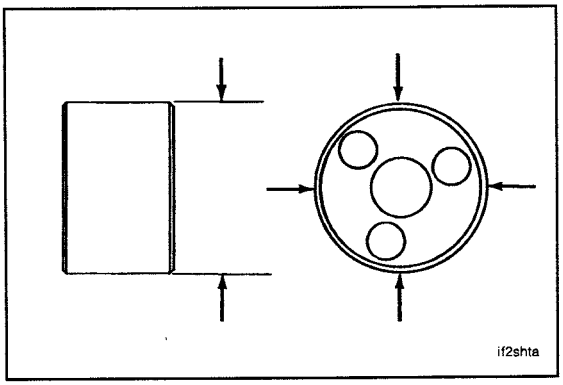


Measure the inside diameter of the idler gear bushing bore.

Camshaft Idler Gear Bushing Bore Inside Diameter		
mm		in
60.045	MIN	2.3640
60.100	MAX	2.3661

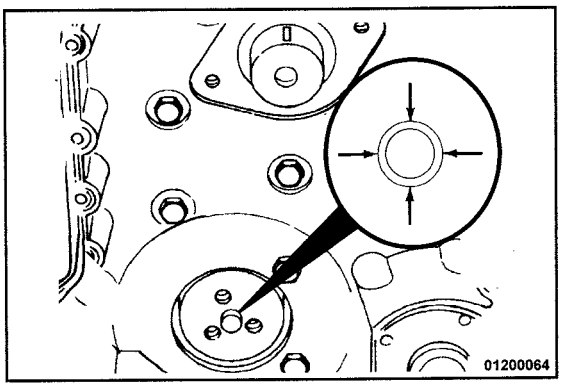
Measure the outside diameter of the idler gear shaft.

Camshaft Idler Gear Shaft Outside Diameter		
mm		in
59.975	MIN	2.3612
60.008	MAX	2.3625



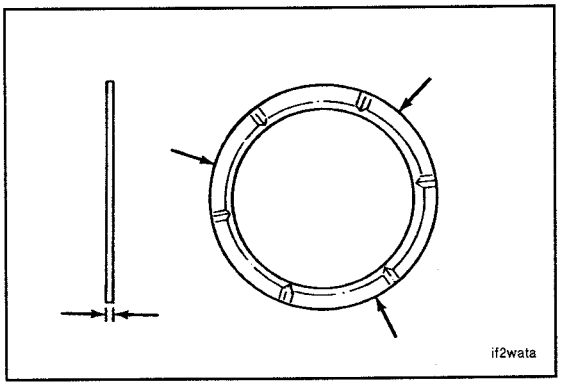
Measure the outside diameter of the camshaft idler shaft ring dowel.

Camshaft Idler Ring Dowel Outside Diameter		
mm		in
19.217	MIN	0.7566
19.243	MAX	0.7576

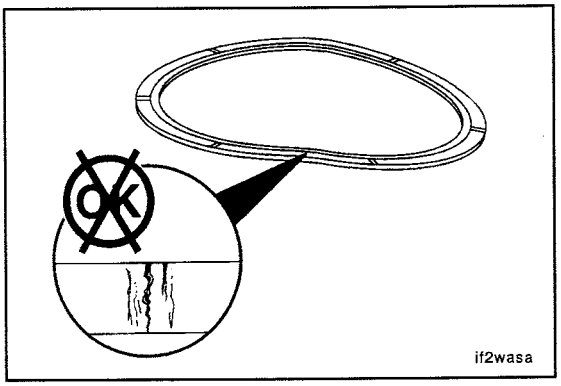


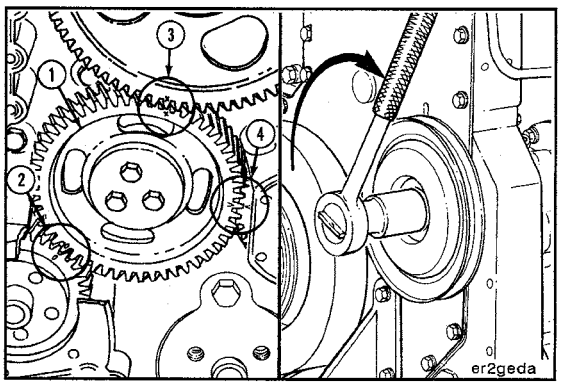
Measure the thrust washer thickness in three places 120-degrees apart.

Camshaft Idler Thrust Washer Thickness		
mm		in
2.400	MIN	0.0945
2.470	MAX	0.0972



Flex the thrust washers approximately 3 to 6 mm [1/8 to 1/4 in], and inspect the surfaces for cracks.

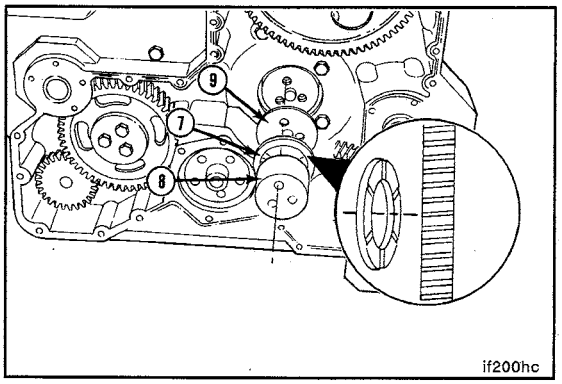




Install (001-036-026)

When installing the camshaft idler gear (1), make certain the timing mark "0"on the crankshaft gear (2), timing mark "X" on the camshaft gear (3), and timing mark "V" on the accessory drive gear (4) are aligned as shown.

The marks on the idler gears should match the same mark on each of the other gears.



NOTE: Only the camshaft idler gear has a wear plate.

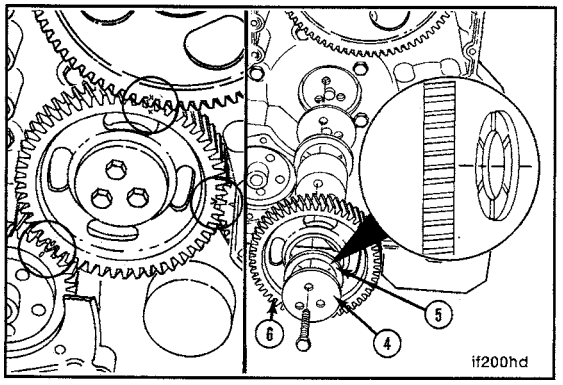
Use Lubriplate™ 105, or equivalent, to lubricate the wear plate, thrust bearing, and idler gear.

Install the camshaft idler gear wear plate (9).

CAUTION

The grooved side of the rear thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Install the idler gear shaft (8) and rear thrust bearing (7).



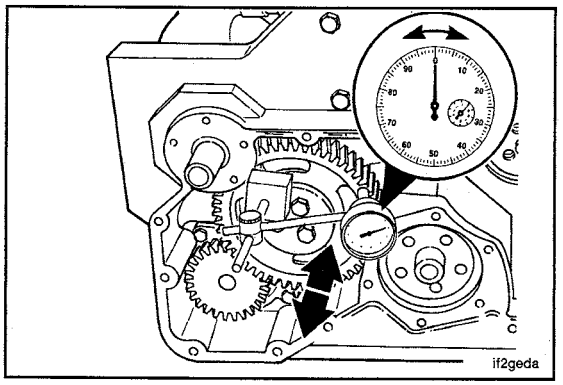
CAUTION

The grooved side of the front thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Align the timing marks and install the idler gear (6), front thrust bearing (5), and gear retainer (4).

Install the retaining capscrews and tighten.

Torque Value: Step 1 61 N•m [45 ft-lb]
2 Rotate 60 degrees



The following idler gear end clearance and backlash checks apply to all three idler gears. The same **MINIMUM** and **MAXIMUM** values apply, also.

Use a dial indicator gauge with a magnetic base to measure the idler gear end clearance.

Place the contact tip of the gauge against the face of the idler gear.

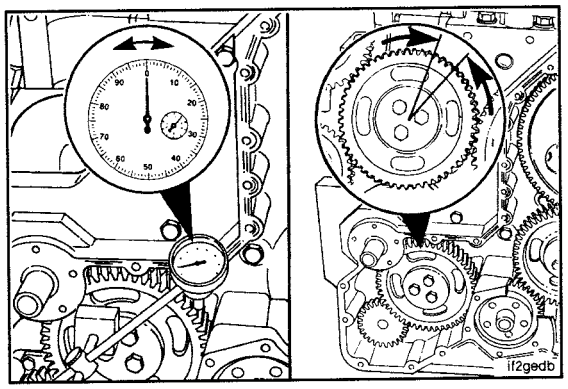
Idler Gear End Clearance		
mm		in
0.30	MIN	0.012
0.53	MAX	0.021

Use a dial indicator gauge with a magnetic base to measure the idler gear backlash.

Place the contact tip of the gauge against a tooth on the idler gear.

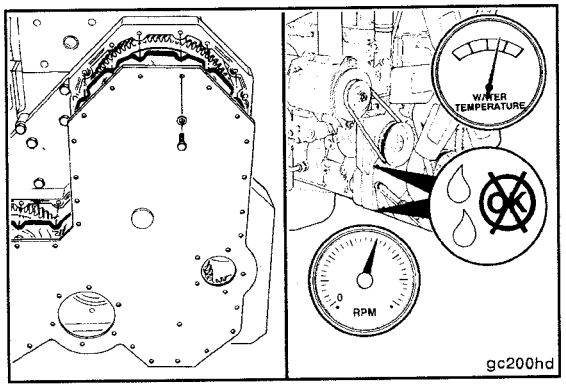
NOTE: Do **not** allow the mating gears to move while measuring the backlash.

Idler Gear Backlash		
mm		in
0.08	MIN	0.003
0.38	MAX	0.015



Install the gear cover. Refer to Procedure 001-031.

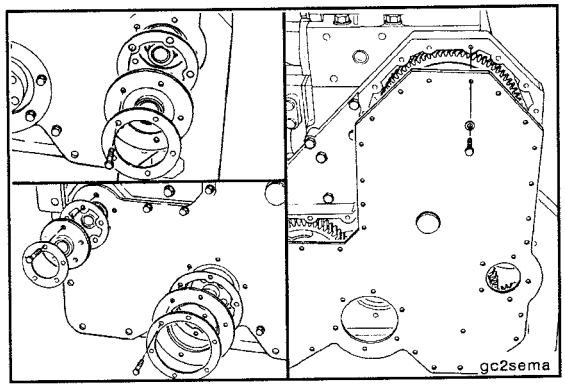
Operate the engine to normal operating temperature and check for leaks.



Idler Gear, Hydraulic Pump (001-039)

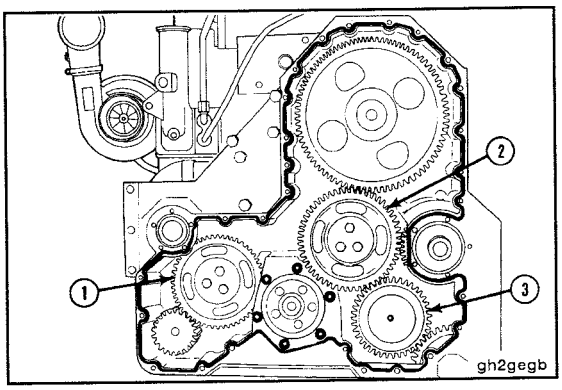
Remove (001-039-002)

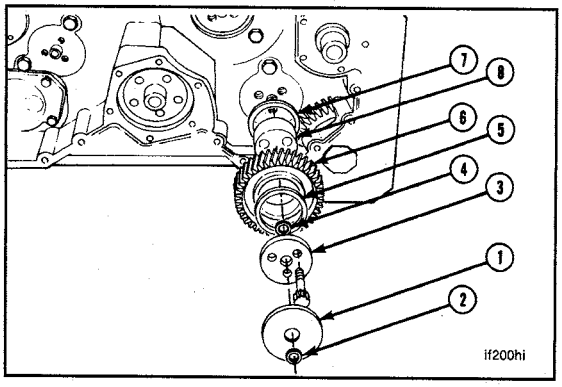
Remove the gear cover. Refer to Procedure 001-031.



Three idler gear assemblies are used:

- Water pump idler gear (1)
- Camshaft idler gear (2)
- Hydraulic pump idler gear (3).



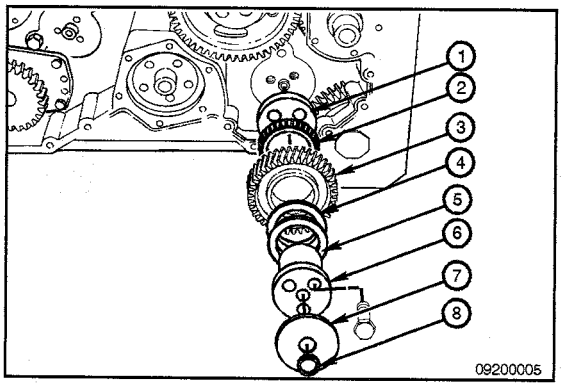


SAE 'A' and SAE 'B' Removal

To remove the hydraulic drive idler gear assembly, remove:

- Mounting spacer (1)
- Rectangular seal (2)
- The three twelve-point capscrews
- Gear retainer (3)
- Rectangular seal (4)
- Front thrust bearing (5)
- Idler gear (6)
- Rear thrust bearing (7)
- Idler gear shaft (8).

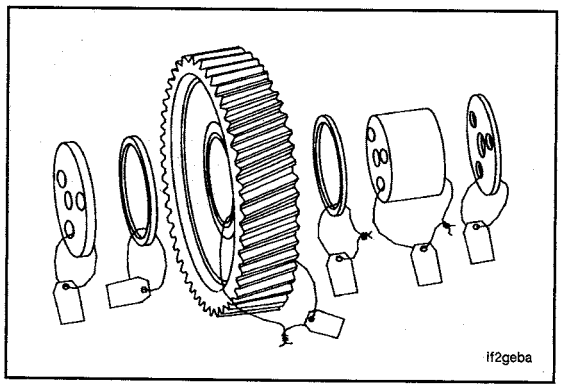
NOTE: SAE "A" drives do **not** use a rectangular seal (4) on the rear surface of the gear retainer.



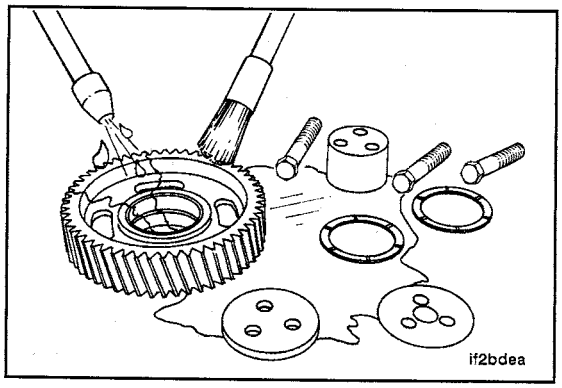
SAE 'B-B' Removal

To remove SAE B-B hydraulic drive idler gear assembly, remove:

- Mounting Spacer (1)
- Tapered Roller Bearing (2)
- Gear Drive (3)
- Tapered Roller Bearing (4)
- Shim(s) (5)
- Idler Gear Shaft (6)
- Mounting Spacer (7)
- Rectangular Seal (8).



Mark or tag the individual pieces of the idler gear assembly and attach them together.

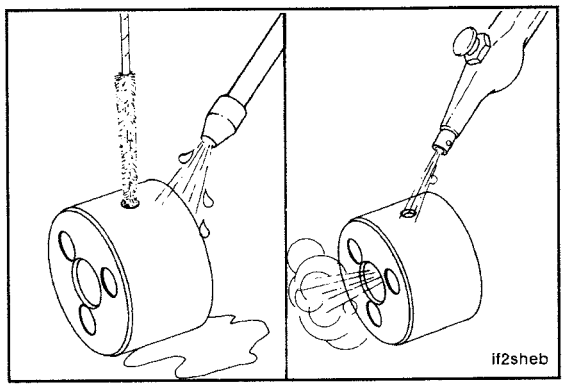


Clean (001-039-006)

Clean the parts with solvent. Dry with compressed air.

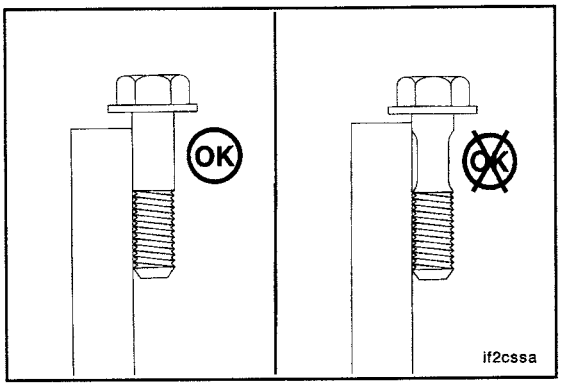
Use a bristle brush to clean the oil drillings in the idler gear shaft.

Blow out the oil drillings with compressed air.

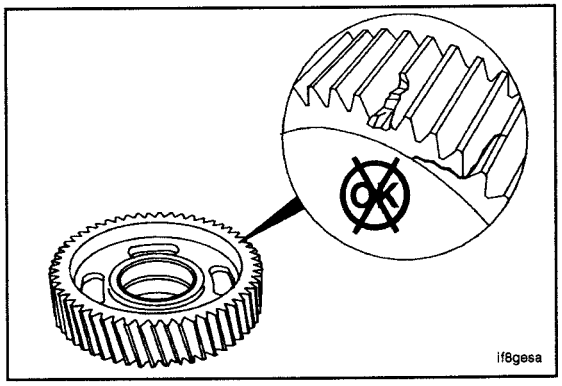


Inspect for Reuse (001-039-007)

Use a straightedge to inspect the retaining capscrews for necking. If necking is observed, do **not** reuse the capscrews. They **must** be replaced.



Inspect the idler gear for chipped, broken, or cracked teeth.

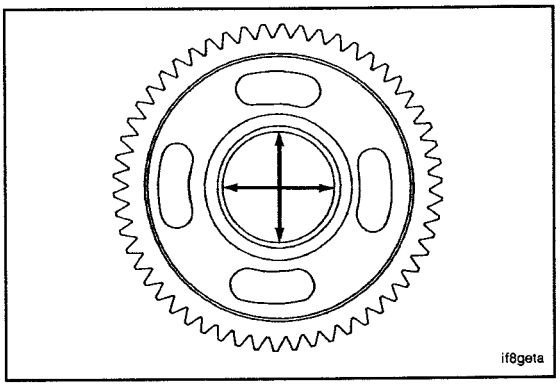


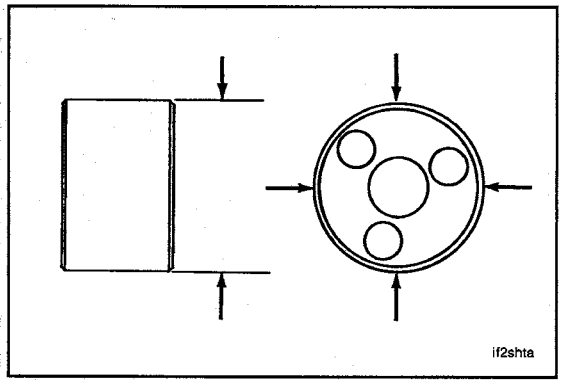
NOTE: Measurements do not apply to SAE 'B-B' hydraulic drive idler gear. Visually inspect the inside diameter of the gear for reuse.

Measure the inside diameter of the idler gear bushing bore.

SAE 'A' and 'B' Hydraulic Drive Idler Gear Bushing Bore Inside Diameter

mm		in
60.045	MIN	2.3640
60.100	MAX	2.3661

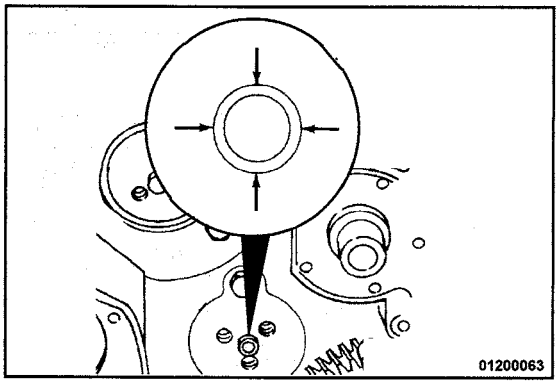




Measure the outside diameter of the idler gear shaft.

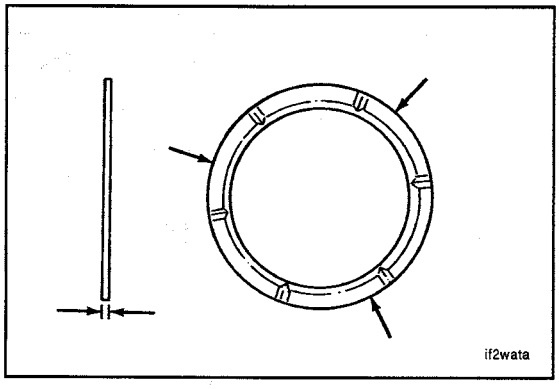
SAE 'A' and 'B' Hydraulic Drive Idler Gear shaft Outside Diameter		
mm		in
59.975	MIN	2.3612
60.008	MAX	2.3625

SAE 'B-B' Hydraulic Drive Idler Gear Shafts Outside Diameter		
mm		in
63.455	MIN	2.4982
63.486	MAX	2.4994



Measure the outside diameter of the ring dowel.

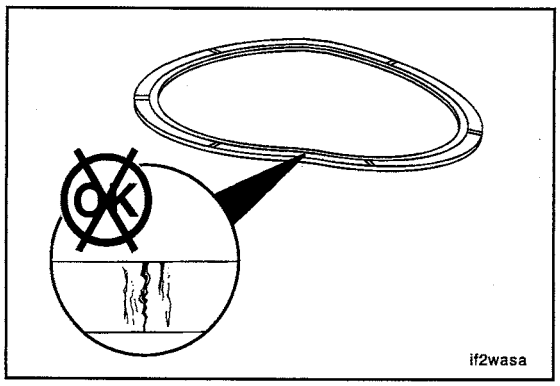
Hydraulic Drive Idler Ring Dowel Outside Diameter		
mm		in
19.217	MIN	0.7566
19.243	MAX	0.7576



NOTE: SAE 'B-B' hydraulic drive gear assembly does **not** use thrust washers.

Measure the thrust washer thickness in three places 120-degrees apart.

Hydraulic Drive Idler Thrust Washer Thickness		
mm		in
2.400	MIN	0.0945
2.470	MAX	0.0972



NOTE: SAE 'B-B' hydraulic drive gear assembly does **not** use thrust washers.

Flex the thrust washers approximately 3 to 6 mm [1/8 to 1/4 in], and inspect the surfaces for cracks.

Install (001-039-026)

SAE 'A' and SAE 'B' Install

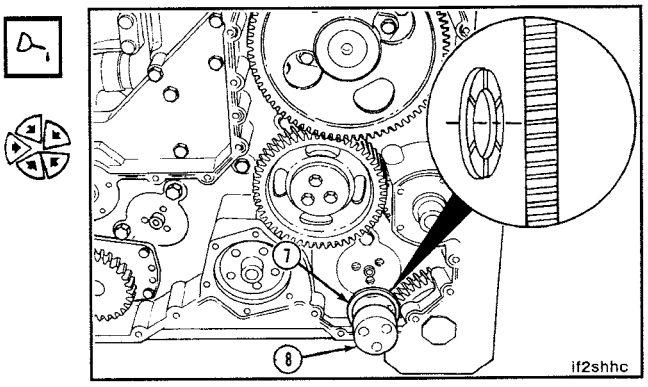
Use Lubriplate™ 105, or equivalent, to lubricate the thrust bearings and idler gear.

⚠ CAUTION ⚠

The grooved side of the rear thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Install the idler gear shaft (8) and rear thrust bearing (7).

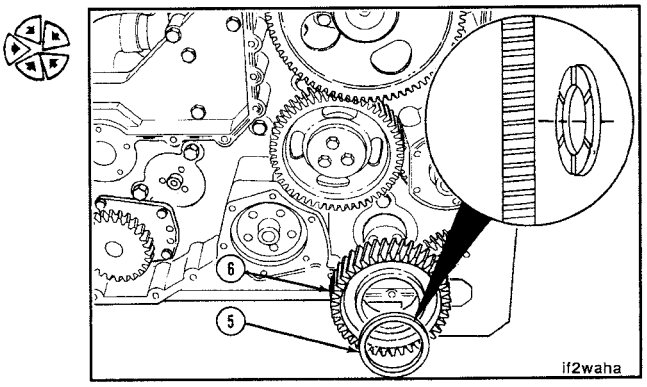
NOTE: When an SAE B drive is used, a special hydraulic drive idler shaft with two oil holes is used. With the engine in the upright position, orientate the shaft so that one oil hole is at twelve- o'clock and the other at four-o'clock.



⚠ CAUTION ⚠

The grooved side of the front thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Install the idler gear (6) and front thrust bearing (5).

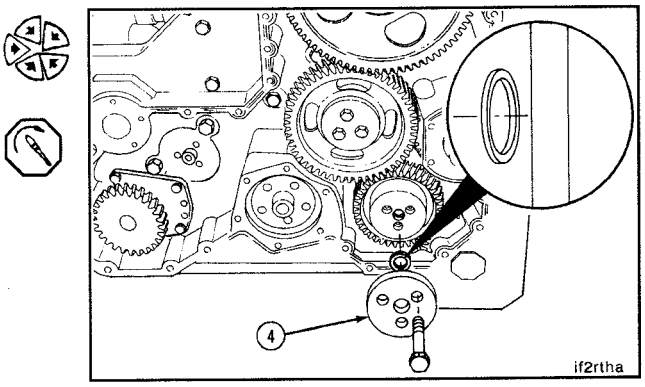


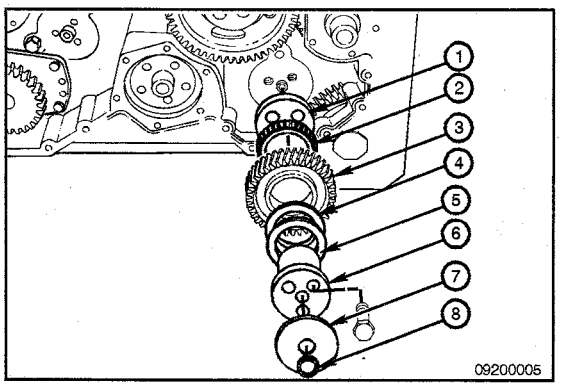
NOTE: On SAE "B" drives, install a new rectangular seal on the rear surface of the gear retainer (4) before installing the retainer.

Install the gear retainer (4).

Install the three retaining capscrews and tighten.

Torque Value: Step 1 61 N•m [45 ft-lb]
2 Rotate 60 degrees





SAE 'B-B' Install

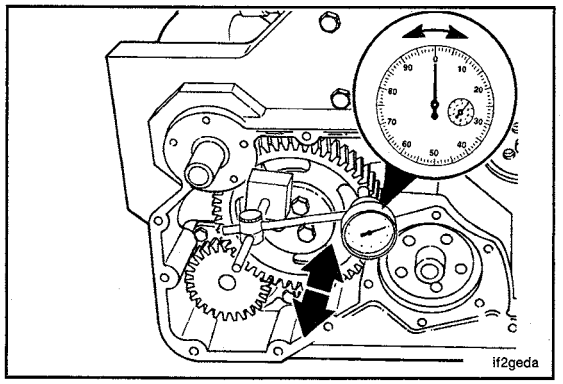
NOTE: Use shim(s) as necessary for proper idler gear end clearance.

Use Lubriplate™ 105, or equivalent to lubricate the roller bearings and gear.

To install SAE B-B hydraulic drive idler gear assembly, install

- Mounting Spacer (1)
- Tapered Roller Bearing (2)
- Gear Drive (3)
- Tapered Roller Bearing (4)
- Shim (s) (5)
- Idler Gear Shaft (6)
- Mounting Spacer (7)
- Rectangular Seal (8).

Torque Value: Step 1 61 N•m [45 ft-lb]
2 Rotate 60 degrees

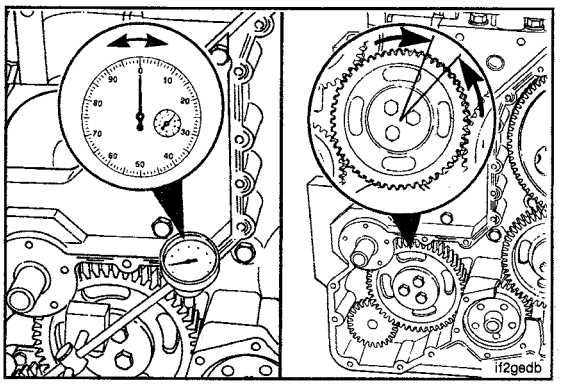


The following idler gear end clearance and backlash checks apply to all three idler gears. The same **MINIMUM** and **MAXIMUM** values apply, also.

Use a dial indicator gauge with a magnetic base to measure the idler gear end clearance.

Place the contact tip of the gauge against the face of the idler gear.

Idler Gear End Clearance		
mm		in
0.30	MIN	0.012
0.53	MAX	0.021



Use a dial indicator gauge with a magnetic base to measure the idler gear backlash.

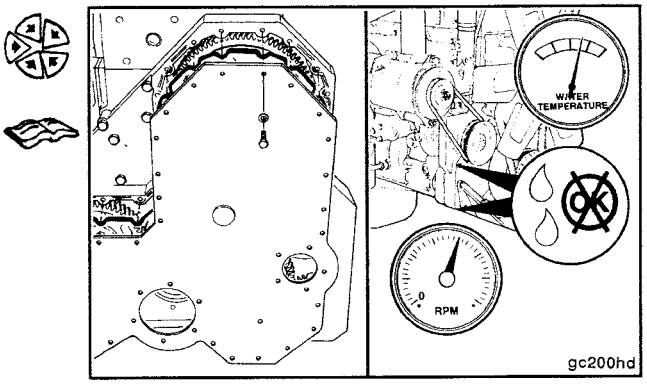
Place the contact tip of the gauge against a tooth on the idler gear.

NOTE: Do **not** allow the mating gears to move while measuring the backlash.

Idler Gear Backlash		
mm		in
0.08	MIN	0.003
0.38	MAX	0.015

Install the gear cover. Refer to Procedure 001-031.

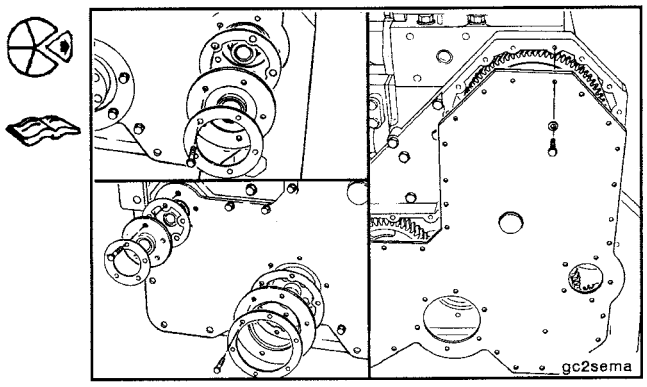
Operate the engine to normal operating temperature and check for leaks.



Idler Gear, Water Pump (001-040)

Remove (001-040-002)

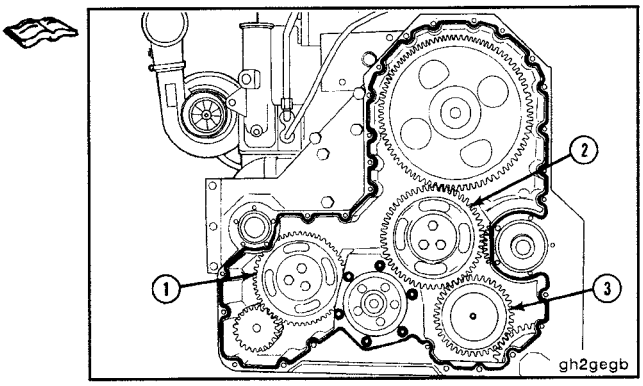
Remove the gear cover. Refer to Procedure 001-031.



Three idler gear assemblies are used:

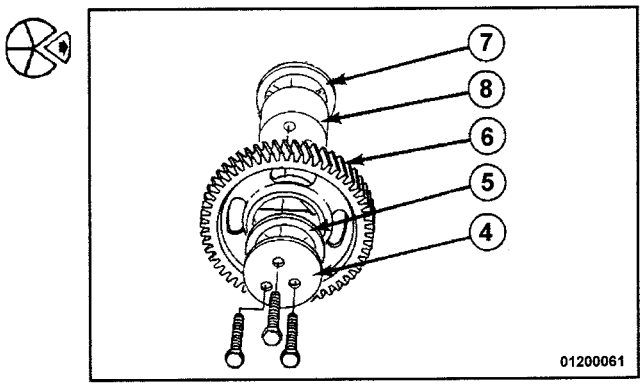
- Water pump idler gear (1)
- Camshaft idler gear (2)
- Hydraulic pump idler gear (3).

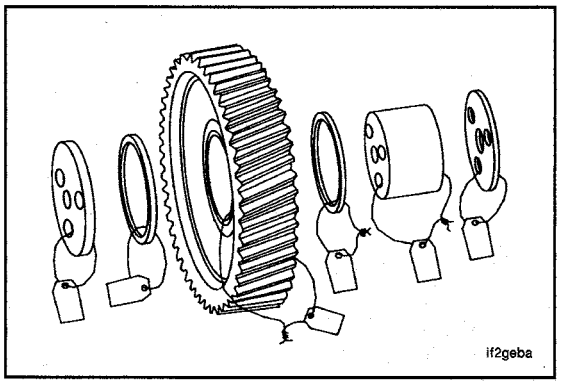
NOTE: The water pump **must** be removed before the water pump idler gear (1) can be removed. Refer to Procedure 008-062.



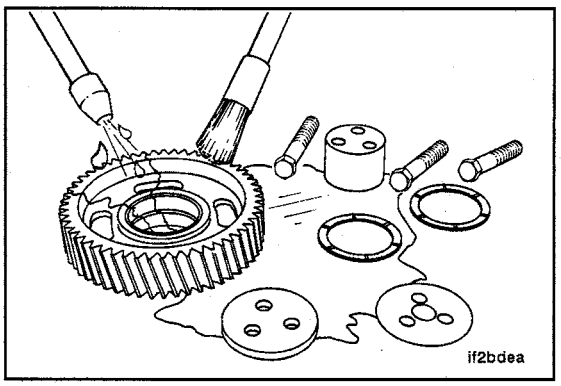
To remove the water pump idler gear assembly, remove:

- The three capscrews
- Cover plate (4)
- Front thrust bearing (5)
- Idler gear (6)
- Rear thrust bearing (7)
- Idler gear shaft (8).



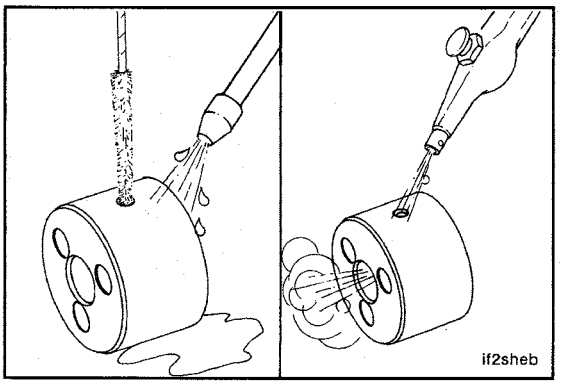


Mark or tag the individual pieces of the idler gear assembly and attach them together.



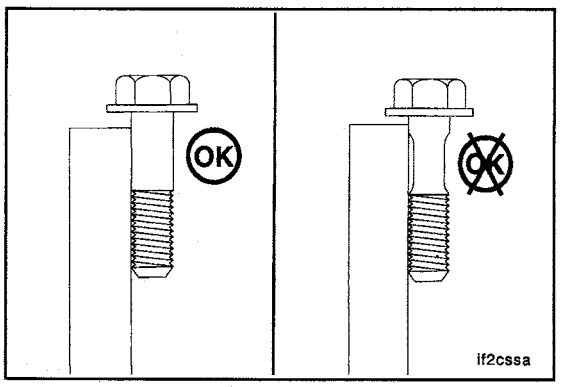
Clean (001-040-006)

Clean the parts with solvent. Dry with compressed air.



Use a bristle brush to clean the oil drilling in the idler gear shaft.

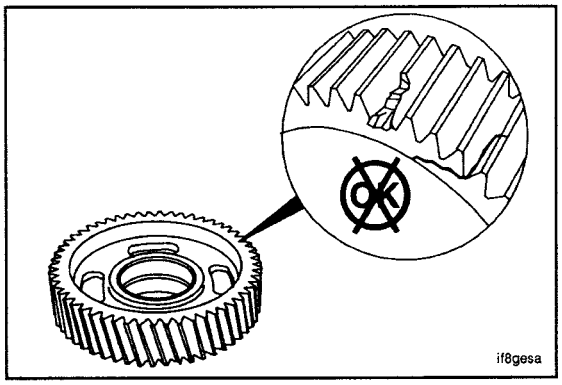
Blow out the oil drilling with compressed air.



Inspect for Reuse (001-040-007)

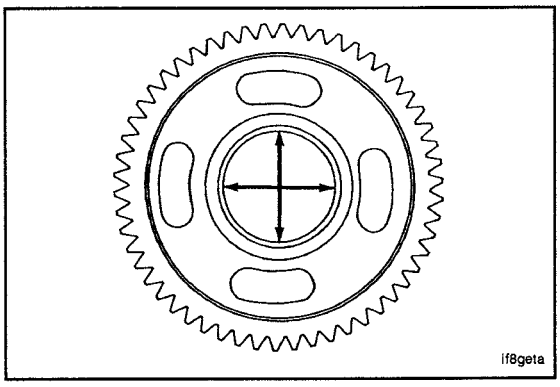
Use a straightedge to inspect the retaining capscrews for necking. If necking is observed, do **not** reuse the capscrews. They **must** be replaced.

Inspect the idler gear for chipped, broken, or cracked teeth.



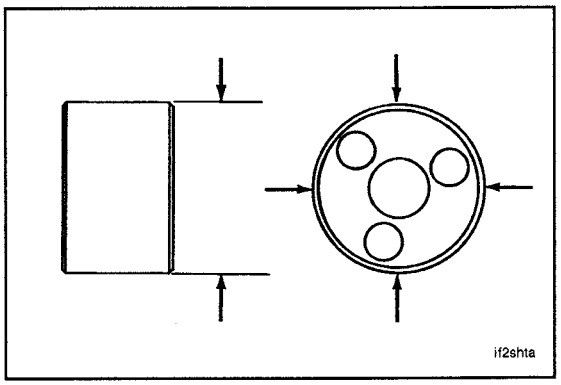
Measure the inside diameter of the idler gear bushing bore.

Water Pump Idler Gear Bushing Bore Inside Diameter		
mm		in
60.045	MIN	2.3640
60.100	MAX	2.3661



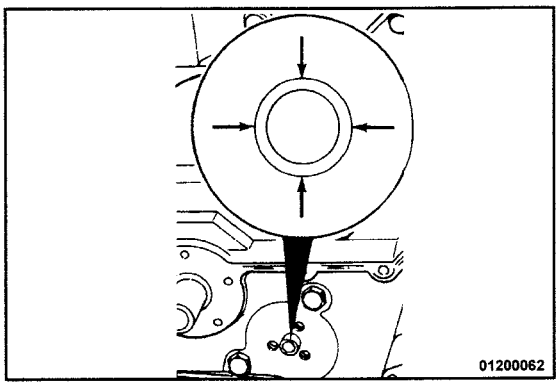
Measure the outside diameter of the idler gear shaft.

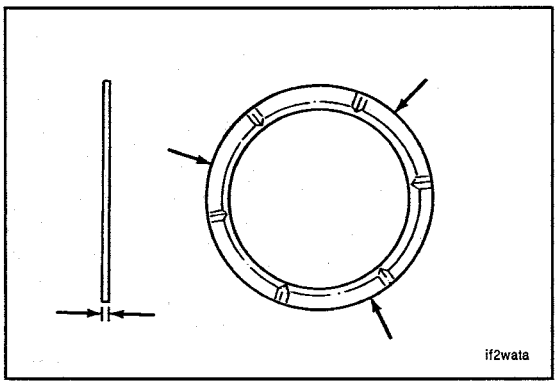
Water Pump Idler Gear Shaft Outside Diameter		
mm		in
59.975	MIN	2.3612
60.008	MAX	2.3625



Measure the outside diameter of the ring dowel.

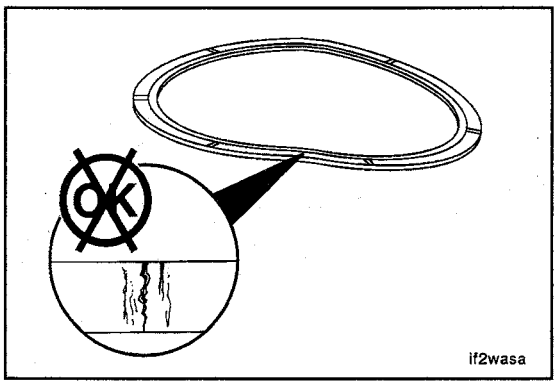
Water Pump Idler Ring Dowel Outside Diameter		
mm		in
19.217	MIN	0.7566
19.243	MAX	0.7576



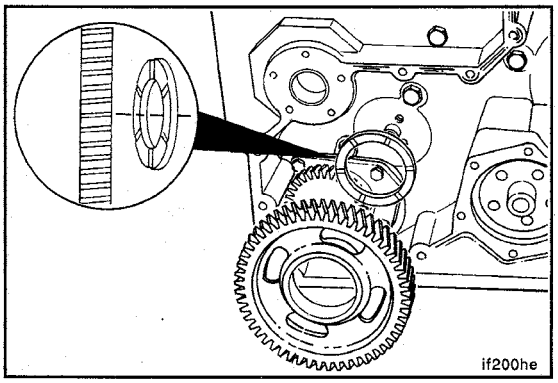


Measure the thrust washer thickness in three places 120-degrees apart.

Water Pump Idler Thrust Washer Thickness		
mm		in
2.400	MIN	0.0945
2.470	MAX	0.0972



Flex the thrust washers approximately 3 to 6 mm [1/8 to 1/4 in], and inspect the surfaces for cracks.



Install (001-040-026)

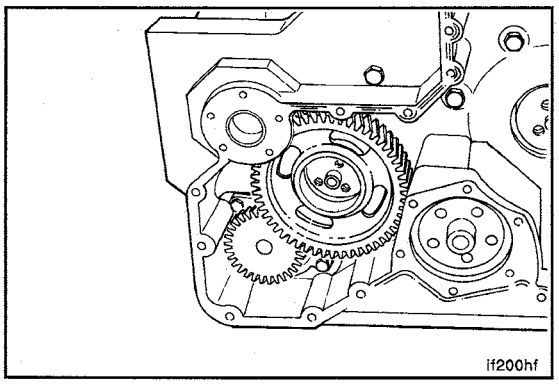
CAUTION

The grooved side of the rear thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Use Lubriplate™ 105, or equivalent, to lubricate the thrust bearings and idler gear shaft.

Install the rear thrust bearing.

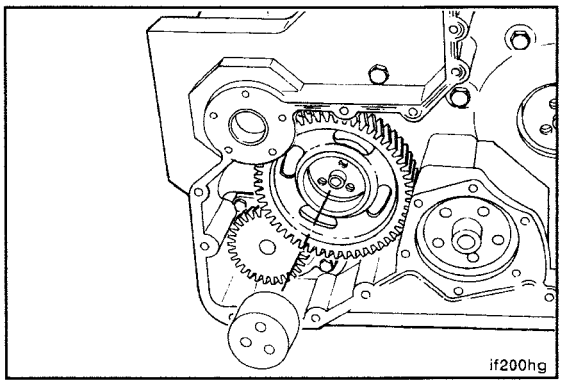
Install the idler gear without the shaft.



Align the inside diameter of the rear thrust bearing with the inside diameter of the idler gear.

The shaft **must** pass through the gear and pilot into the rear thrust bearing. After installation, the shaft **must** protrude **only** slightly more than the thickness of the front thrust bearing. Excessive shaft protrusion beyond the thickness of the front thrust bearing indicates the shaft is **not** properly piloted into the rear thrust bearing.

Install the shaft into the gear bore.



△ CAUTION △

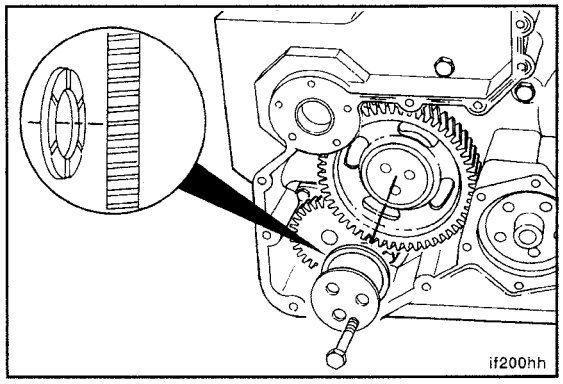
The grooved side of the front thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Install the front thrust bearing.

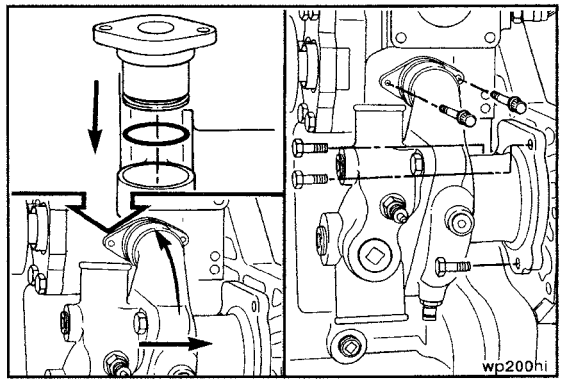
Install the gear retainer.

Install the capscrews and tighten.

Torque Value: Step 1 61 N•m [45 ft-lb]
2 Rotate 60 degrees



Install the water pump. Refer to Procedure 008-062.

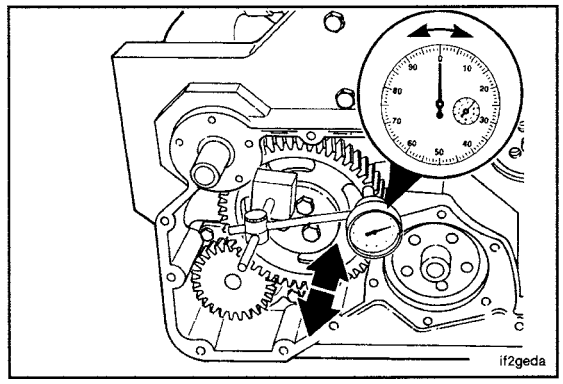


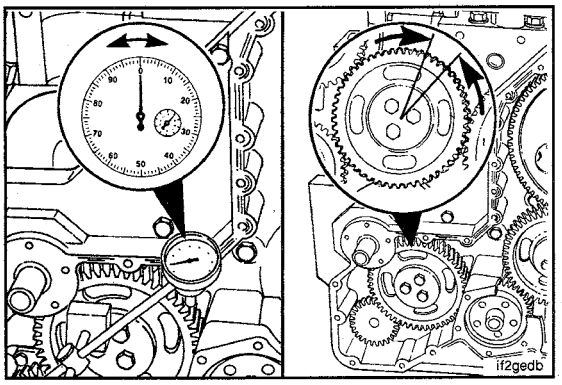
The following idler gear end clearance and backlash checks apply to all three idler gears. The same **MINIMUM** and **MAXIMUM** values apply, also.

Use a dial indicator gauge with a magnetic base to measure the idler gear end clearance.

Place the contact tip of the gauge against the face of the idler gear.

Idler Gear End Clearance		
mm		in
0.30	MIN	0.012
0.53	MAX	0.021



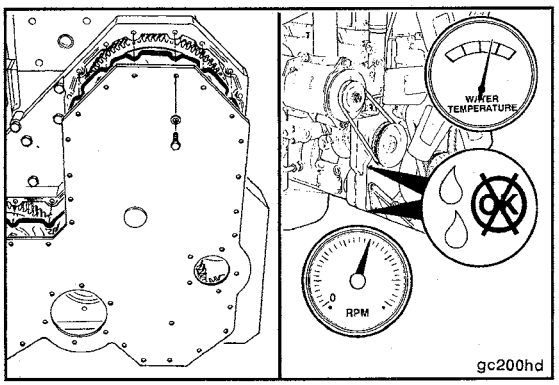


Use a dial indicator gauge with a magnetic base to measure the idler gear backlash.

Place the contact tip of the gauge against a tooth on the idler gear.

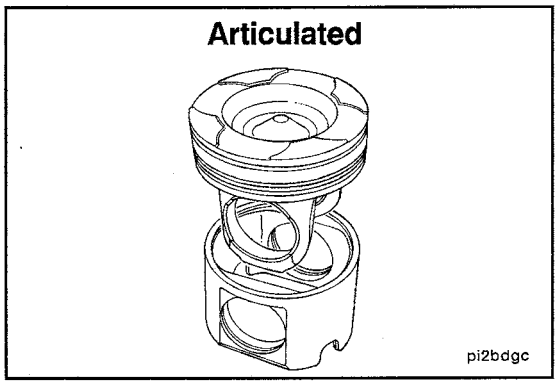
NOTE: Do **not** allow the mating gears to move while measuring the backlash.

Idler Gear Backlash		
mm		in
0.08	MIN	0.003
0.38	MAX	0.015



Install the gear cover. Refer to Procedure 001-031.

Operate the engine to normal operating temperature and check for leaks.



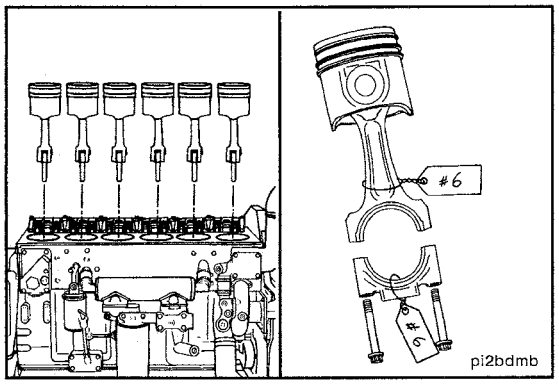
Piston (001-043)

General Information

All M Series engines are equipped with articulated pistons.

The articulated piston is a two-piece piston consisting of a forged-steel crown and an aluminum skirt.

A closed chamber oil gallery is located on the underside of the crown of the piston to provide more oil contact with the piston and give better piston cooling. Piston cooling nozzle targeting is critical because of the closed chamber oil gallery.



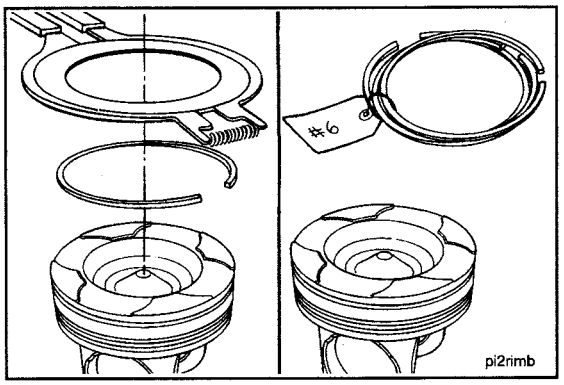
Remove (001-043-002)

The piston and connecting rod **must** be removed as an assembly. To remove the piston and connecting rod, refer to Procedure 001-054.

Disassemble (001-043-003)

Refer to Procedure 001-054 to disassemble the piston and connecting rod assembly.

NOTE: Refer to Procedure 001-047 for piston ring inspection.



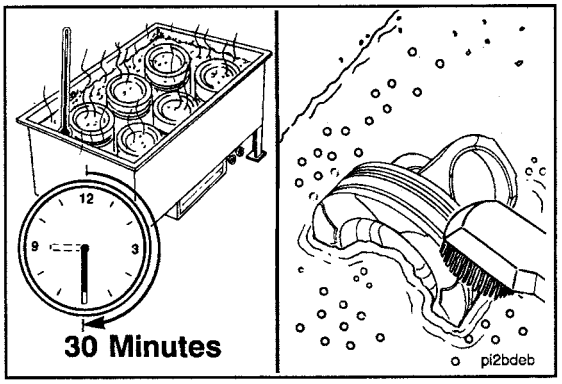
Clean (001-043-006)

⚠ CAUTION ⚠

Be sure the cleaning solvent is approved for aluminum. Damage to the pistons can result if the wrong solution is used.

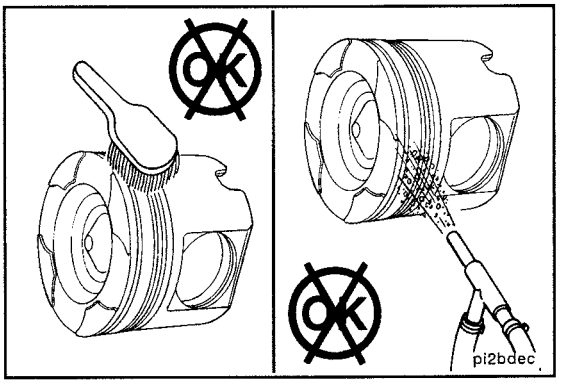
Allow the pistons to soak for a minimum of 30 minutes in a tank containing an approved cleaning solvent for aluminum.

Use a hot, soapy solution and a nonmetallic brush to remove carbon deposits.



⚠ CAUTION ⚠

Do not use a metal brush. A metal brush will damage the piston ring grooves. Do not use glass beads to clean the grooves. Walnut shell or plastic bead, Part No. 3822735, blasting can be used on ring grooves on the dome or crown of the piston. Use the minimum effective pressure, and do not concentrate the spray in one area for an extended period of time. The recommended blast pressure for plastic bead blasting is 276 kPa [40 psi]. Do not use glass beads or walnut shell blasting on the aluminum piston pin bores or articulated piston skirts. This can cause piston pin bore damage.

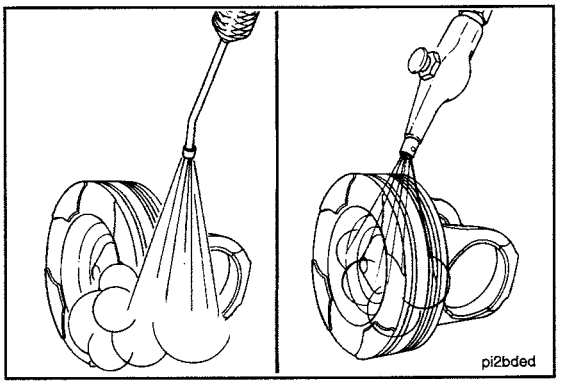


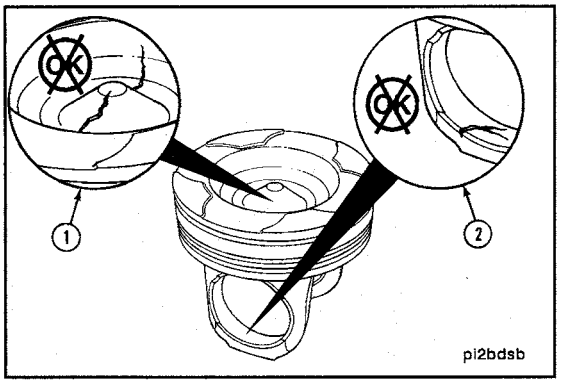
⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

Use steam to clean the pistons.

Dry with compressed air.



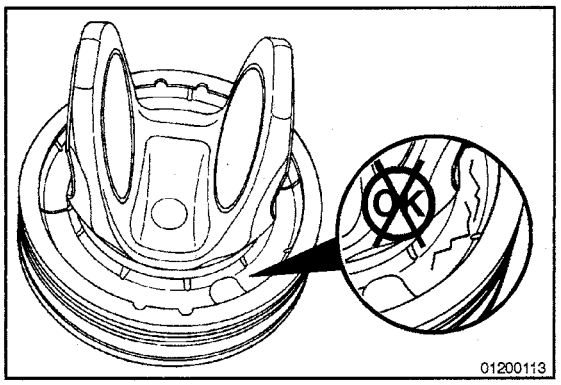


Inspect for Reuse (001-043-007)

Articulated Piston

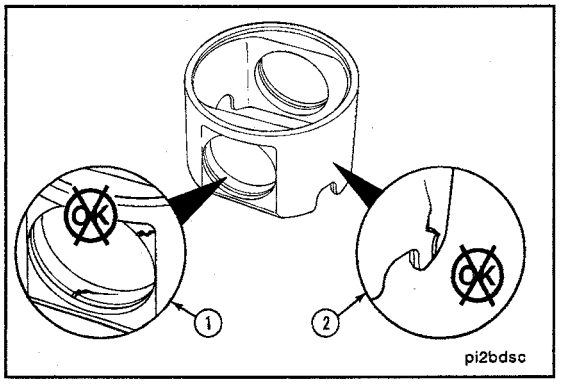
Inspect the piston bowl (1) and crown piston pin bore (2) for cracks or damage.

Do **not** use pistons with cracks. If the crown is cracked, it **must** be replaced.



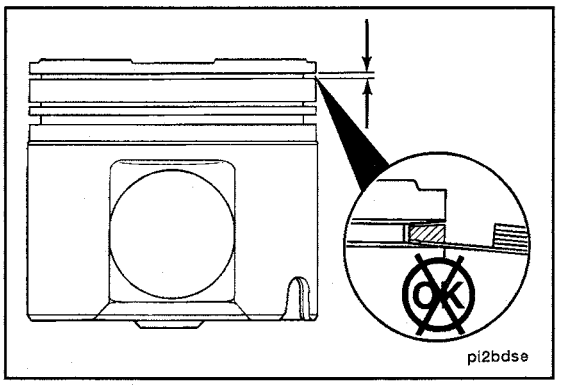
Inspect the piston gallery cover plate in the piston crown for cracks or looseness.

If the gallery is cracked or loose, the piston crown **must** be replaced.



Inspect the piston skirt pin bore (1) and sides (2) for cracks or damage.

Do **not** use pistons with cracks. If the skirt is cracked, it **must** be replaced.



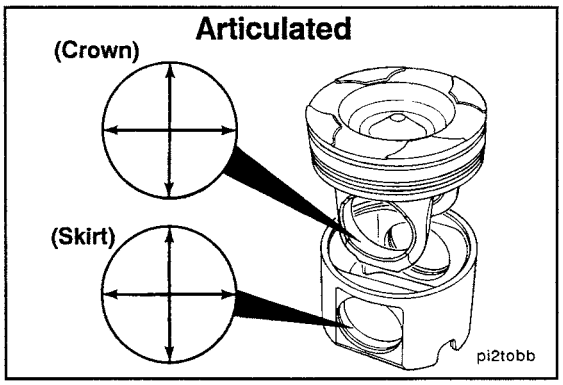
The ring groove can be inspected with a new ring and a feeler gauge.

Hold a new ring in the groove even with the outside diameter of the piston. Install a 0.15-mm [0.006-in] feeler gauge. If the feeler gauge enters the groove without resistance, there is too much wear. Replace the piston.

Measure the piston pin bore inside diameter.

Articulated Piston Pin Bore Inside Diameter (Crown)		
mm		in
54.040	MIN	2.1276
54.055	MAX	2.1281

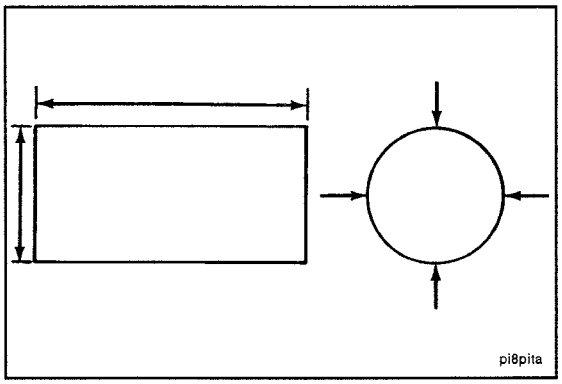
Articulated Piston Pin Bore Inside Diameter (Skirt)		
mm		in
54.007	MIN	2.1263
54.015	MAX	2.1266



Measure the piston pin outside diameter and length.

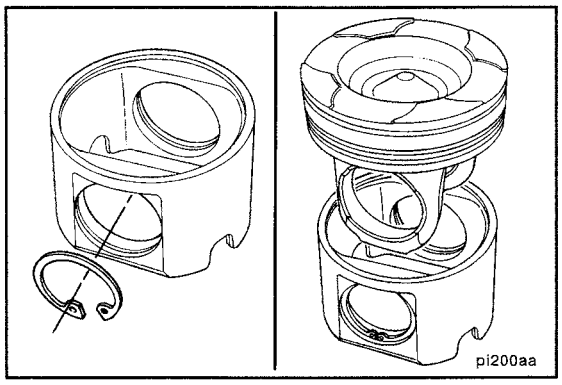
Piston Pin Outside Diameter		
mm		in
53.997	MIN	2.1259
54.003	MAX	2.1261

Piston Pin Length		
mm		in
101.70	MIN	4.0039
102.00	MAX	4.0157



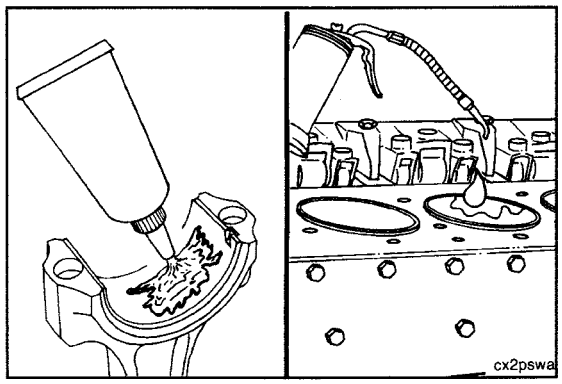
Assemble (001-043-025)

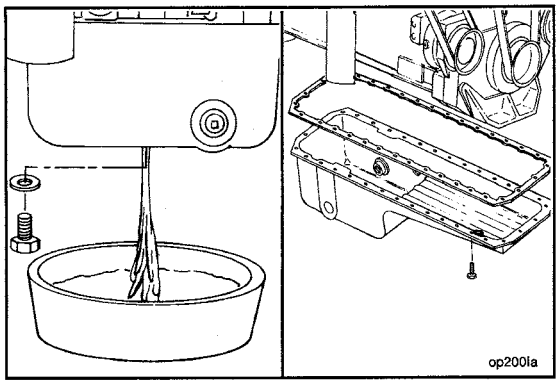
Refer to Procedure 001-054 for piston and connecting rod assembly instructions.



Install (001-043-026)

The piston and connecting rod **must** be installed as an assembly on M series engines. Refer to Procedure 001-054 for installation instructions.



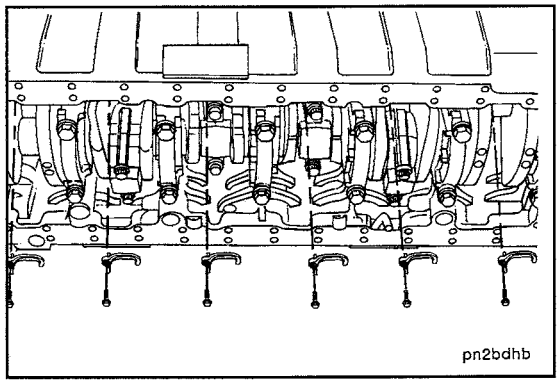


Piston Cooling Nozzle (001-046)

Remove (001-046-002)

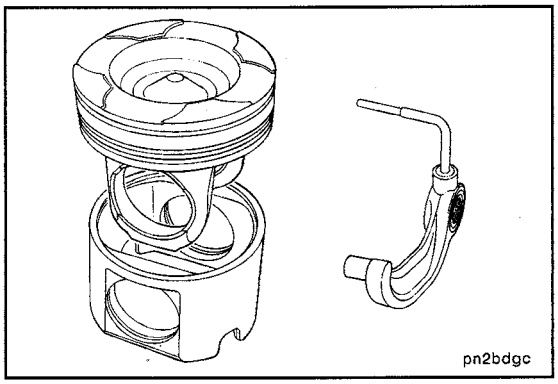
Drain the lubricating oil. Refer to Procedure 007-025.

Remove the lubricating oil pan. Refer to Procedure 007-025.



Remove the piston cooling nozzles.

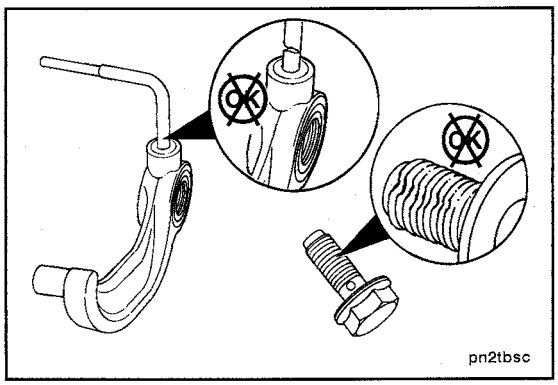
NOTE: The crankshaft **must** be rotated to allow access to remove all the nozzles.



Inspect for Reuse (001-046-007)

Measure the piston cooling nozzle length.

Piston Cooling Nozzle Length		
mm		in
44.5	NOMINAL	1.752



Inspect the capscrews, washers, and piston cooling nozzles for damage.

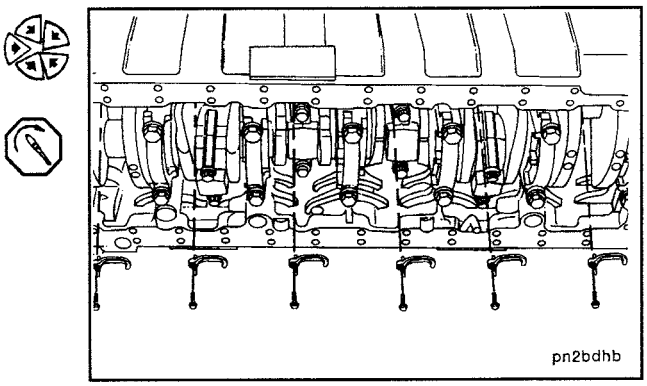
Install (001-046-026)

Install the nozzles, washers, and capscrews.

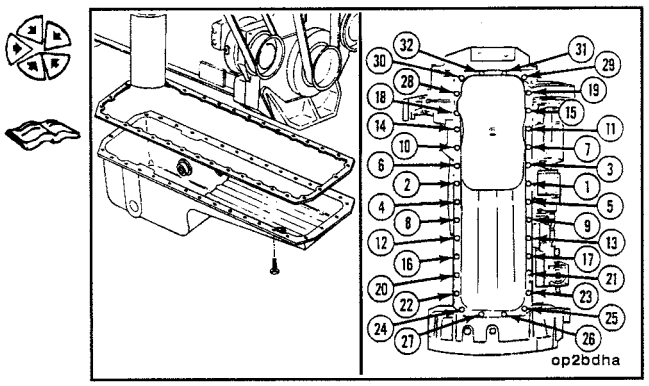
Tighten the capscrews.

Torque Value: 28 N•m [21 ft-lb]

NOTE: The crankshaft **must** be rotated to allow access to install all the nozzles.

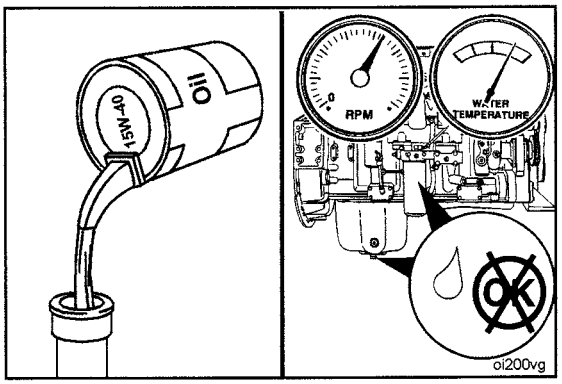


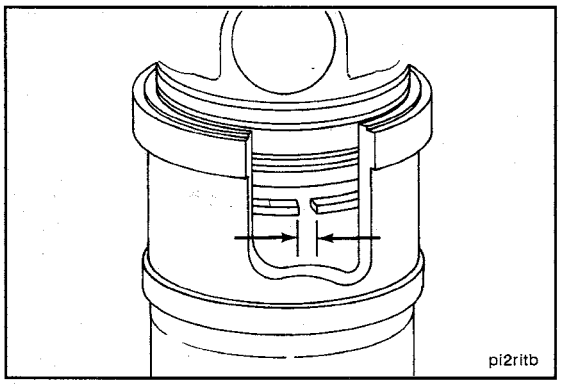
Install the lubricating oil pan. Refer to Procedure 007-025.



Fill the engine with lubricating oil. Refer to Procedure 007-025.

Operate the engine to normal operating temperature and check for oil leaks.





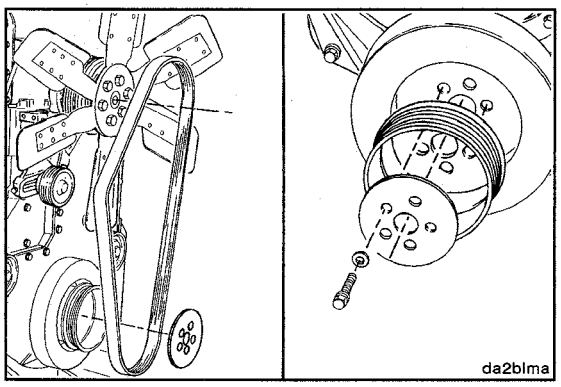
Piston Rings (001-047)

Inspect for Reuse (001-047-007)

To check the ring gap, install the piston rings in the wear area of the cylinder liner in which they will be used.

Use a feeler gauge to measure the ring gap. Replace the ring if it does **not** meet the following specifications.

Piston Ring Gap			
	mm		in
Top	0.46	MIN	0.018
	0.71	MAX	0.028
Intermediate	0.76	MIN	0.030
	1.14	MAX	0.045
Oil	0.25	MIN	0.010
	0.64	MAX	0.025

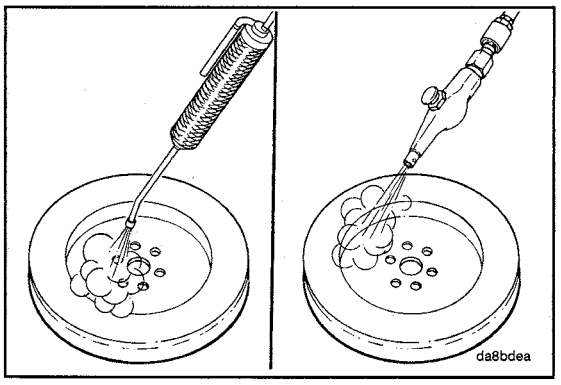


Vibration Damper (001-052)

Remove (001-052-002)

Remove the fan drive belt. Refer to Procedure 008-002.

Remove the clamping plate, crankshaft pulley, and vibration damper. Refer to Procedure 001-022.



Clean (001-052-006)

⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

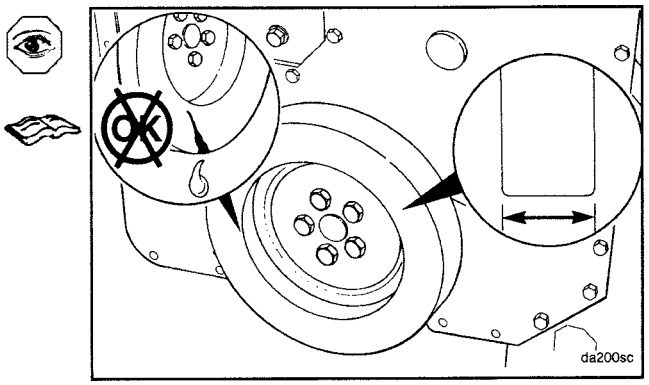
Use steam or solvent to clean the vibration damper. Dry with compressed air.

Maintenance Check (001-052-008)

⚠ CAUTION ⚠

The silicone fluid in the vibration damper will become solid after extended service, which makes the vibration damper inoperative. An inoperative vibration damper can cause major engine or driveline failures.

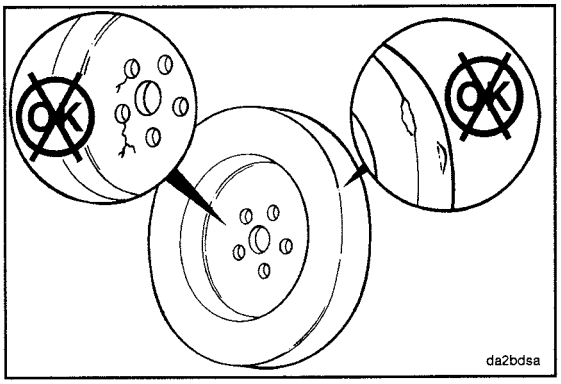
Check the vibration damper for evidence of fluid loss, dents, and wobble. Inspect the vibration damper thickness for any deformation or raising of the damper front cover plate.



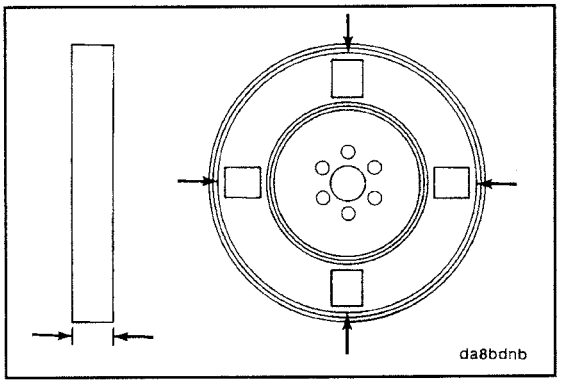
Check the mounting web for cracks.

Check the housing for dents or raised surfaces.

Replace the damper if any of these defects are identified.



Remove the paint from four locations on either side of the damper.

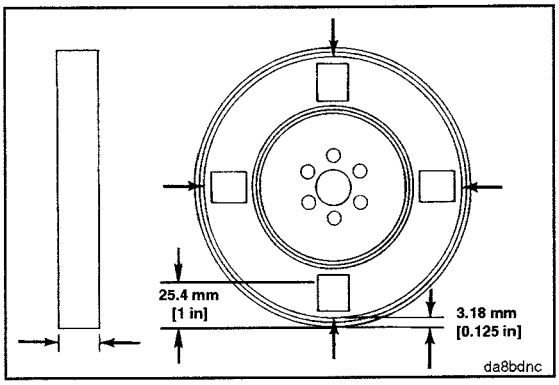


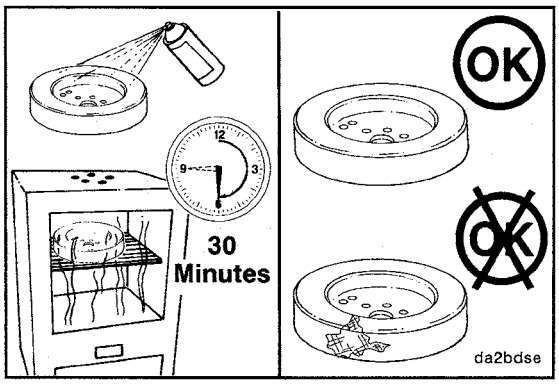
Measure and record the vibration damper thickness at two points at each of the four locations.

- Measure the thickness at 3.18 mm [0.125 in] from the outer lip.
- Measure the thickness at 25.4 mm [1.0 in] from the outer lip.

NOTE: This procedure will result in a total of eight measurements.

If the variations between any of the eight measurements exceed 0.25 mm [0.010 in], or if the thickness at any point exceeds 45 mm [1.772 in], replace the vibration damper.





To check for oil leaks, spray the damper with crack detection developer, Part No. 3375434.

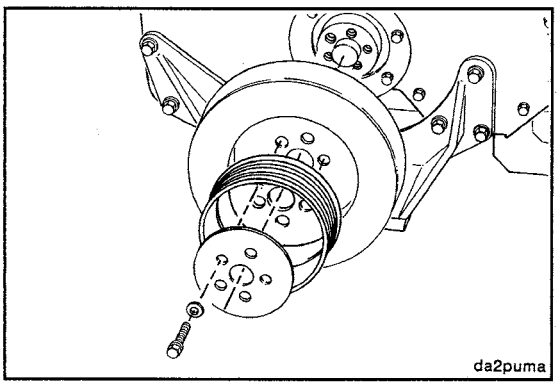
⚠ WARNING ⚠

Use insulated gloves, Part No. 3823730, when handling heated parts. Hot parts can cause serious personal injury.

Heat the damper in an oven, rolled-lip side down, for a minimum of 30 minutes, but **not** longer than 2 hours.

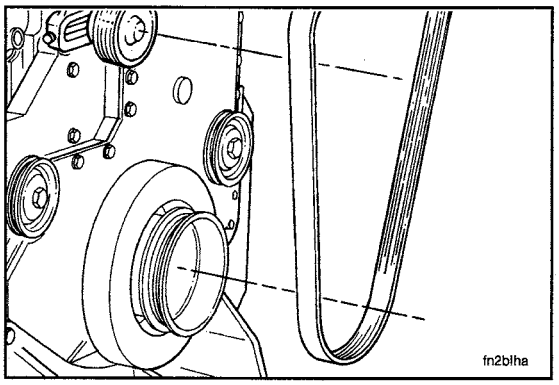
Temperature: 93 °C [200 °F]

Replace the damper if oil leaks are found.

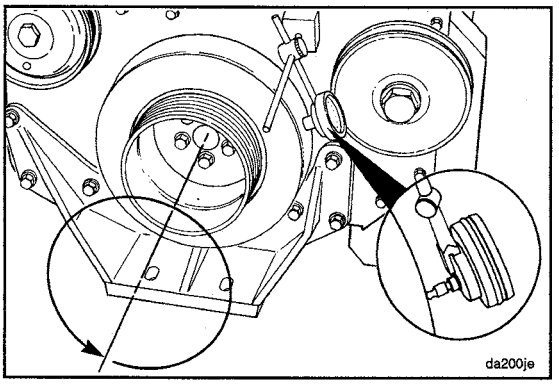


Install (001-052-026)

Install the vibration damper, crankshaft pulley, and clamping plate. Refer to Procedure 001-022.



Install the fan drive belt. Refer to Procedure 008-002.



Eccentricity Check (001-052-064)

Clean the outside surface of the vibration damper.

To measure damper eccentricity (out of round), install the dial indicator gauge, Part No. 3376050 and extension Part No. ST-537-4, on the gear cover as indicated.

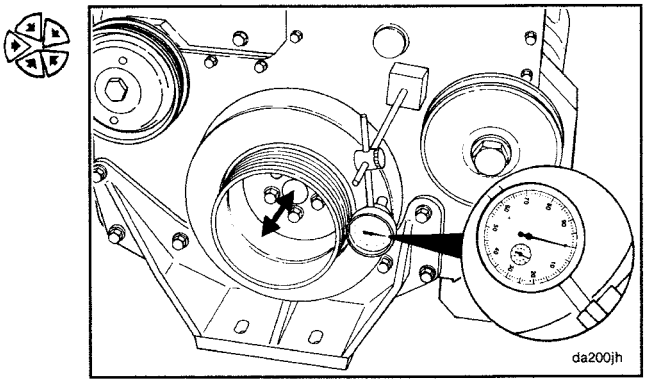
Rotate the crankshaft with the accessory driveshaft one complete revolution (360 degrees), and record the total indicator movement.

Replace the vibration damper if the eccentricity exceeds 0.28 mm [0.011 in].

Wobble Check (001-052-065)

To measure wobble (face alignment), install the dial indicator as shown.

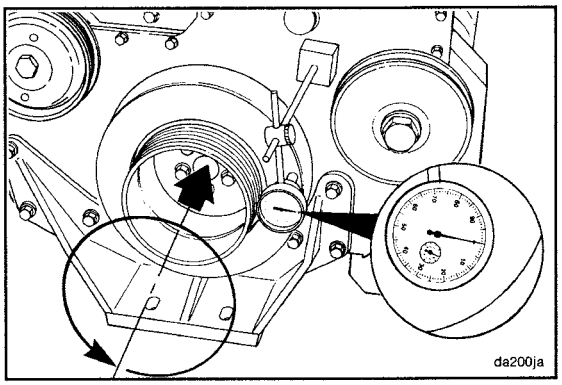
Push the crankshaft to the front or rear of the engine and "0" (zero) the indicator.



Rotate the crankshaft with the accessory driveshaft one complete revolution (360 degrees) while maintaining the position of the crankshaft either toward the front or the rear of the engine.

Record the total indicator movement.

Replace the damper if wobble exceeds 0.28 mm [0.011 in].



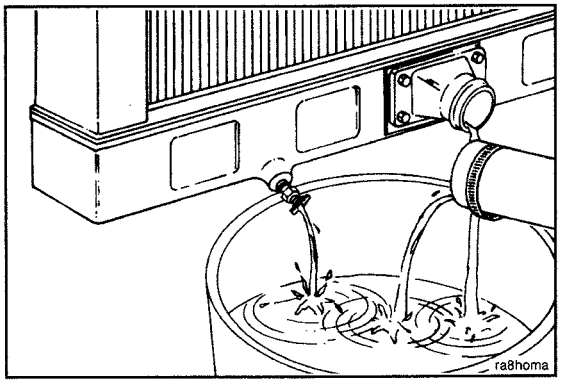
Water Header Plate, Cylinder Block (001-053)

Remove (001-053-002)

Drain the cooling system. Refer to Procedure 008-018.

Remove the intake piping.

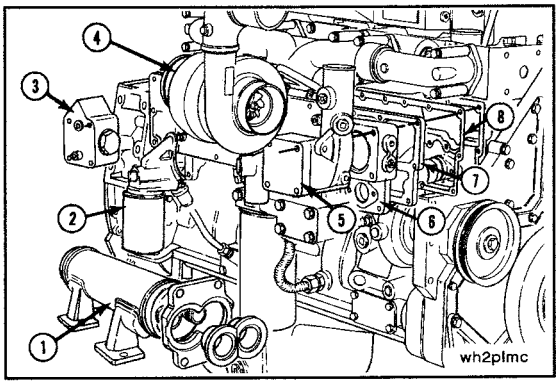
Remove the alternator belt and the alternator. Refer to Procedures 013-005 and 013-001.

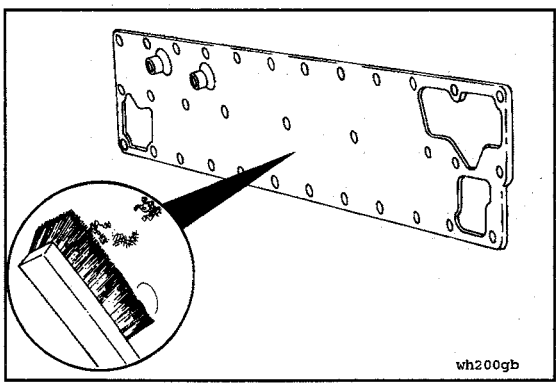


Remove the following components:

- Lubricating oil cooler (1), Procedure 007-003
- Coolant filter and filter head (2), Procedure 008-007
- Coolant heater housing (3), Procedure 008-011
- Turbocharger (4), Procedure 010-033.
- Coolant thermostat housing (5), Procedure 008-014
- Coolant thermostat housing support (6), Procedure 008-015.

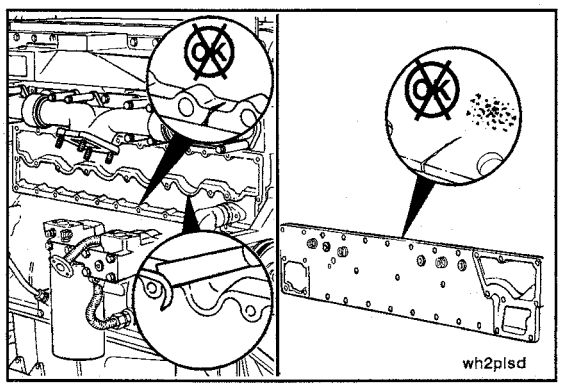
Remove the water header plate (7) and gasket (8).





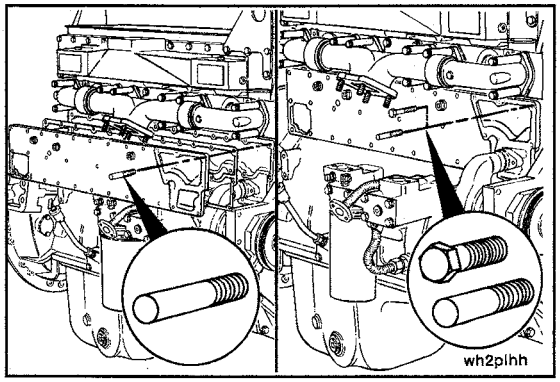
Clean (001-053-006)

Use a wire brush and a gasket scraper to clean the water header plate and the cylinder block gasket surface.



Inspect for Reuse (001-053-007)

Inspect the water header plate and the cylinder block gasket surface for cracks or other damage.



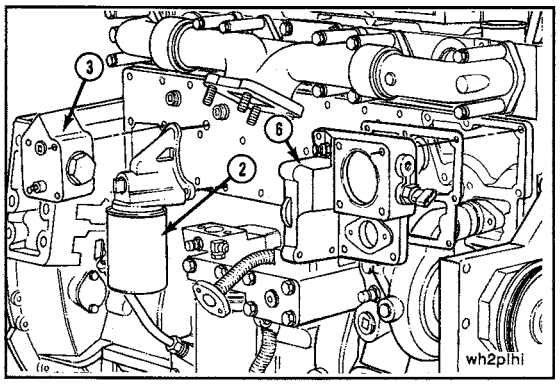
Install (001-053-026)

Install two guide pins, Part No. 3376488, in the top row of the water header plate mounting capscrew holes.

Use a new gasket, and install the water header plate and capscrews.

Remove the two guide pins, and install the other two capscrews.

NOTE: The capscrews are **not** tightened to their final value until all related components are installed.

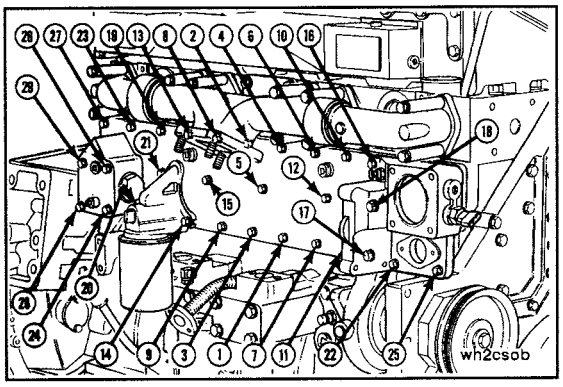


Install the following components:

- Coolant heater housing (3), Procedure 008-012
- Coolant filter head and filter (2), Procedure 008-007
- Coolant thermostat housing support and gasket (6), Procedure 008-015.

Tighten all capscrews in the sequence shown.

Torque Value: 54 N•m [40 ft-lb]

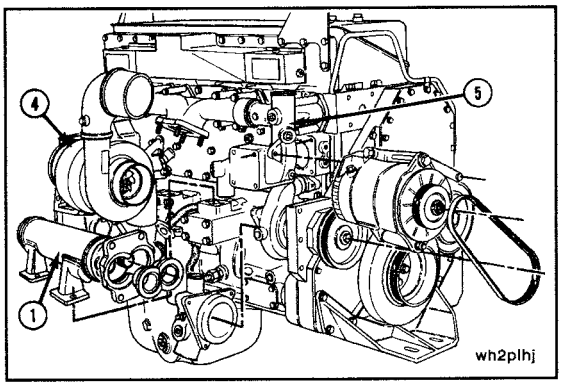


Install the following components:

- Lubricating oil cooler (1), Procedure 007-003
- Turbocharger (4), Procedure 010-033
- Coolant thermostat housing (5), Procedure 008-014.

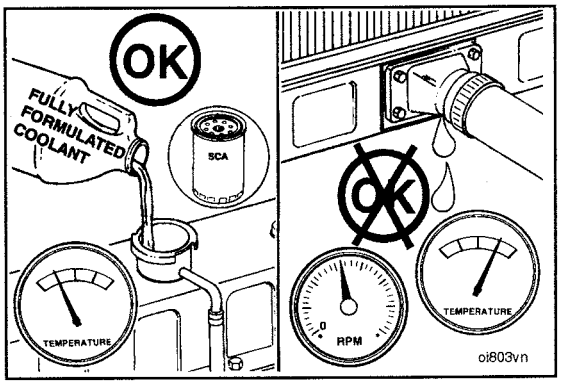
Install the intake piping.

Install the alternator and alternator belt. Refer to Procedures 013-001 and 013-005.



Fill the cooling system. Refer to Procedure 008-018.

Operate the engine until it reaches a temperature of 80°C [180°F] and check for coolant leaks.

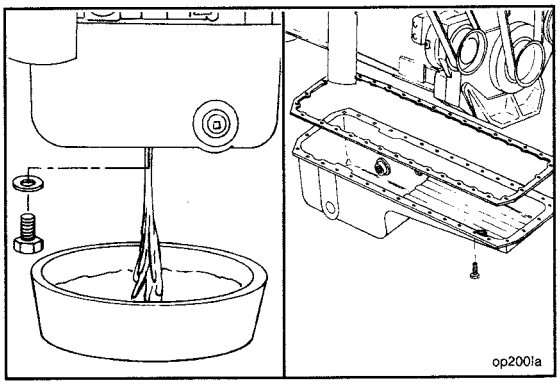


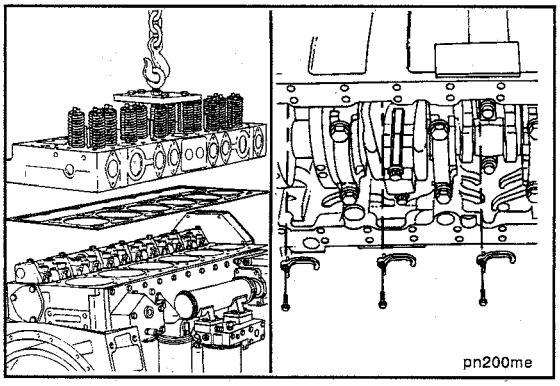
Piston and Connecting Rod Assembly (001-054)

Remove (001-054-002)

Drain the lubricating oil. Refer to Procedure 007-025.

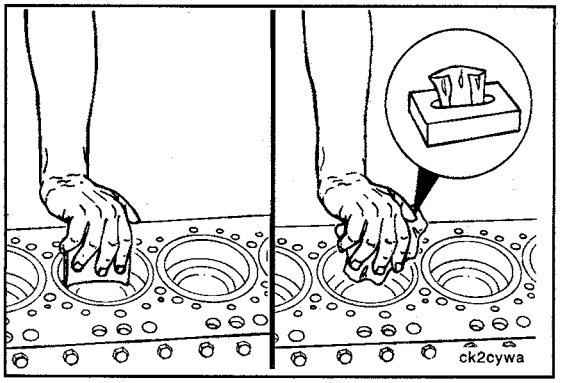
Remove the lubricating oil pan. Refer to Procedure 007-025.





Remove the cylinder head. Refer to Procedure 002-004.

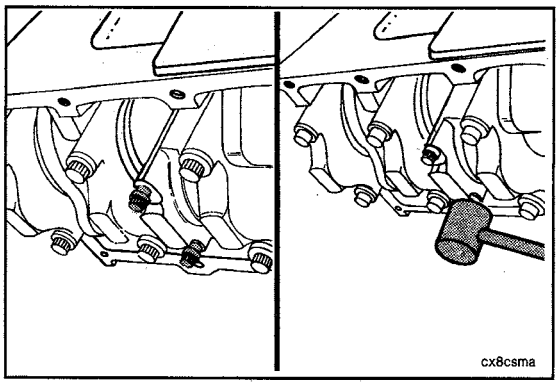
Remove the piston cooling nozzles. Refer to Procedure 001-046.



⚠ CAUTION ⚠

Do not use emery cloth or sandpaper to remove carbon from the cylinder liners. Aluminum oxide or silicon particles from emery cloth or sandpaper can cause serious engine damage. Do not use any abrasives in the ring travel area. The cylinder liner can be damaged.

Use a fine fibrous abrasive pad such as Scotch-Brite™ 7448, Part No. 3823258, or equivalent, and solvent to remove the carbon.

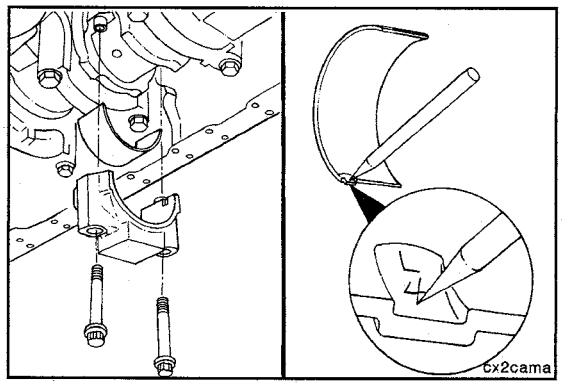


Rotate the crankshaft to position the rod caps at bottom dead center for removal.

Loosen the connecting rod capscrews.

NOTE: Do **not** remove the capscrews from the rods at this time.

Use a rubber hammer to hit the connecting rod capscrews to loosen the caps from the dowel rings.



Remove the connecting rod capscrews.

Remove the rod caps.

Remove the lower rod bearings.

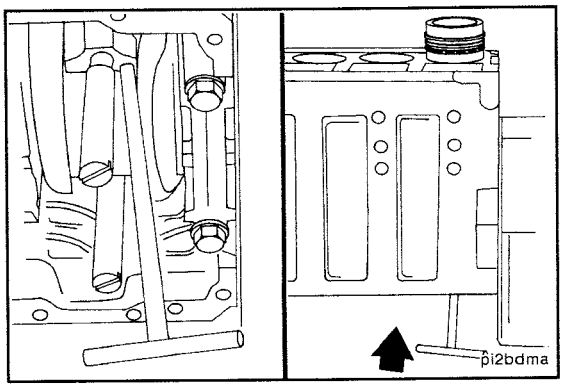
Mark the cylinder number and the letter "L" (lower) in the flat surface of the bearing tangs.

NOTE: Some M Series engines were built without drilled connecting rods and without bearings with an oil hole in the upper bearing shell. Beginning in the fall of 1995, all M series engines are built with drilled connecting rods and bearings with an oil hole in the upper bearing shell.

Install two connecting rod guide pins, Part No. 3376038.

Use a "t-handle" piston pusher to push the rod away from the crankshaft.

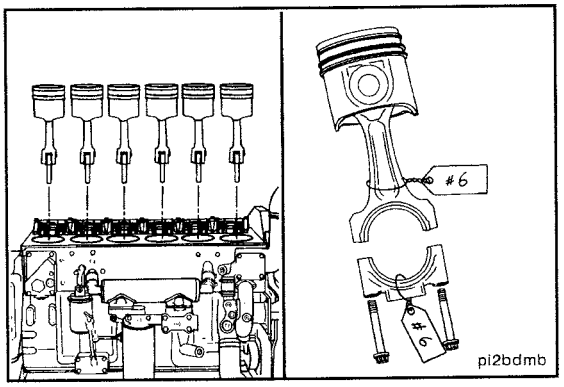
Push the rod until the piston rings are outside of the top of the cylinder liner.



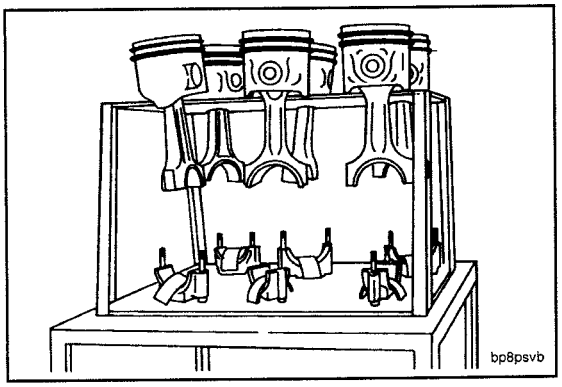
Use both hands to remove the piston and rod assembly.

The piston and connecting rod assemblies **must** be installed in the same cylinder number they were removed from to make sure a proper fit of worn mating surfaces exists if parts are used again.

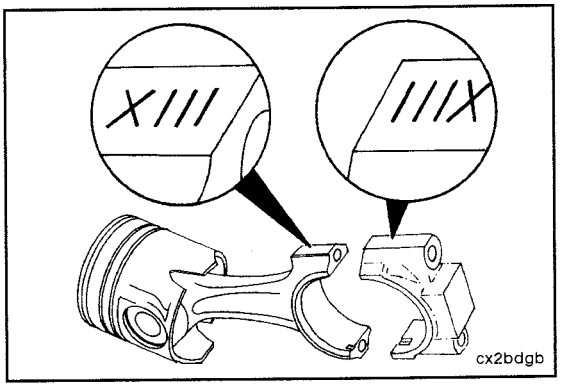
Use a tag to mark the cylinder number each piston and rod assembly was removed from.

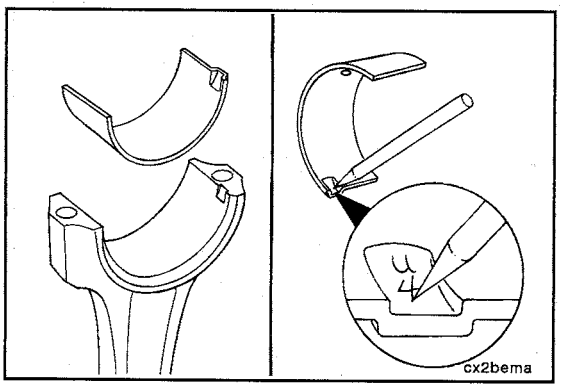


Place the rod and piston assemblies in a container to protect them from damage.



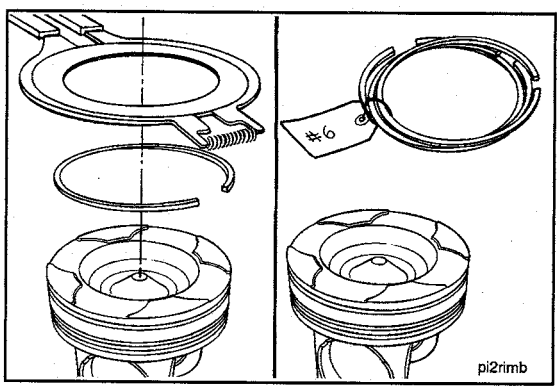
A unique number (**not** cylinder number) is stamped on the connecting rod and matching cap. When the rods and caps are installed in the engine, the numbers on the rods and caps **must** match and be installed on the same side of the engine.





Remove the upper rod bearing.

Mark the cylinder number and the letter "U" (upper) in the flat surface of the bearing tang.

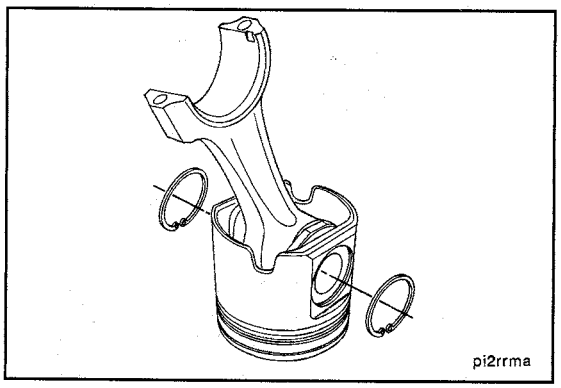


Disassemble (001-054-003)

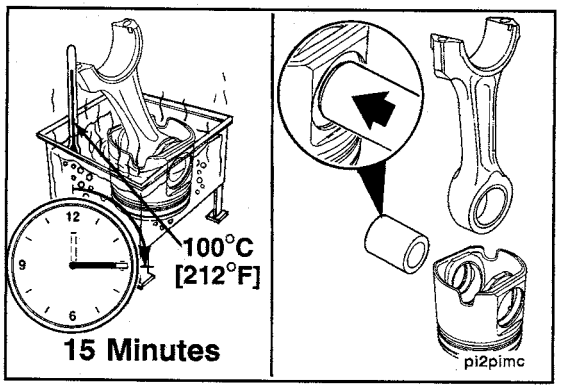
Use piston ring expander, Part No. ST-821, to remove the piston rings.

Place a tag on the rings, and record the cylinder number of the piston on the tag.

NOTE: Refer to Procedure 001-047 for piston ring inspection.



Use internal snap ring pliers to remove the snap rings from both sides of the piston.



⚠ CAUTION ⚠

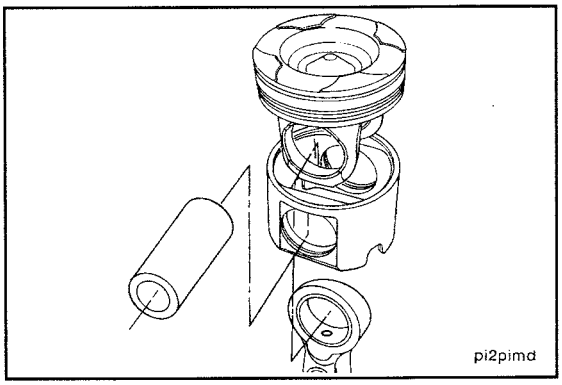
Do not use a hammer to remove the piston pins. The piston can distort, causing it to seize in the liner.

If the piston pin can**not** be easily removed by hand:

- Install the piston and rod assembly in a container of water.
- Heat the piston in boiling water for 15 minutes.
- Use a blunt tool to push the piston pin from the piston and rod assembly.

NOTE: When the piston pin is removed from an articulated piston, the skirt will separate from the crown. Use care to prevent damage to the piston.

Mark the cylinder number the piston, crown, skirt, and pin was removed from on the parts to **make sure** they are installed in the correct cylinder if they are used again.



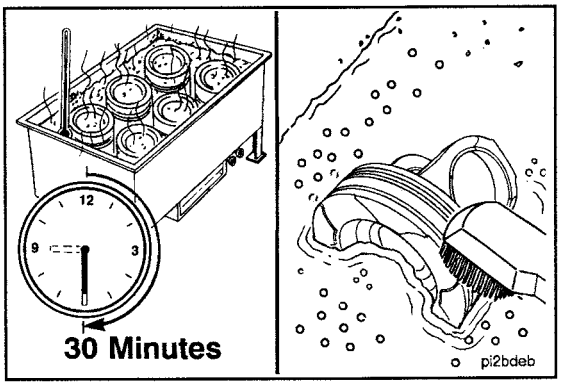
Clean (001-054-006)

⚠ CAUTION ⚠

Be sure the cleaning solvent is approved for aluminum. Damage to the pistons can result if the wrong solution is used.

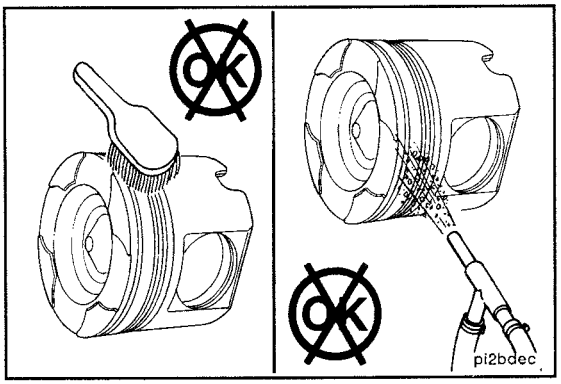
Allow the pistons to soak for a minimum of 30 minutes in a tank containing an approved cleaning solvent for aluminum.

Use a hot, soapy solution and a nonmetallic brush to remove carbon deposits.



⚠ CAUTION ⚠

Do not use a metal brush. A metal brush will damage the piston ring grooves. Do not use glass beads to clean the grooves. Walnut shell or plastic bead, Part No. 3822735, blasting can be used on ring grooves on the dome or crown of the piston. Use the minimum effective pressure, and do not concentrate the spray in one area for an extended period of time. The recommended blast pressure for plastic bead blasting is 276 kPa [40 psi]. Do not use glass beads or walnut shell blasting on the aluminum piston pin bores or articulated piston skirts. This can cause piston pin bore damage.

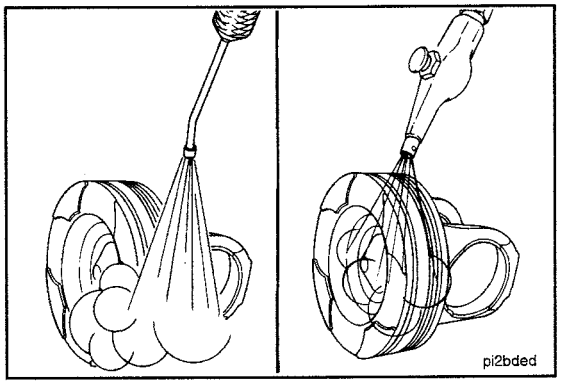


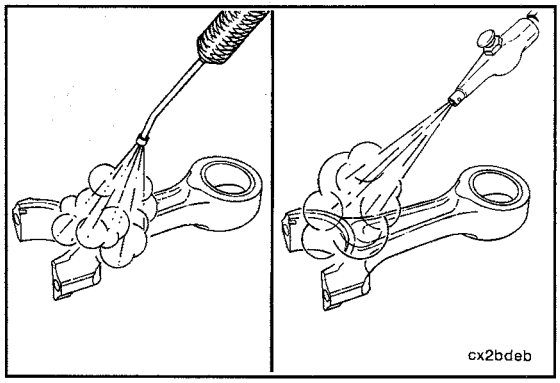
⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

Use steam to clean the pistons.

Dry with compressed air.

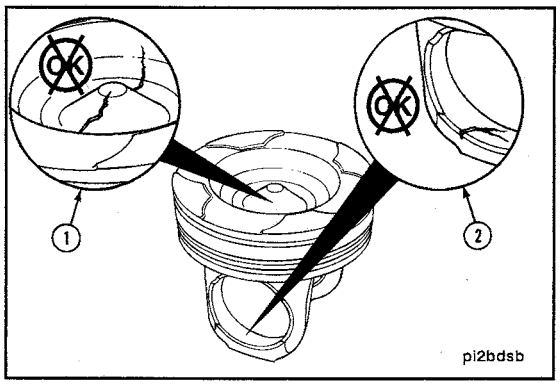




⚠ WARNING ⚠

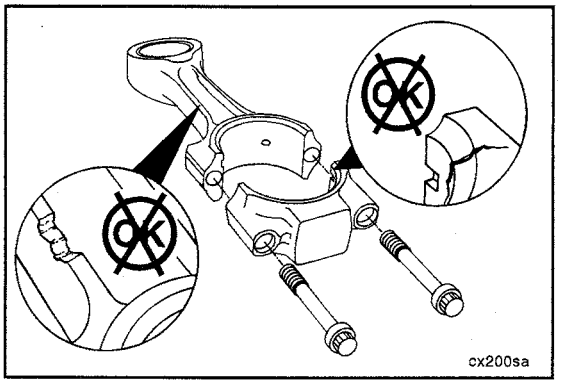
When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

Use steam or solvent to clean the connecting rods. Dry with compressed air.

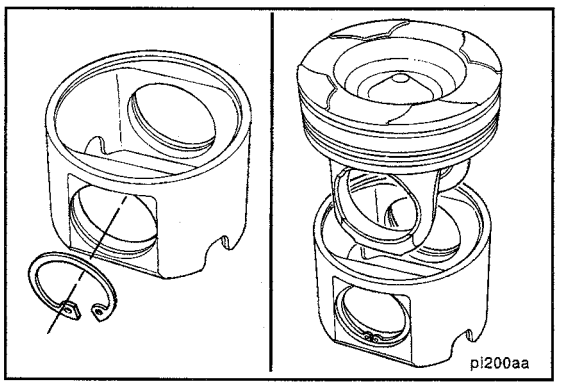


Inspect for Reuse (001-054-007)

Refer to Procedure 001-043 for inspection specifications for M series pistons.



Refer to Procedure 001-014 for inspection specifications for M series connecting rods.



Assemble (001-054-025)

△ CAUTION △

The retainer snap ring must be seated completely in the piston pin groove to prevent engine damage during engine operation.

Install a new snap ring in one piston pin bore of each piston skirt.

NOTE: If the pistons are being reused, the crown, skirt, and pin **must** be matched as they were when they were removed.

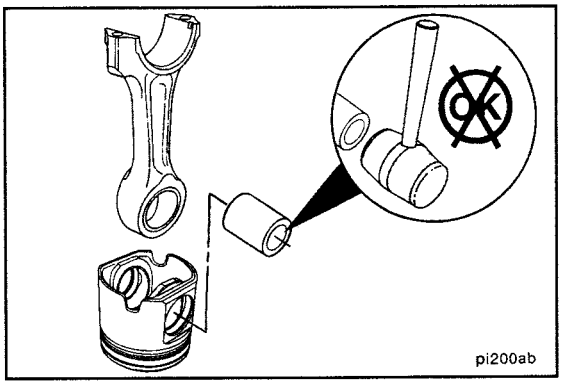
Position the skirt over the piston crown.

NOTE: It is **not** necessary to heat the articulated pistons before assembly. The piston pin is slip fitted.

⚠ CAUTION ⚠

Do not use a hammer to install the piston pin. The piston can distort, causing it to seize in the liner.

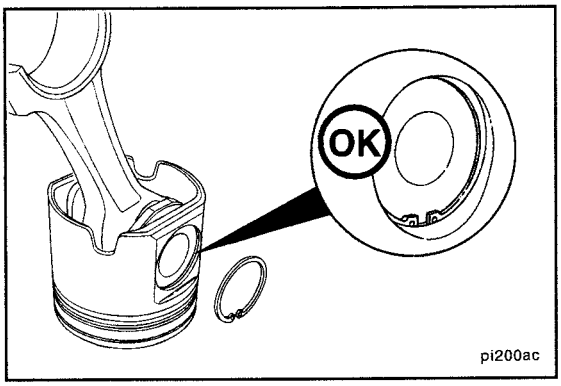
Align the pin bore of the rod with the pin bore of the piston skirt and crown, and install the piston pin.



⚠ CAUTION ⚠

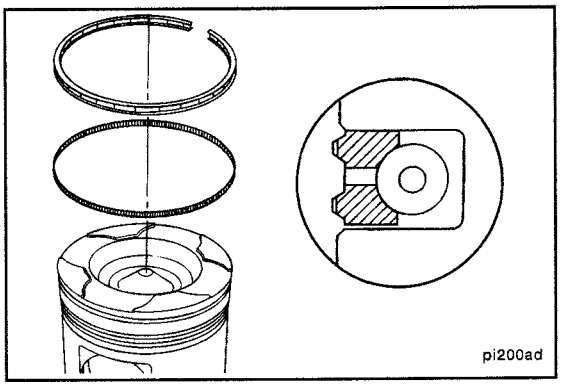
The snap ring must be seated completely in the piston groove to prevent engine damage during engine operation.

Install a new snap ring in the piston pin bore.



A cross-sectioned view of an oil control ring is shown.

The two-piece oil control ring **must** be installed with the expander ring gap 180 degrees from the gap of the oil ring. Do **not** overlap the ends of the expander ring.

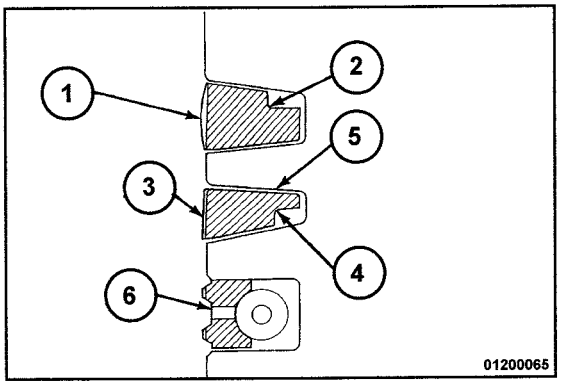


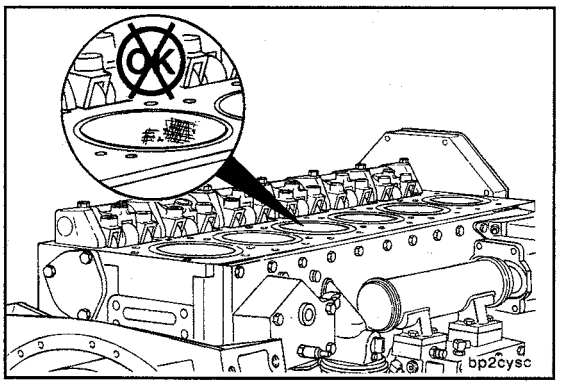
Use piston ring expander, Part No. ST-821, to install the rings on the piston.

The top piston ring (1) is a positive twist design that has a cutback notch (2) on the topside of the ring.

The intermediate ring (3) is a negative twist design with a cutback notch (4) on the bottomside and a two-degree taper face. It also has a black phosphate coating (5), which helps to readily distinguish it from the top ring.

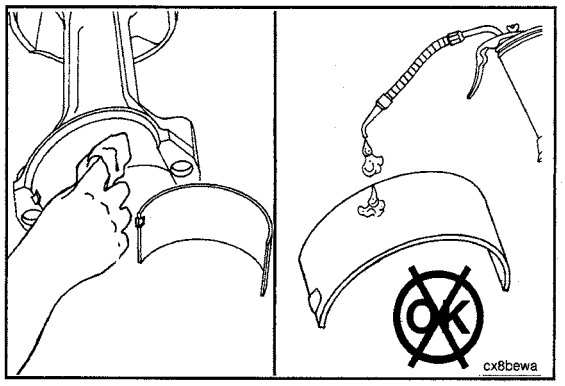
The oil control ring (6) is the bottom piston ring.





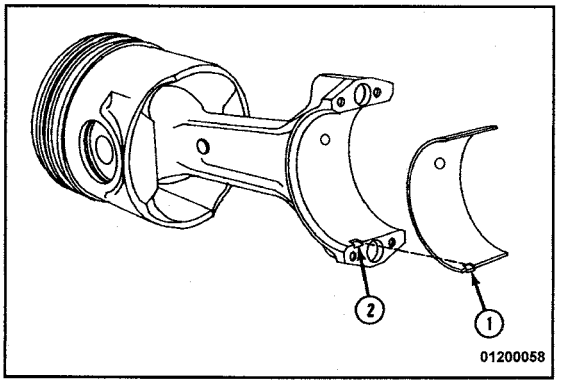
Install (001-054-026)

The cylinder block and all parts **must** be clean before assembly. Refer to Procedure 001-028 to inspect the cylinder liners for reuse.



Use a clean, lint free cloth to clean the connecting rods and bearing shells.

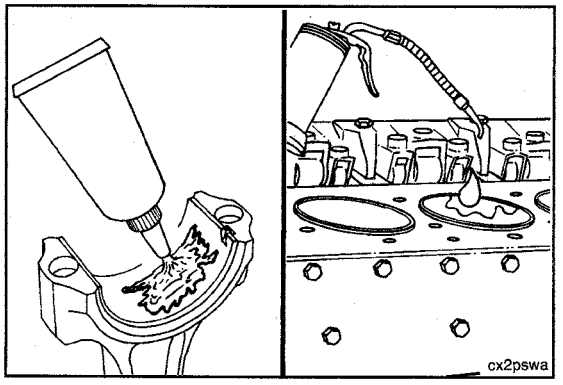
Do **not** lubricate the backside of the bearing shells. The operating clearance of the bearing will be reduced and the bearing can be damaged during engine operation.



If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod from which they were removed.

Install the upper bearing shell into the connecting rod.

The tang of the bearing shell (1) **must** be in the slot of the rod (2). The end of the bearing shell **must** be even with the cap mounting surface.

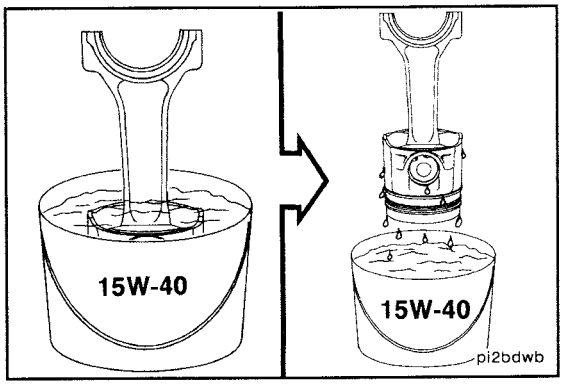


Use Lubriplate™ 105, or equivalent, to coat the inside diameter of the bearing shell.

Apply a heavy film of clean 15W-40 oil to the liner.

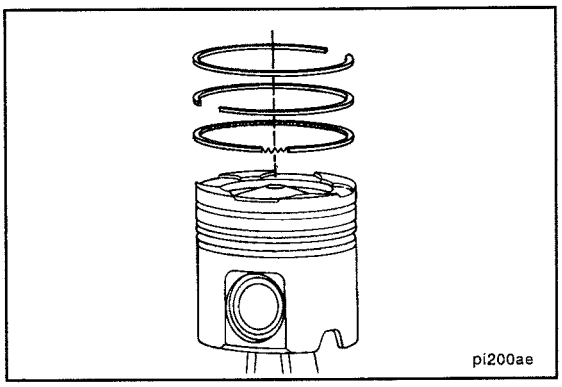
Install the piston and ring assembly in a container of clean 15W-40 oil.

Remove the piston and ring assembly from the container, and let the excess oil drain from the piston.



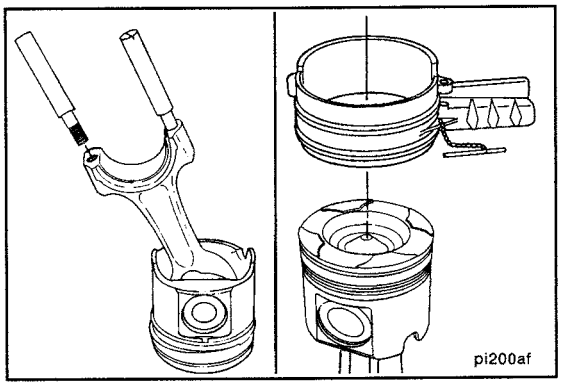
Rotate the rings to position the ring gaps as shown.

NOTE: The ring gap of each ring **must not** be aligned with the piston pin or with any other ring. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.

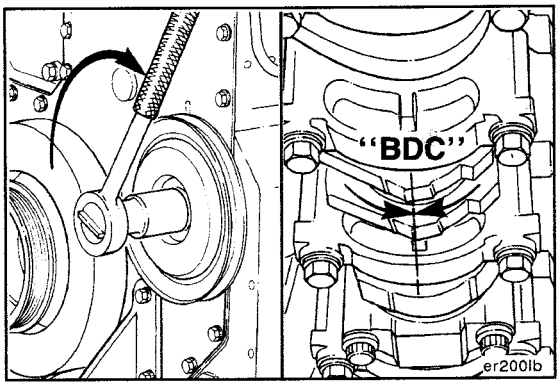


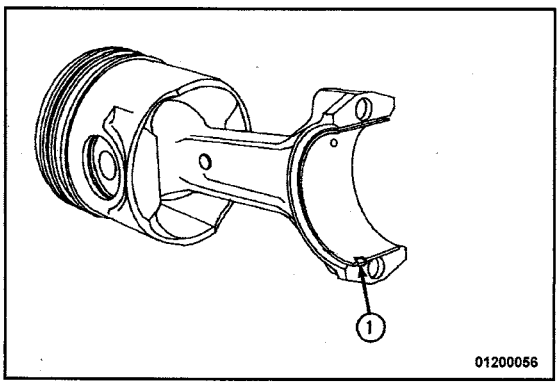
Install connecting rod guide pins, Part No. 3376038.

Use piston ring compressor, Part No. 3823309, to compress the rings.

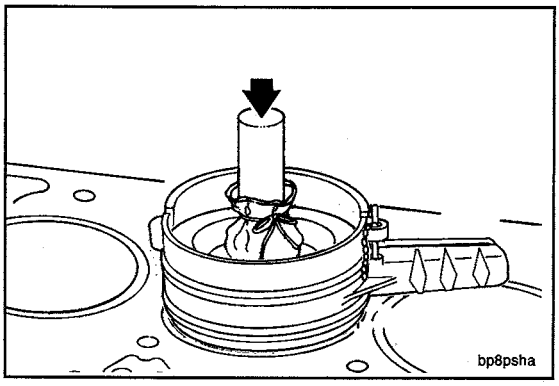


Use the accessory drive pulley to rotate the crankshaft so the connecting rod journal of the connecting rod being installed is at bottom dead center.





Insert the connecting rod through the cylinder liner with the bearing tang (1) toward the camshaft side of the engine until the ring compressor contacts the top of the liner.

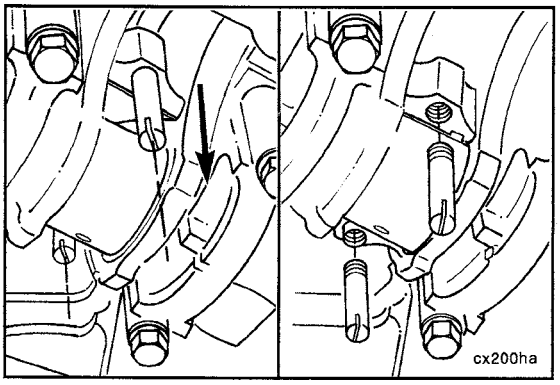


⚠ CAUTION ⚠

Do not use a metal drift to push the piston into the cylinder liner. The piston rings or cylinder liner can be damaged.

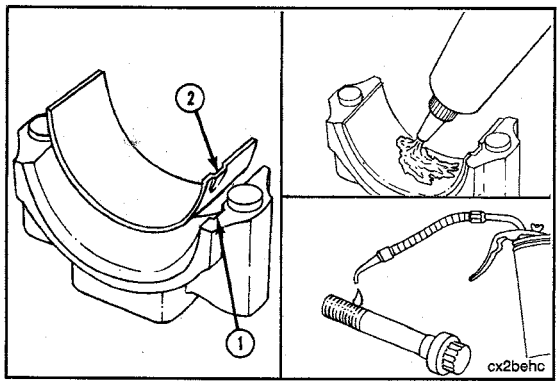
Hold the ring compressor against the cylinder liner. Push the piston through the ring compressor and into the cylinder liner. Push the piston until the top ring is completely in the cylinder liner.

NOTE: If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.



Use the nylon guide pins to align the connecting rod with the crankshaft while pushing the piston and rod assembly in place.

Remove the nylon guide pins.



NOTE: If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod cap from which they were removed.

Install the bearing in the connecting rod cap.

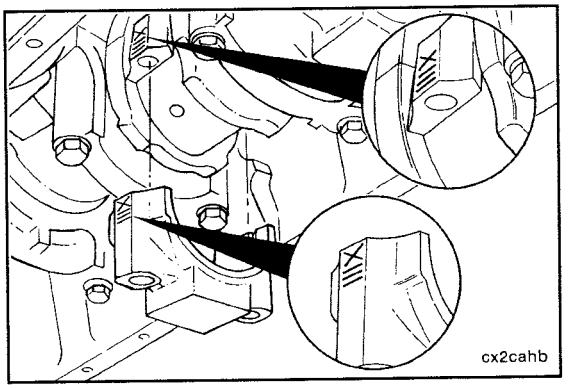
The tang of the bearing (2) **must** be in the slot of the cap (1).

Use Lubriplate™ 105, or equivalent, to coat the inside diameter of the bearing shell.

Use clean 15W-40 oil to lubricate the connecting rod capscrew threads.

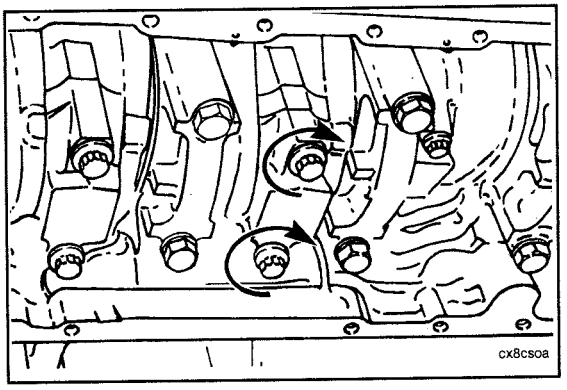
The connecting rod and cap **must** have the same number and **must** be installed in the proper cylinder. The connecting rod cap number and rod number **must** be on the same side of the connecting rod to prevent engine damage during engine operation.

Install the connecting rod caps and capscrews.



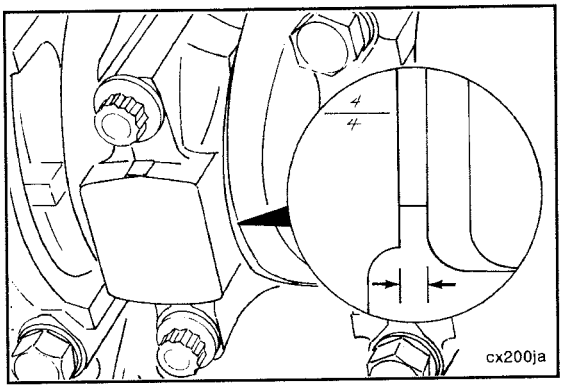
Complete the following steps to tighten the rod capscrews in alternating sequence:

Torque Value: Step 1 68 N•m [50 ft-lb]
2 142 N•m [105 ft-lb]
3 210 N•m [155 ft-lb]
4 Loosen completely
5 Repeat steps 1 through 3



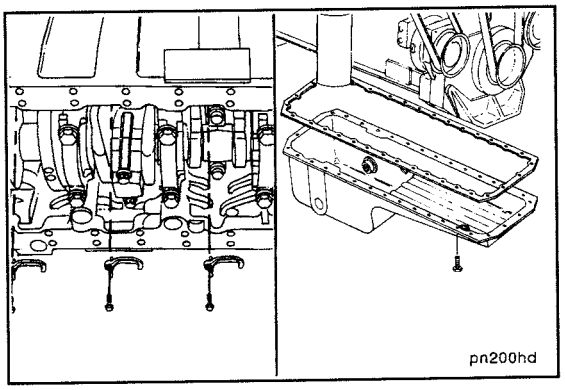
Measure the connecting rod side clearance.

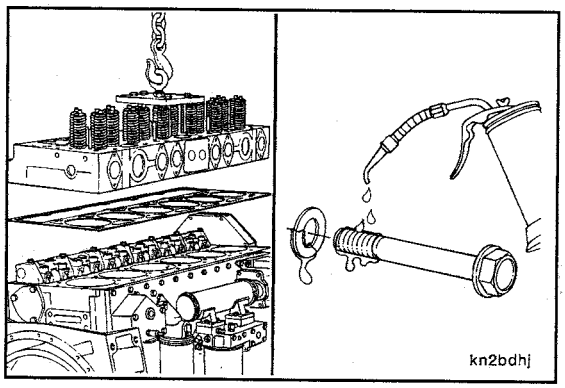
Connecting Rod Side Clearance		
mm		in
0.10	MIN	0.004
0.30	MAX	0.012



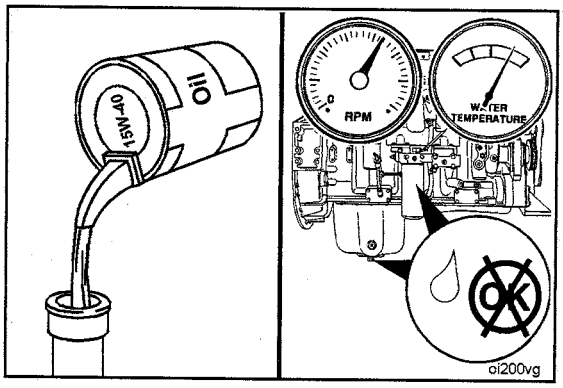
Install the piston cooling nozzles. Refer to Procedure 001-046.

Install the lubricating oil pan. Refer to Procedure 007-025.



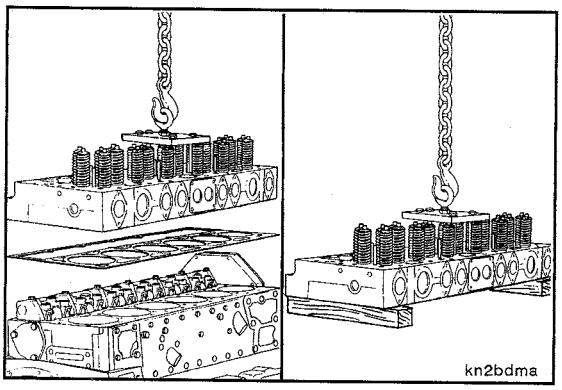


Install the cylinder head. Refer to Procedure 002-004.



Fill the lubricating oil pan. Refer to Procedure 007-025.

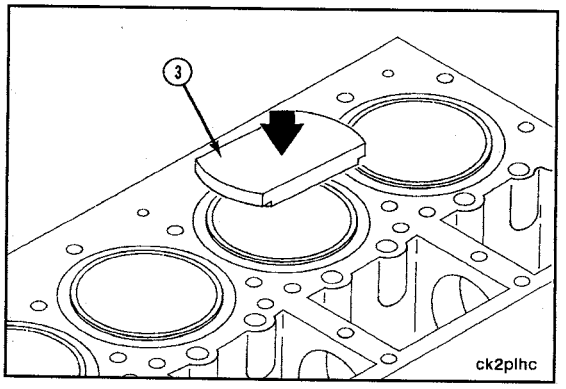
Operate the engine to normal operating temperature and check for leaks.



Cylinder Liner Protrusion (001-064)

Preparatory (001-064-000)

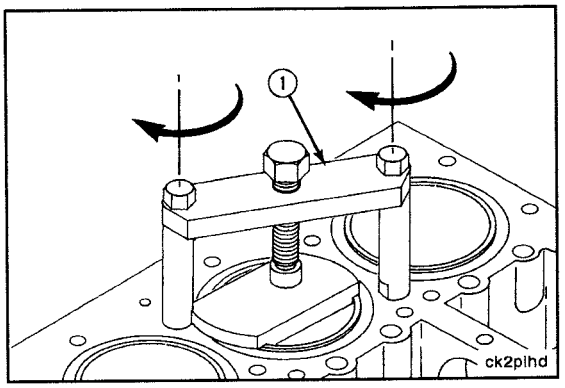
To measure the cylinder liner protrusion, the cylinder head **must** be removed. If the cylinder head is **not** removed, Refer to Procedure 002-004 for instructions on how to remove the cylinder head.



Use cylinder liner clamping tool, Part No. 3824272, to seat the liner in the cylinder block.

Place the force plate (3) across the top of the liner with the step inside the liner bore.

Put the installation tool bridge (1) across the liner, and install the two cylinder head capscrews finger-tight to hold the bridge down. Rotate the force plate until the areas where the protrusion measurements will be taken are exposed.



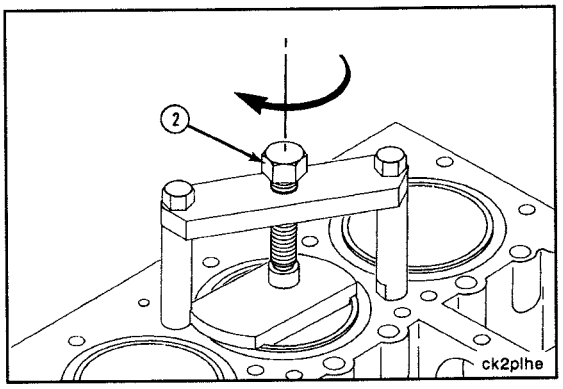
⚠ CAUTION ⚠

Do not use an impact wrench to tighten the liner force plate screw. Excessive torque will cause damage to the liner installation tool.

Tighten the forcing screw (2).

Torque Value: 136 N•m [100 ft-lb]

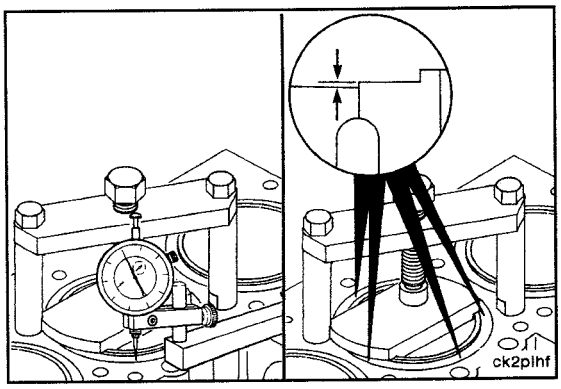
Check for correct protrusion.



Measure (001-064-010)

Use a depth gauge, Part No. 3823495, to measure the liner protrusion at four points 90-degrees apart.

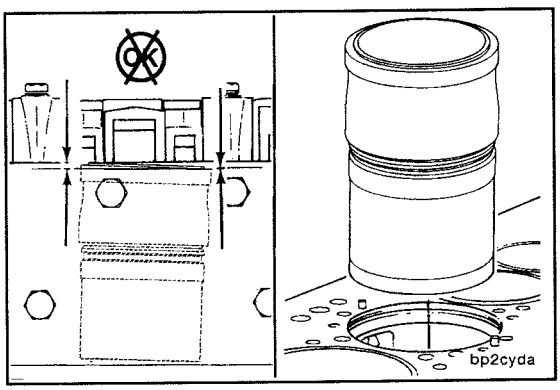
Cylinder Liner Protrusion		
mm		in
0.00	MIN	0.000
0.13	MAX	0.005

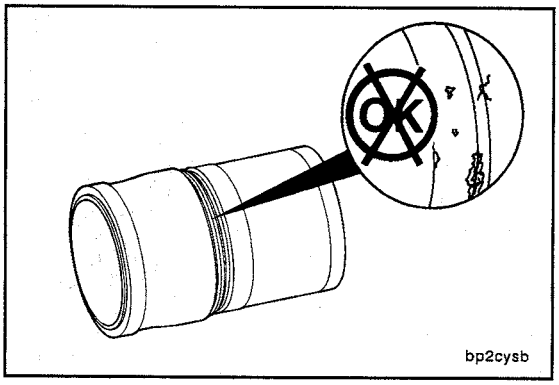


If the liner protrusion varies more than 0.025 mm [0.0010 in] for each 180 degrees:

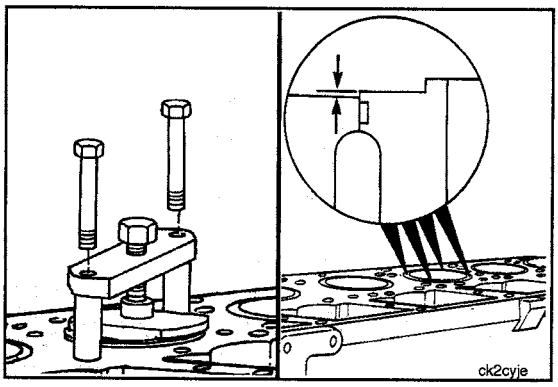
- Remove the liner.

NOTE: It will be necessary to remove the piston and connecting rod assembly, if this has **not** already been done, before removing the cylinder liner. Refer to Procedure 001-054.



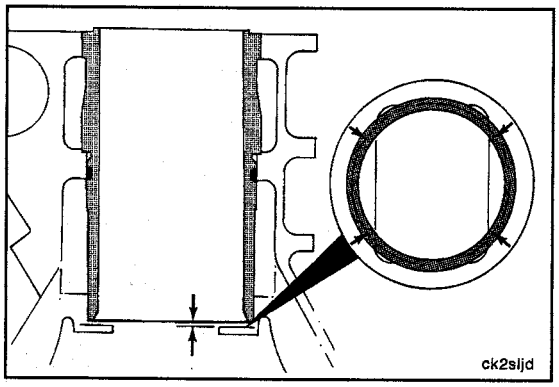


- Inspect the liner sealing edge for burrs, dirt, or damage.
- Replace the liner if it is damaged.



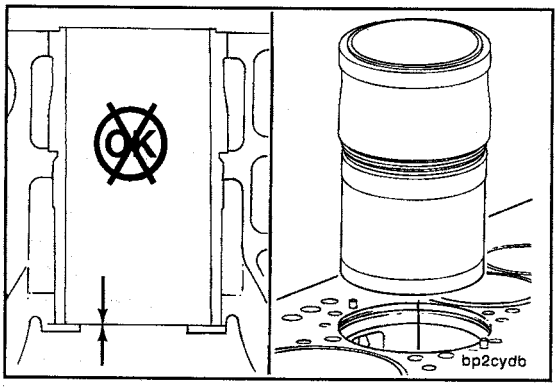
- Install the liner again.
- Inspect the liner protrusion.

If the liner protrusion still does **not** meet the specifications, cut the cylinder block liner bore for shims. Refer to the Alternative Repair Manual, Bulletin No. 3810310, for the correct procedure.



Use a feeler gauge to inspect the liner-to-block clearance at the four-block casting points.

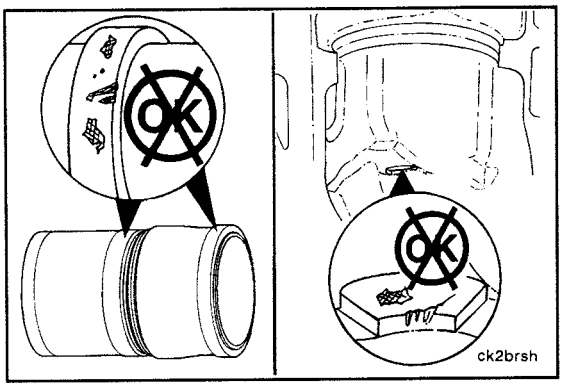
Cylinder Liner-to-Block Clearance		
mm		in
0.25	MIN	0.010



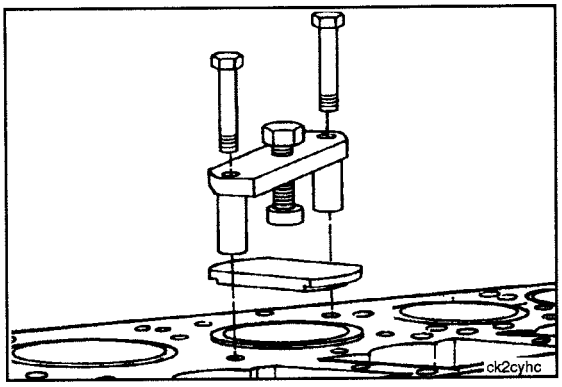
If the clearance is less than 0.25 mm [0.010 in]:

- Remove the liner.

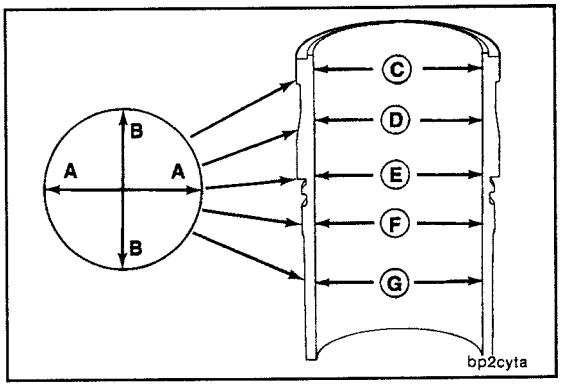
- Inspect the liner and cylinder block for dirt or damage.



- Replace the liner if it is damaged.
- Install the liner again.



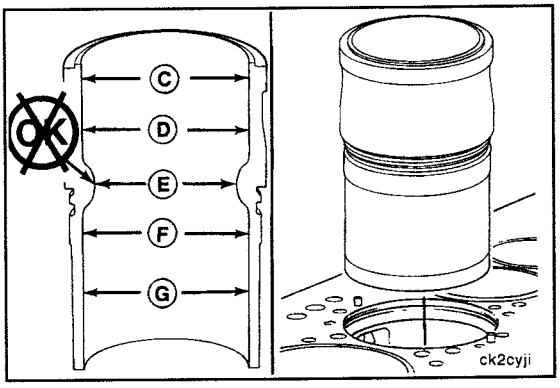
Measure the liner bore for out of roundness at points "C," "D," "E," "F," and "G." Measure each point in the direction "AA" and "BB". The bore **must not** be more than 0.10 mm [0.004 in] out-of-round.

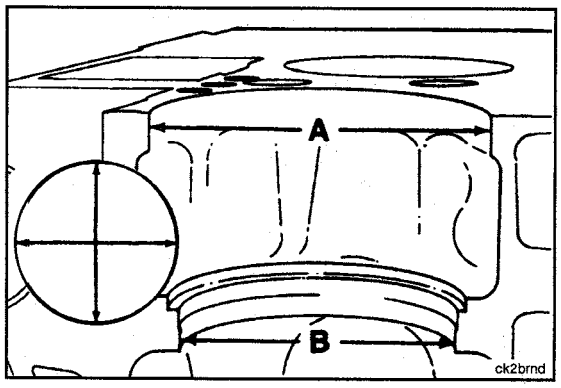


If the liner bore is more than 0.10 mm [0.004 in] out-of-round:

- Remove the liner so the cylinder block liner bore can be measured.

NOTE: The block counterbore diameters above and below the cylinder block counterbore area are **not** critical dimensions, and do **not** need to be measured.



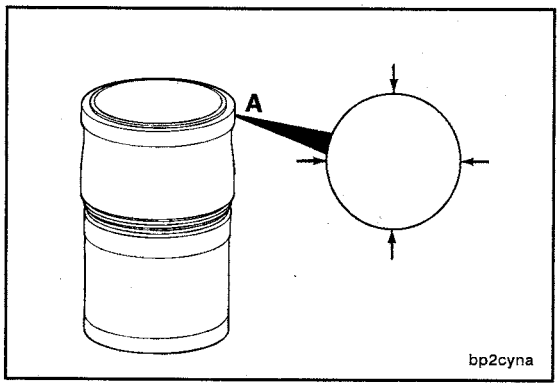


Measure the cylinder block upper liner bore (A).

Cylinder Block Upper Liner Bore Inside Diameter (A)		
mm		in
145.900	MIN	5.7441
146.027	MAX	5.7491

Measure the cylinder block liner seal seat bore (B) 8.0 to 13.5 mm [0.32 to 0.53 in] below the counterbore.

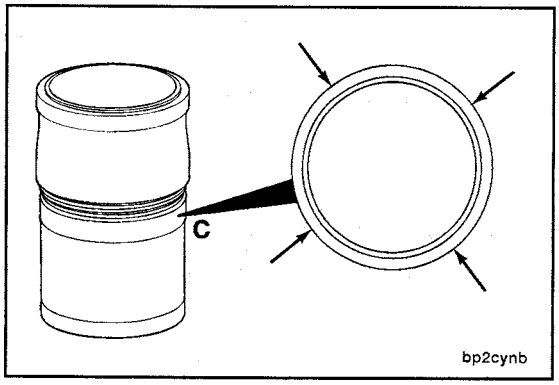
Cylinder Block Liner Seal Seat Bore Inside Diameter (B)		
mm		in
138.063	MIN	5.4355
138.113	MAX	5.4375



Measure the liner outside diameter (A).

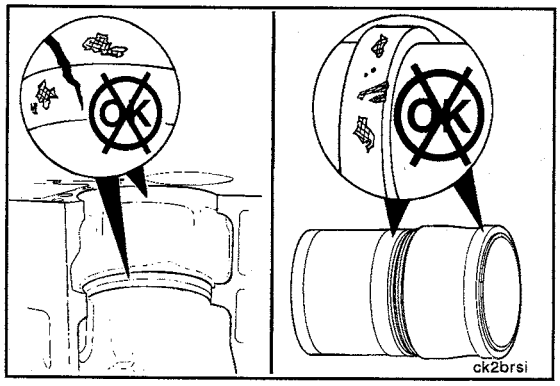
Cylinder Liner Top Press Fit Outside Diameter (A)		
mm		in
145.938	MIN	5.7456
145.976	MAX	5.7471

NOTE: The cylinder block liner counterbore flange diameter is **not** a critical dimension and does **not** need to be measured.



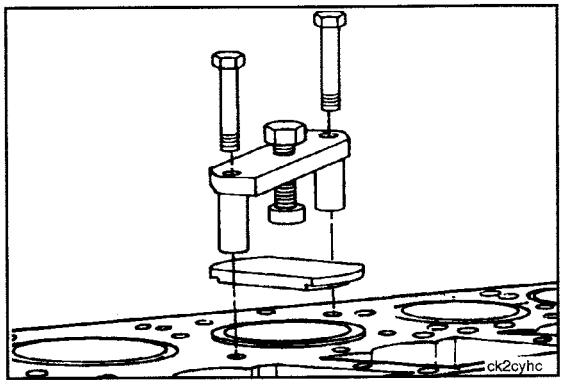
Measure the cylinder liner seal seat outside diameter (C).

Cylinder Liner Seal Seat Outside Diameter (C)		
mm		in
137.937	MIN	5.4306
138.013	MAX	5.4336



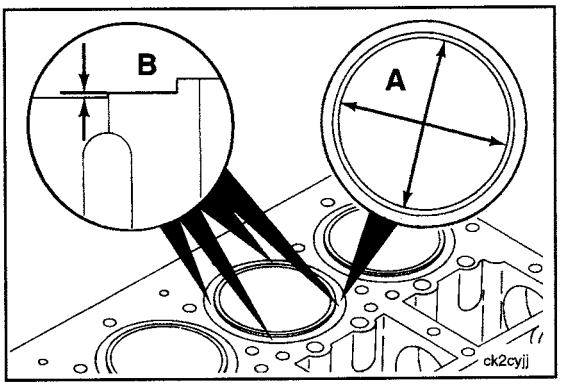
Inspect the cylinder block liner bore and liner for burrs, dirt, or damage.

Replace the liner if it is damaged.



Inspect the liner bore (A) and protrusion again (B).

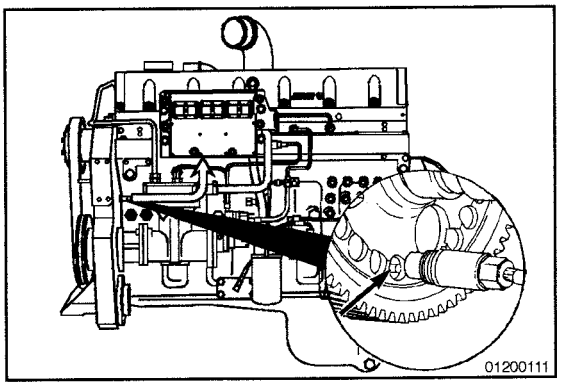
Replace the liner if it does **not** meet the specifications.



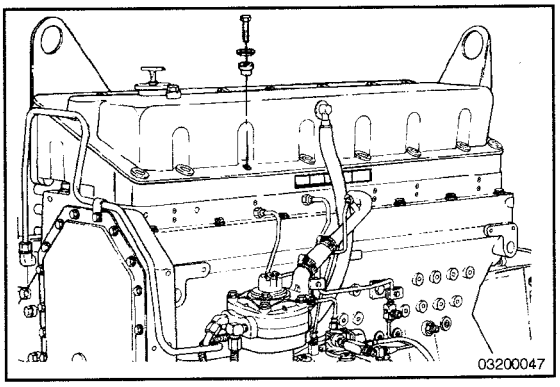
Camshaft End Clearance (001-065)

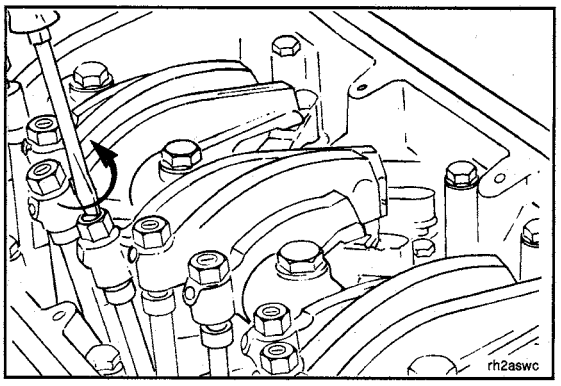
Measure (001-065-010)

A condition on M series engines where the engine will **not** start or is difficult to start can be caused by excessive clearance between the engine position sensor and the pickup on the back of the camshaft gear. This condition prevents the engine position sensor from sending the necessary signal to the electronic control module. The excessive clearance can be caused by a failed thrust bearing on the camshaft. Use this procedure to measure the camshaft end clearance in-chassis on M series engines without removing the front gear cover. If the end clearance is **not** within the specifications given, the gear cover **must** be removed and the cause of the excessive end clearance repaired.



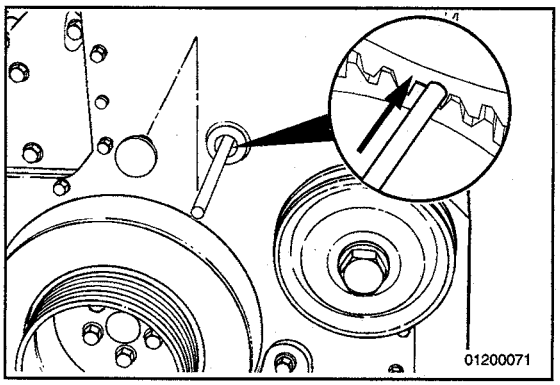
To measure the camshaft end clearance without removing the front gear cover, first remove the rocker lever cover. Refer to Procedure 003-011.





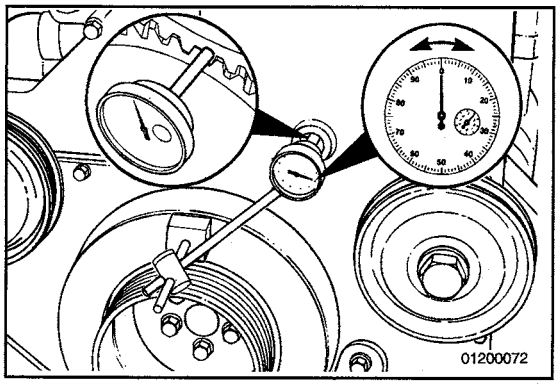
Loosen the locknut and turn out the adjusting screw on each injector and valve rocker lever. The overhead load on the camshaft **must** be released to allow free movement of the camshaft.

NOTE: It is **not** necessary to remove the push rods or push tubes.



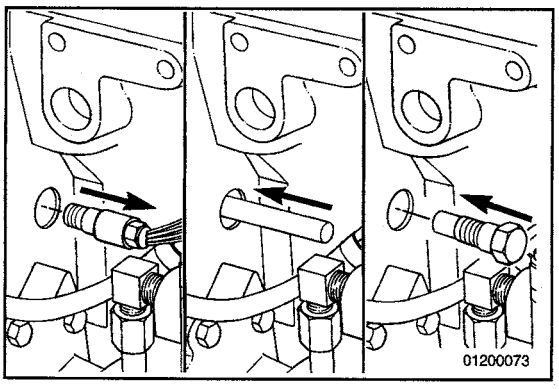
Remove the inspection plug in the front of the gear cover.

Use a rod against the camshaft gear to push the camshaft as far as possible toward the rear of the engine.



Set up a dial indicator gauge, Part No. 3376050, and extension, Part No. ST-537-4, with a magnetic base on the front of the cylinder head or vibration damper. Place the tip of the indicator on the face of the camshaft gear through the gear cover inspection hole.

Set the dial indicator to zero.



Remove the engine position sensor from the rear of the gear housing.

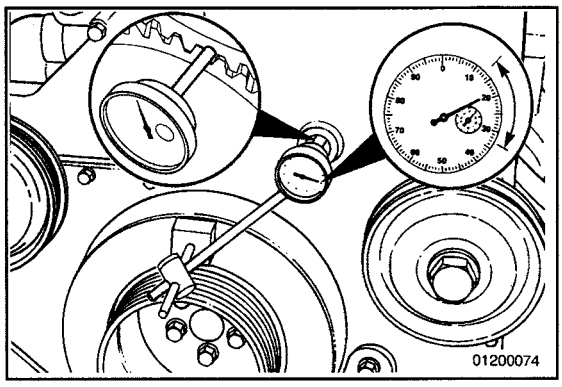
Use a rod to reach inside the gear housing through the engine position sensor mounting hole and push the camshaft gear as far as possible toward the front of the engine.

NOTE: If access limits make it difficult to push the camshaft by hand, a threaded bolt (3/4 x 16) can be threaded into the hole and used as a pushing device against the back of the cam gear. The capscrew needs to have the threads ground off, approximately 25.4 mm [1 in] back from the end. Although the hole is threaded clear through the gear housing, this will make sure the capscrew does **not** contact anything but the camshaft gear.

Record the measurement on the dial indicator.

Camshaft End Clearance		
mm		in
0.13	MIN	0.005
0.33	MAX	0.013

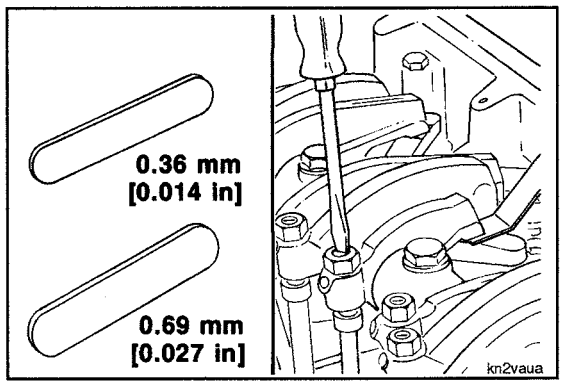
If the camshaft end clearance does **not** meet the above specifications, the front cover **must** be removed and the camshaft thrust plate inspected. Refer to Procedure 001-008.



Adjust the valve and injectors. Refer to Procedure 003-004.

Install the camshaft inspection plug in the gear cover.

Install the engine position sensor.



NOTES

Section 2 - Cylinder Head - Group 02

Section Contents

Page

Cylinder Head 2-2
Clean 2-6
Inspect for Reuse 2-7
Install 2-13
Leak Test 2-12
Pressure Test 2-10
Remove 2-2

Service Tools 2-1
Cylinder Head 2-1

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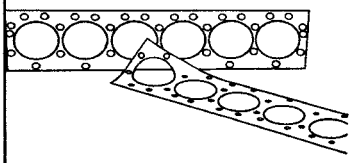
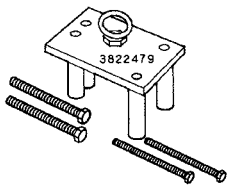
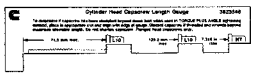
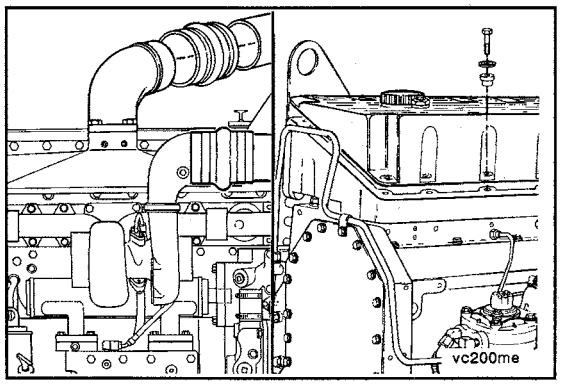
Service Tools

Cylinder Head

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3376082	**Cylinder Head Water Test Fixture** Used to pressure-test the cylinder head injector sleeves for leakage.	 kn2togv
3822479	**Cylinder Head Lifting Bracket** Used for lifting the cylinder head on and off the engine.	 3822479
3823546	**Cylinder Head Capscrew Length Gauge** Used to measure the length of the cylinder head mounting capscrews.	 3823546

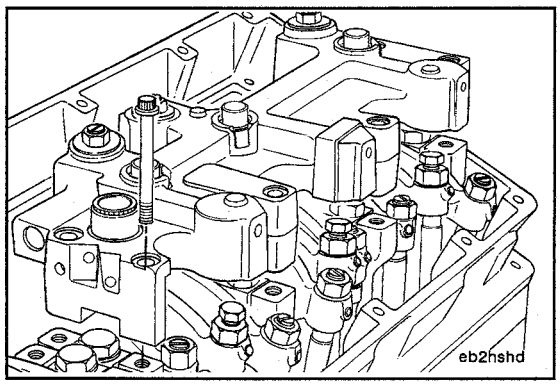


Cylinder Head (002-004)

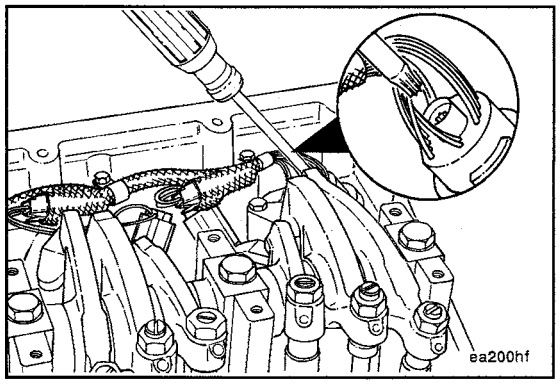
Remove (002-004-002)

Remove the air piping from the intake manifold and the turbocharger.

Remove the rocker lever cover. Refer to Procedure 003-011.



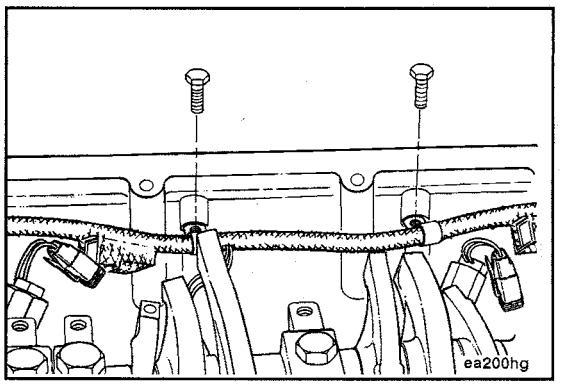
Remove the engine brakes, if applicable. Refer to Procedure 020-001.



The internal engine wiring harness is located under the rocker lever cover.

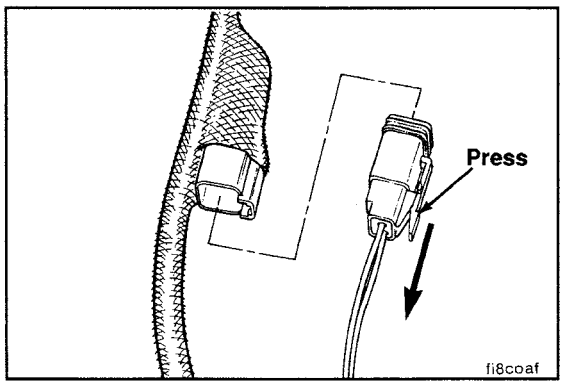
Remove the locking capscrew from the Metri-Pack 12-pin connector at the rear end of the rocker lever housing, and separate the connector.

NOTE: The connector is held together with a Torx (six-pointed star) screw. Use a Torx (size T-25) screwdriver to disconnect this connector.

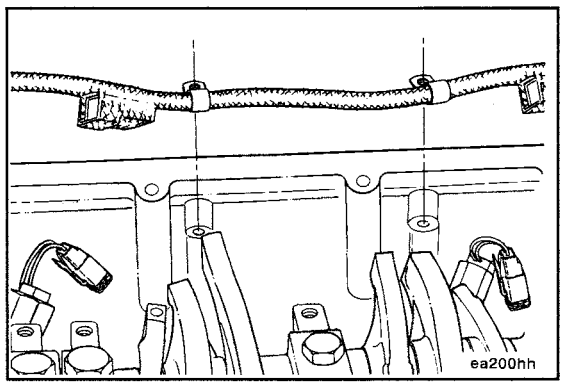


Remove the internal engine wiring harness holding clamp capscrews.

Separate the Deutsch 2-pin connectors from the internal engine wiring harness to the fuel injectors.

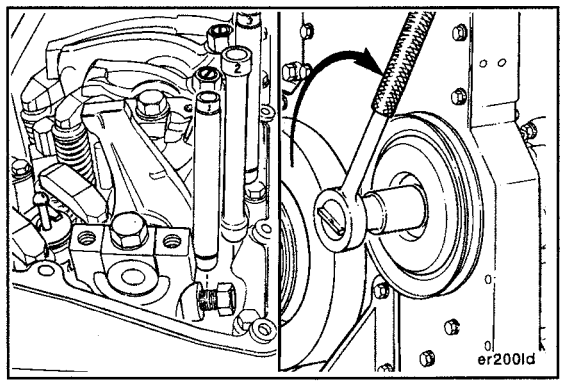


Remove the internal engine wiring harness from the engine.

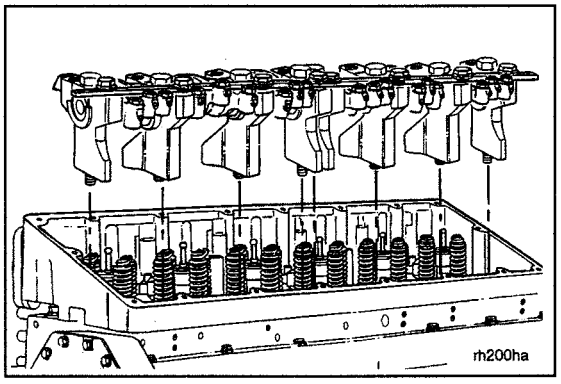


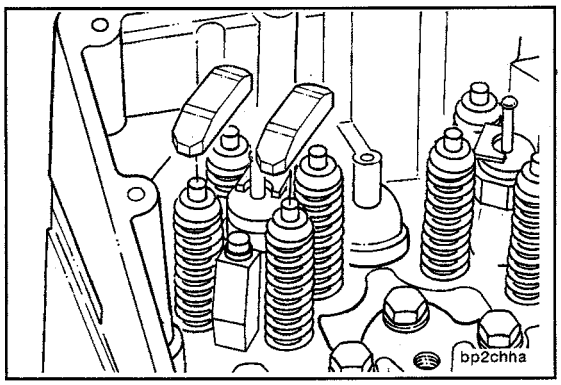
Remove the push tubes and push rods. Refer to Procedure 004-014.

NOTE: Mark the position of the crossheads as they are removed. The crossheads **must** be installed in the same position when the engine is assembled.



Remove the rocker lever assemblies. Refer to Procedure 003-009.

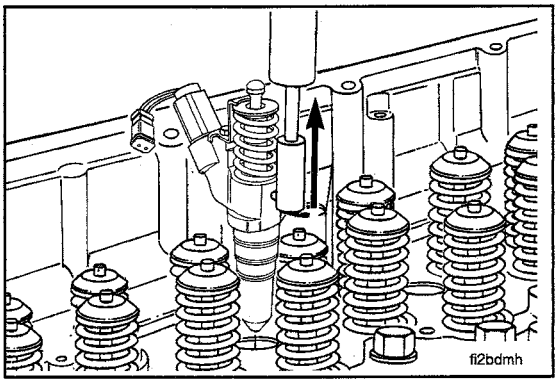




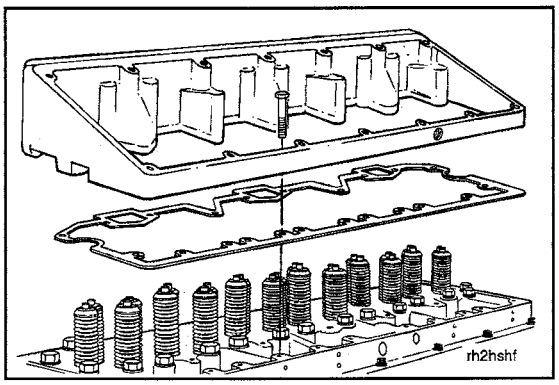
Remove the crossheads.

Number each crosshead with the cylinder number and position, as it is removed.

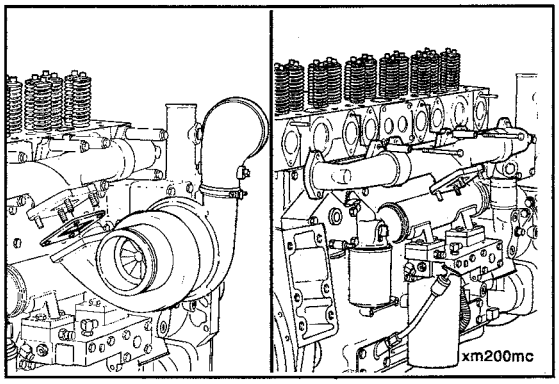
NOTE: Each crosshead **must** be installed in the same position as it was removed when the engine is assembled.



Remove the injectors. Refer to Procedure 006-026.



Remove the rocker lever housing. Refer to Procedure 003-013.



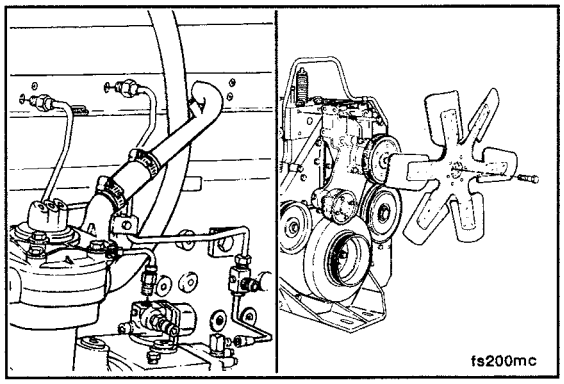
Remove the turbocharger. Refer to Procedure 010-033.

Remove the exhaust manifold. Refer to Procedure 011-007.

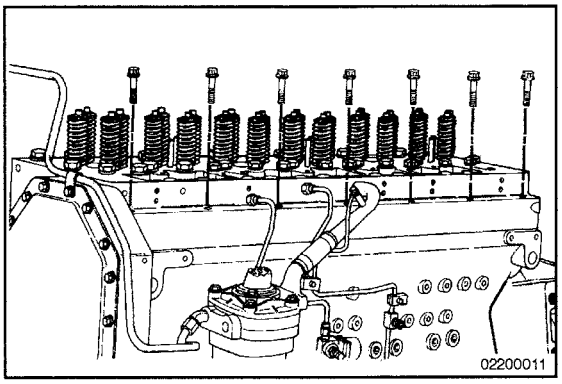
Disconnect the fuel lines and air compressor tube from the cylinder head.

Remove the fan and fan hub. Refer to Procedure 008-037.

Remove all the necessary brackets and clamps.

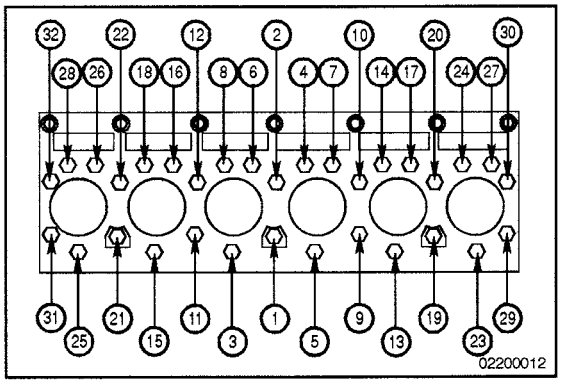


Remove the seven 12-point cylinder head capscrews on the fuel pump side of the engine.



Remove the remaining 32 cylinder head capscrews in the sequence shown.

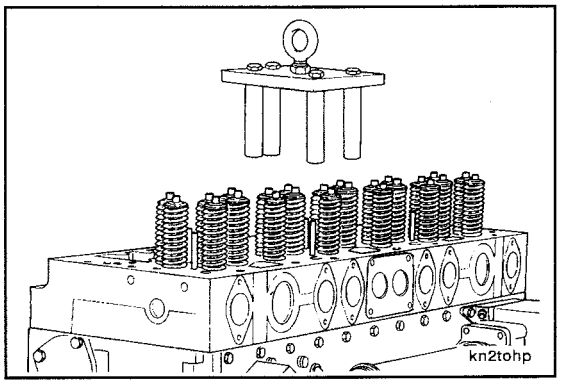
NOTE: Three capscrews are located inside the intake ports.

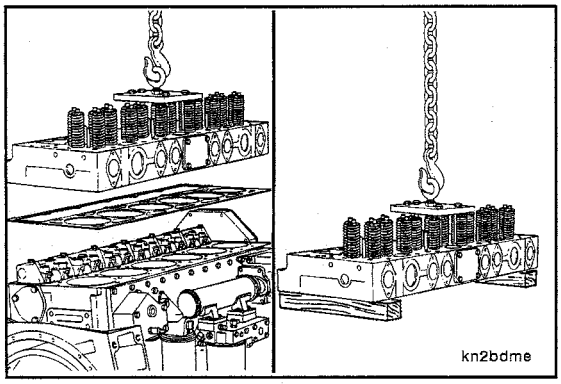


Install cylinder head lifting bracket, Part No. 3822479, with two rocker lever support mounting capscrews and two of the long rocker housing mounting capscrews.

Tighten the capscrews.

Torque Value: 47 N•m [35 ft-lb]





⚠ WARNING ⚠

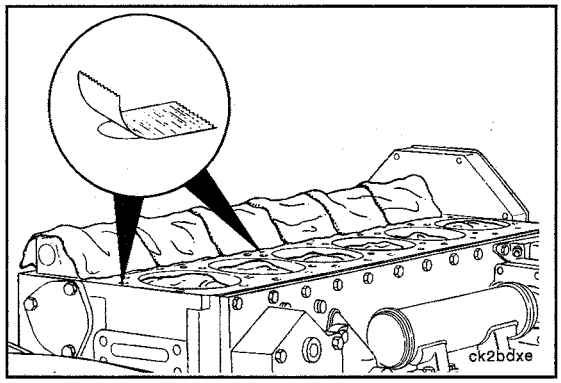
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

⚠ CAUTION ⚠

Place the cylinder head on wood blocks to prevent damage to the combustion face.

Use a hoist or hydraulic arm, and remove the cylinder head.

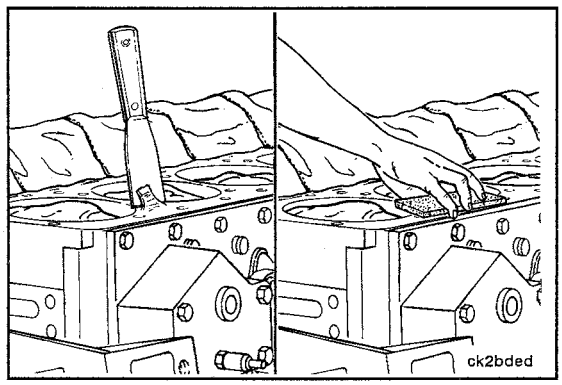
Remove the cylinder head gasket.



Clean (002-004-006)

Place clean, lint-free rags over the cam followers and above the pistons to prevent dirt from falling into the engine.

Plug or cover the coolant and oil passages in the cylinder block deck.



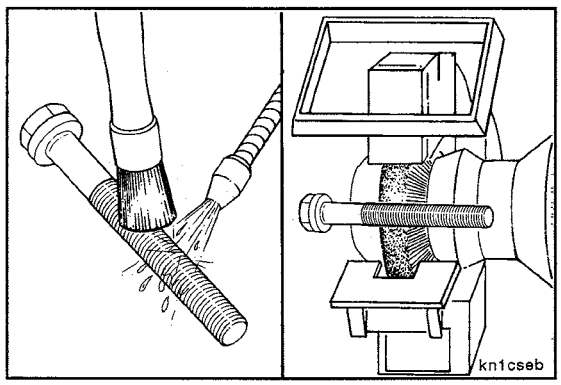
⚠ WARNING ⚠

When using compressed air to clean capscrew holes, always wear safety glasses or a face shield to protect the eyes. Personal injury can result.

Use a gasket scraper to clean the cylinder block deck surface.

Use Scotch-Brite™ 7448, Part No. 3823258, or equivalent, and solvent to remove any residual gasket material from the cylinder block deck surface.

Make sure the cylinder head capscrew holes are clean and free of debris, oil, or coolant.



⚠ CAUTION ⚠

Do not use caustic or acid solutions to clean the cylinder head capscrews.

Clean the cylinder head capscrews with a petroleum-based solvent.

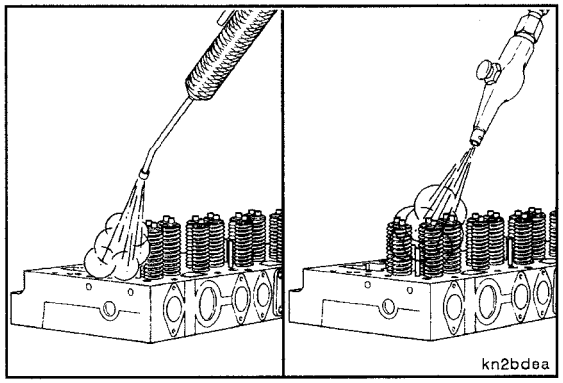
Clean the capscrews thoroughly with a wire brush, with a wire wheel (soft), or use a nonabrasive bead blast to remove deposits from the shank and threads.

⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

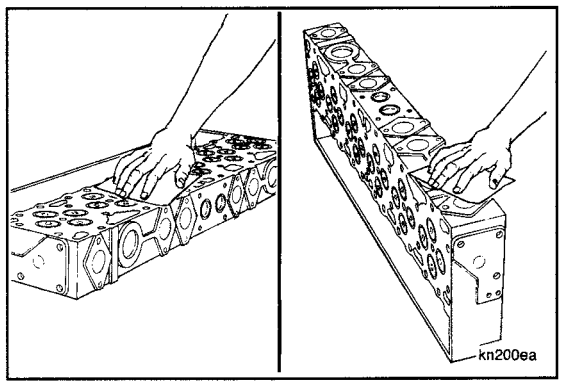
Steam clean the cylinder head and dry with compressed air.

Use compressed air to blow out all capscrew holes.

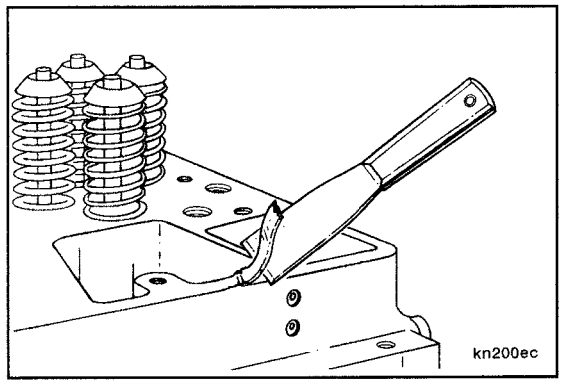


Use Scotch-Brite™ 7448, Part No. 3823258, or equivalent, and solvent to clean the cylinder head combustion face.

Clean the exhaust manifold gasket surface.



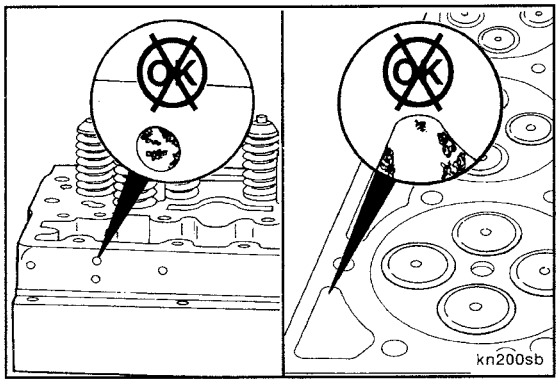
Clean the rocker housing gasket surface.

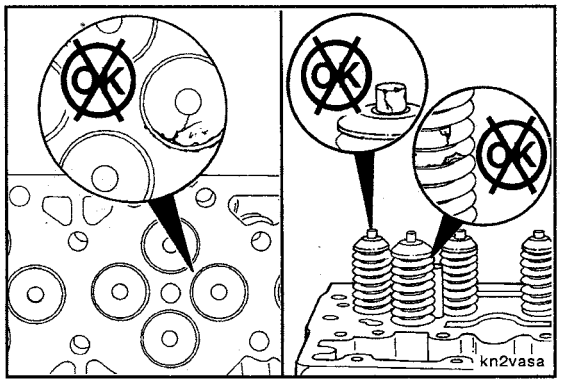


Inspect for Reuse (002-004-007)

Inspect the fuel drillings and water passages for restrictions or foreign material.

Remove any obstructions.

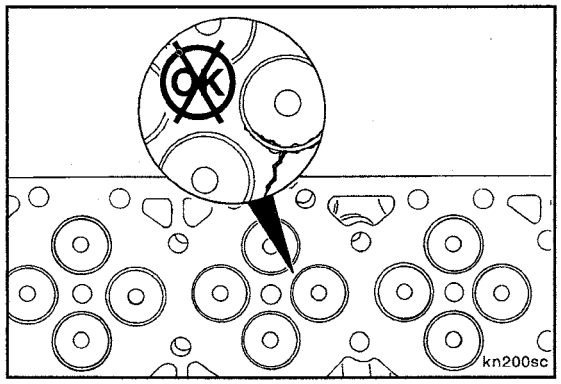




Inspect the valves and valve springs for cracks, bent or broken valve stems, broken valve spring collets, or other damage.

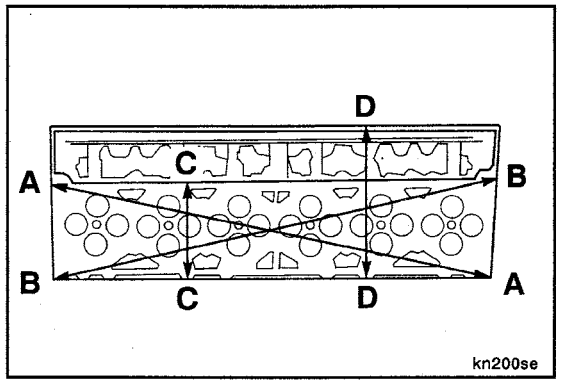
Inspect the valves for indications of leaking or burning.

If cracked or damaged parts or indication of leaking or burning is found, the cylinder head **must** be rebuilt. Refer to the M11 Shop Manual, Bulletin No. 3666075.



Inspect the cylinder head and valves for cracks or damage.

If a crack in the cylinder head is suspected, pressure-test the cylinder head. Refer to Procedure 002-004.



Measure the flatness of the cylinder head combustion face surface as follows:

- AA and BB (corner to corner)
- CC (across combustion face)
- DD (across entire head surface).

NOTE: Dimensions CC and DD **must** be checked from front to rear of cylinder head.

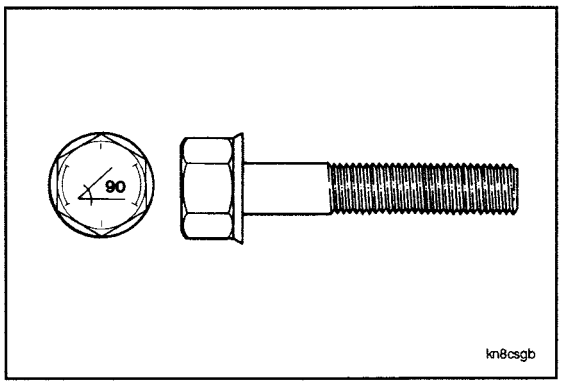
Cylinder Head Flatness

	mm		in
AA and BB	0.200	MAX	0.008
CC	0.076	MAX	0.003
DD	0.127	MAX	0.005

If the cylinder head is pitted, has grooves or wear greater than the maximum specified, the cylinder head surface **must** be machined or cut. Refer to the Alternative Repair Manual, Bulletin No. 3810310.

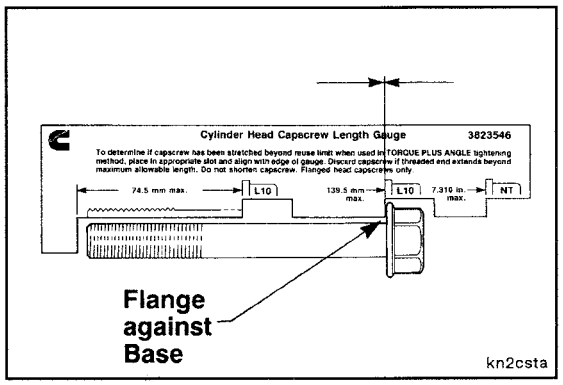
Using flange head capscrews with the torque plus angle method of installation places the capscrew beyond the yield point and permanently stretches the capscrew. These capscrews can be reused throughout the life of the engine unless the capscrew exceeds the specified free length. The free length **must** be checked to avoid bottoming in the block during installation.

Cylinder head capscrew length gauge, Part No. 3823546, has been designed to check capscrew free length.

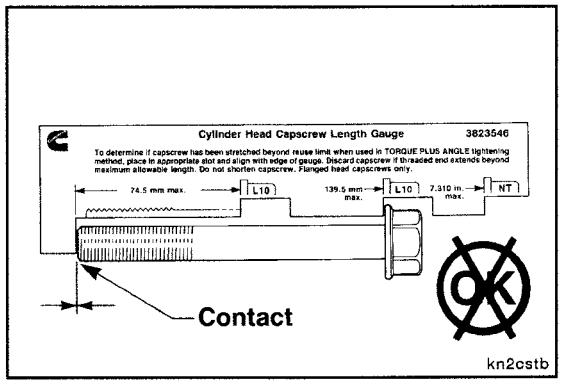


To check the capscrew free length, place the head of the capscrew in the appropriate slot, long or short, with the flange against the base of the slot.

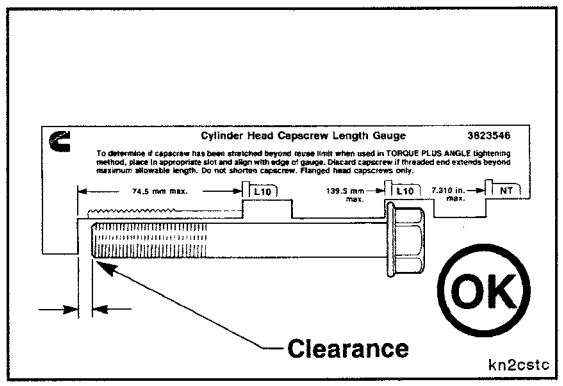
NOTE: Use the slot marked for L10 cylinder head capscrews when checking M11 cylinder head capscrews.

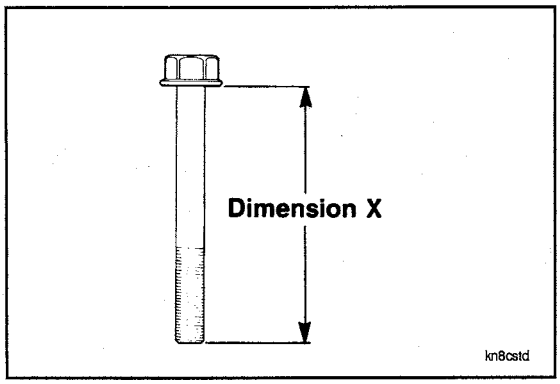


If the end of the capscrew touches the foot of the gauge, the capscrew is too long and **must** be discarded.



If there is clearance between the end of the capscrew and the bottom base of the tool, the capscrew can be reused.





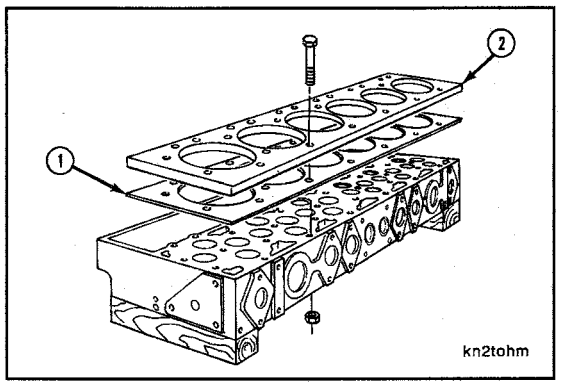
The capscrew can also be checked using a set of calipers. The maximum allowable free length is measured from the bottom of the flange to the end of the capscrew (dimension X).

Cylinder Head Capscrew Free Length			
	mm		in
3045849	74.5	MAX	2.933
3045850	139.5	MAX	5.492

Pressure Test (002-004-013)

△ CAUTION △

Do not pressure-test the cylinder head with the valves and valve springs installed. Water entering the cylinder head cannot be dried thoroughly and will damage the valve guides and valve stems. Refer to Engine Shop Manual, Bulletin No. 3810476, for cylinder head disassembly procedures.

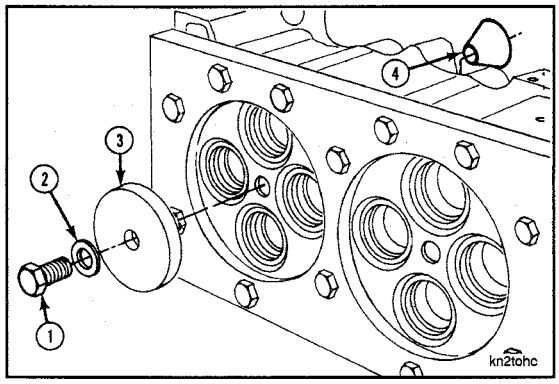


Install cylinder head water test fixture, Part No. 3376082:

- Install gasket, Part No. 3376084 (1)
- Install test plate, Part No. 3376658 (2)
- Install the 32 cylinder head capscrews and 32 (M14 x 1.50) nuts.

Tighten the nuts.

Torque Value: 47 N•m [35 ft-lb]

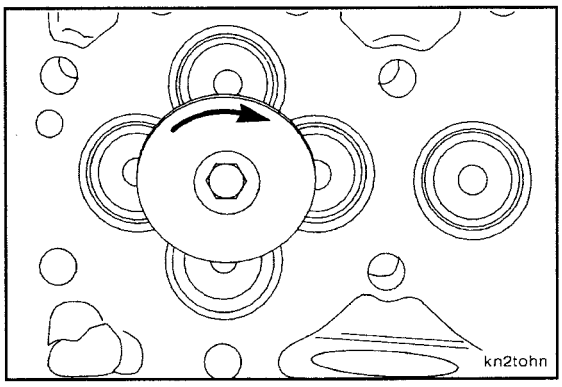


Use six injector sleeve holding tools, Part No. ST-1179.

Install the capscrew (1), flat washer (2), anvil (3), Part No. ST-179-4, and mandrel (4), Part No. ST-1179-2 in each injector bore as shown.

Tighten the six injector sleeve holding tool capscrews.

Torque Value: 75 N•m [55 ft-lb]



⚠ WARNING ⚠

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

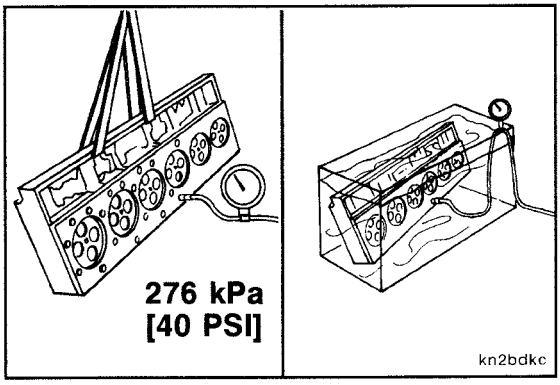
Connect a regulated air supply hose to the test fixture plate. Apply air pressure.

Air Pressure 276 kPa [40 psi]

Use a nylon lifting strap and a hoist to place the cylinder head in a tank of heated water.

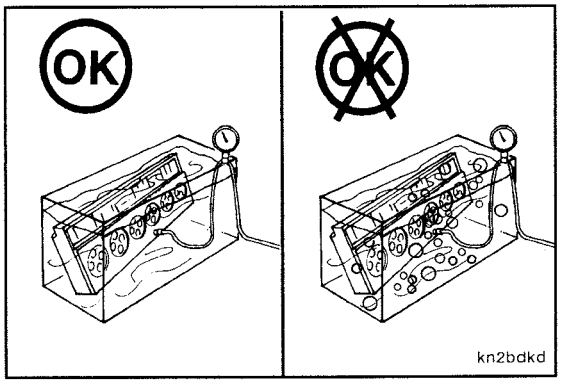
Completely submerge the cylinder head in the water.

Water Temperature: 60 °C [140 °F]



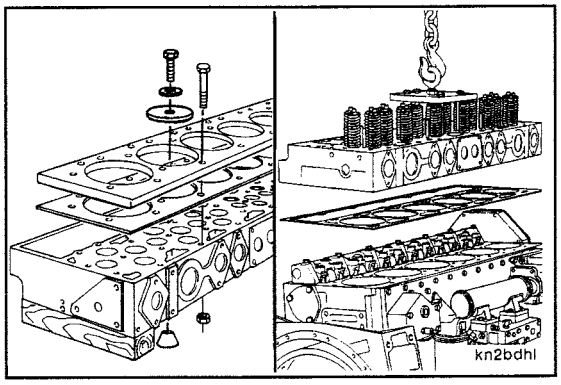
Inspect for air bubbles rising from the water.

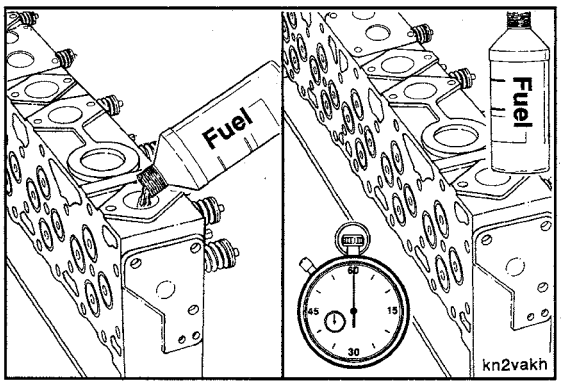
If air bubbles are seen, replace or rebuild the cylinder head. Refer to the M11 Shop Manual, Bulletin No. 3666075, for rebuild procedures.



Remove the test equipment.

Assemble the cylinder head. Refer to the M11 Shop Manual, Bulletin No. 3666075.

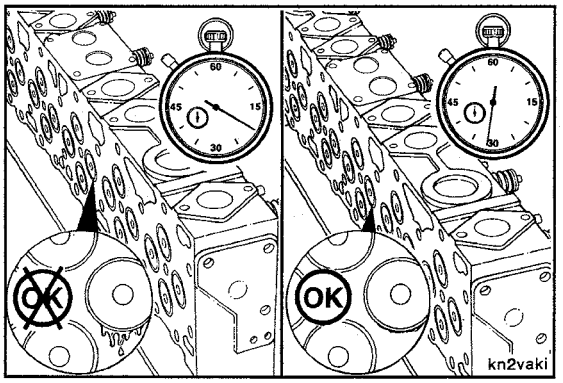




Leak Test (002-004-014)

Inspect the valves for indications of leaking or burning. If indications of leaking or burning are found, the valves and the seats **must** be resurfaced. Refer to the M11 Shop Manual, Bulletin No. 3666075.

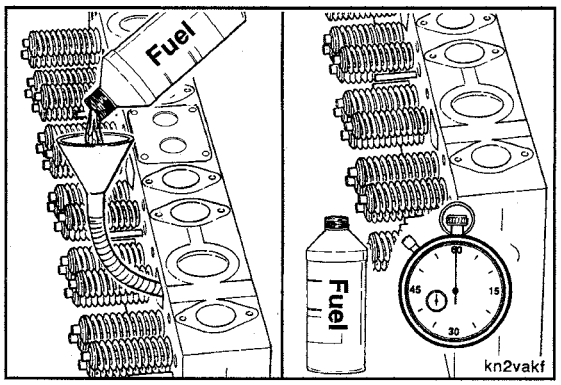
Test the cylinder head for damage. Set the head down with the exhaust ports facing up. Pour fuel into one of the exhaust ports until it is full. Set the container of fuel down, and start a timer.



If a drop of fuel drips or runs down the face of the head within 30 seconds, the exhaust valves and the seats **must** be resurfaced. Refer to the M11 Shop Manual, Bulletin No. 3666075.

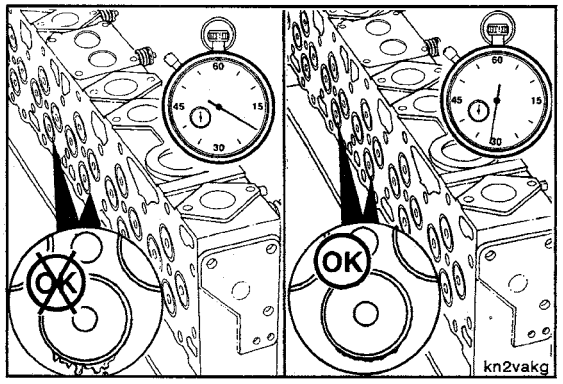
If a drop of fuel has **not** run down the face of the head in 30 seconds, the exhaust valves are acceptable.

Repeat the process for all six cylinders.



Pour fuel into one of the intake ports until it is full. Set the container of fuel down, and start the timer.

NOTE: Each intake port supplies fuel to four intake valves (two cylinders) on M Series cylinder heads.



If a drop of fuel drips or runs down the face of the head within 30 seconds, the intake valves and the seats **must** be resurfaced. Refer to the M11 Shop Manual, Bulletin No. 3666075.

If a drop of fuel has **not** run down the face of the head in 30 seconds, the intake valves are acceptable.

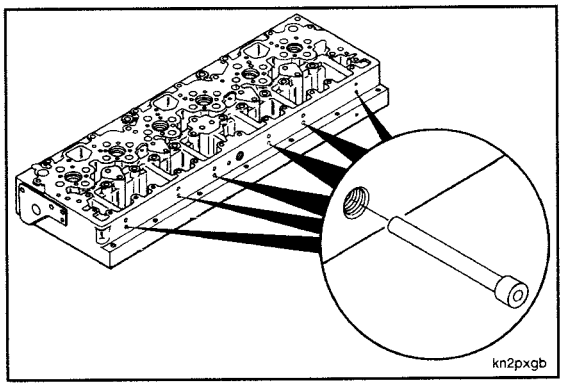
Repeat the process for all six cylinders.

NOTE: If any of the intake or exhaust valves fail the test, all the valves and valve seats **must** be resurfaced.

Install (002-004-026)

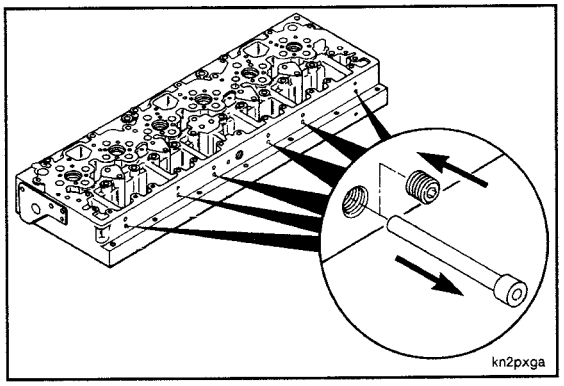
A plastic insert is installed in all fuel inlet passages on new and ReCon® cylinder heads.

NOTE: The fuel inlet passages are the lower row of drillings.



Depending on the fuel plumbing option, one fuel inlet passage insert **must** be removed to allow fuel to flow to the injectors. If the insert is **not** removed, the engine will **not** start.

Remove the pipe plug and use a sharp object to pull the insert from the hole.



⚠ WARNING ⚠

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

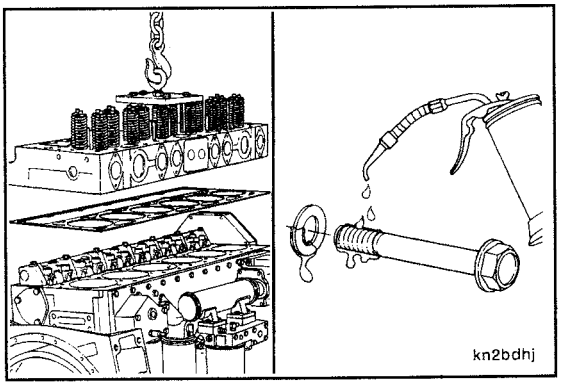
△ CAUTION △

Do not drop the cylinder head on the cylinder head gasket. The gasket material can be damaged.

Use a new gasket, and install the cylinder head.

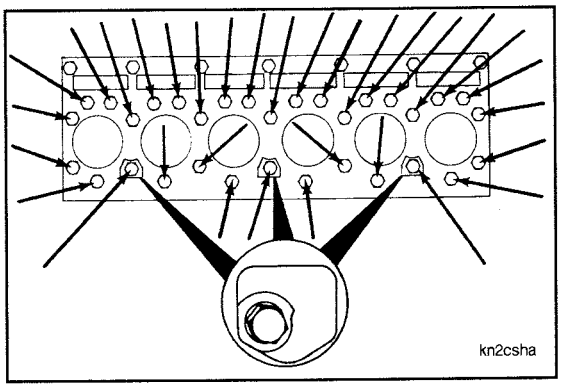
Use clean 15W-40 oil to lightly coat the cylinder head capscrew threads and bottom of the flange.

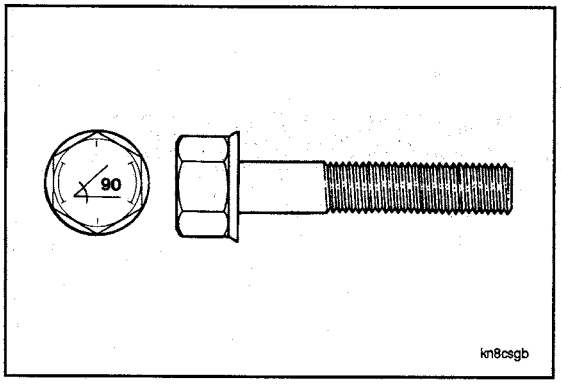
Allow the excess oil to drain from the capscrew threads.



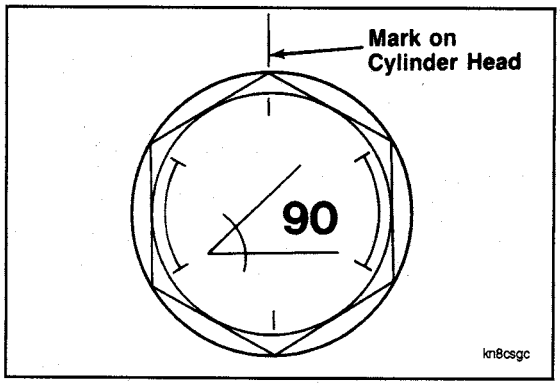
Install the cylinder head capscrews.

NOTE: Be sure to install the three capscrews inside the intake ports.

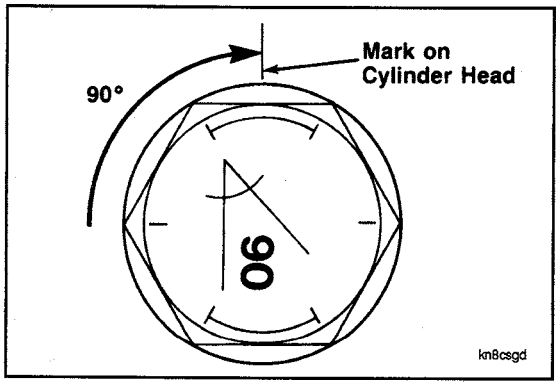




The markings on the head of the flange head capscrews serve as an aid during installation.

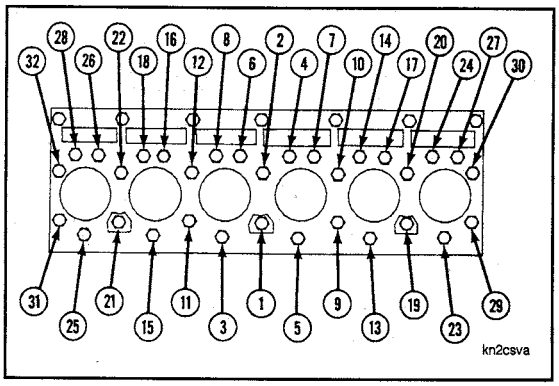


After tightening according to step 2, mark the cylinder head adjacent to one of the two single marks on the capscrew head.



All 32 capscrews **must** be rotated 90 degrees after they have been tightened according to step 2. Rotate the capscrew until the mark on the cylinder head is between the next two marks joined by an arc (more than one flat and less than two flats).

NOTE: When using torque plus angle, the tolerance on the 90-degree angle of rotation is between one and two flats. If the capscrew is unintentionally rotated beyond two flats, do **not** loosen the capscrew. The clamp load is still acceptable. However, rotating the capscrew beyond two flats reduces the number of reuses.

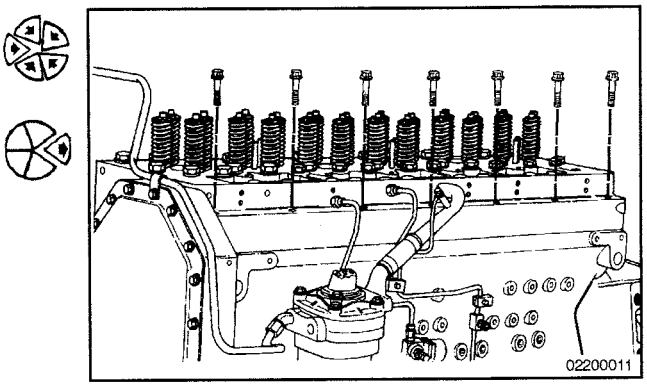


Tighten the capscrews in the sequence shown to the specified values:

Torque Value: Step 1 136 N•m [100 ft-lb]
2 217 N•m [160 ft-lb]
3 Rotate 90 Degrees

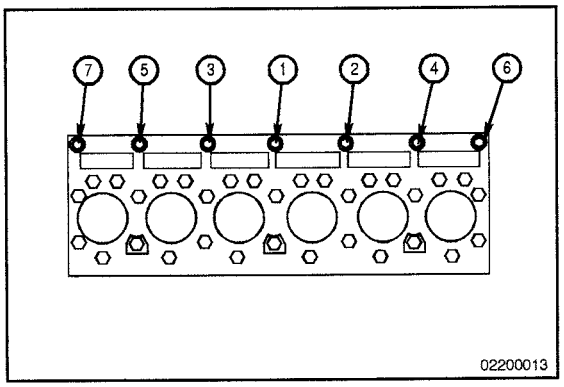
NOTE: Rotate at least one flat, but **not** more than two.

Use new sealing washers, and install the seven capscrews on the fuel pump side of the cylinder head.



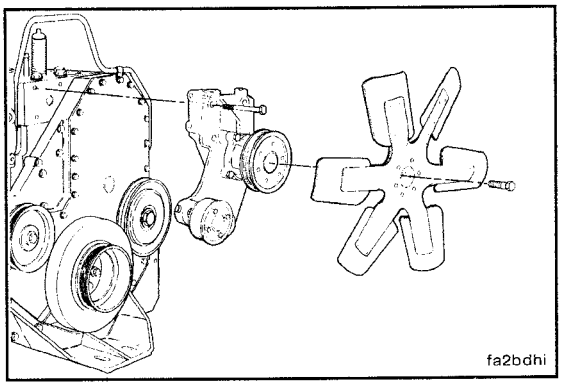
Tighten the capscrews in the sequence shown.

Torque Value: 68 N•m [50 ft-lb]



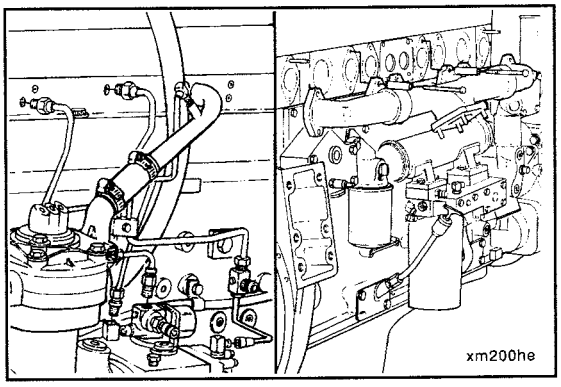
Install the fan hub and fan. Refer to Procedure 008-037.

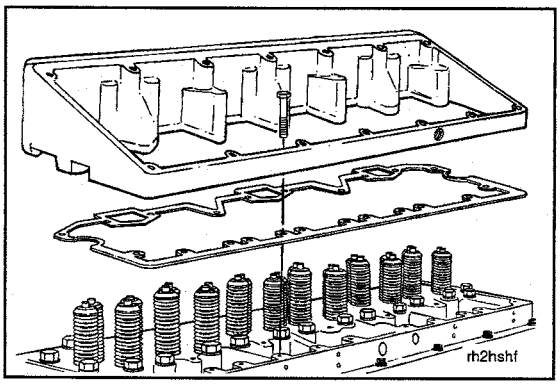
Install all brackets and clamps that were removed.



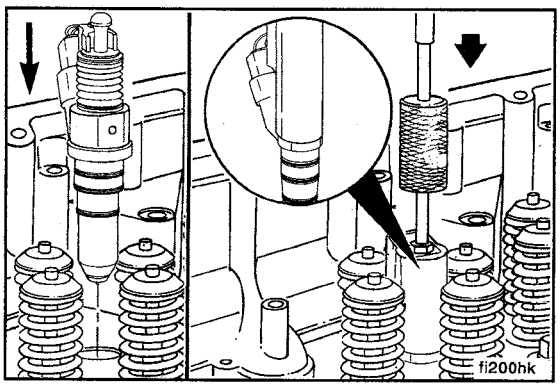
Install the fuel lines and air compressor tube to the cylinder head.

Install the exhaust manifold. Refer to Procedure 011-007.

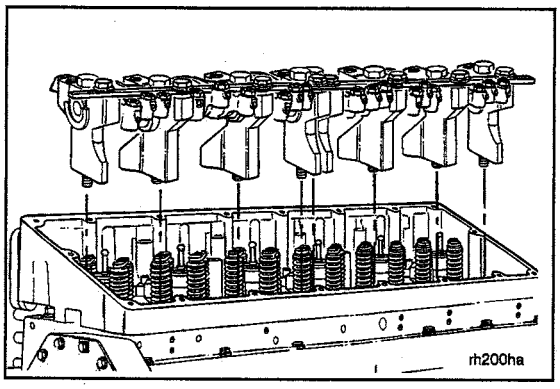




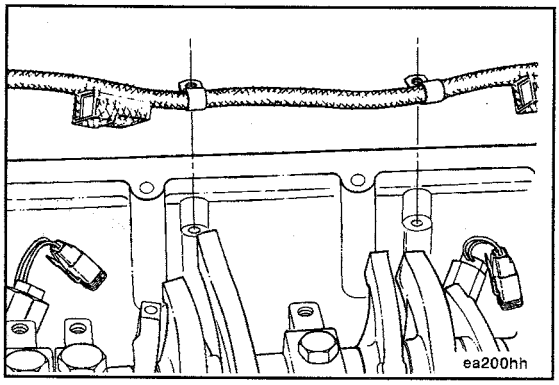
Install the rocker lever housing. Refer to Procedure 003-013.



Install the injectors. Refer to Procedure 006-026.



Install the rocker lever assemblies. Refer to Procedure 003-009.



Install the internal engine wiring harness on the engine.

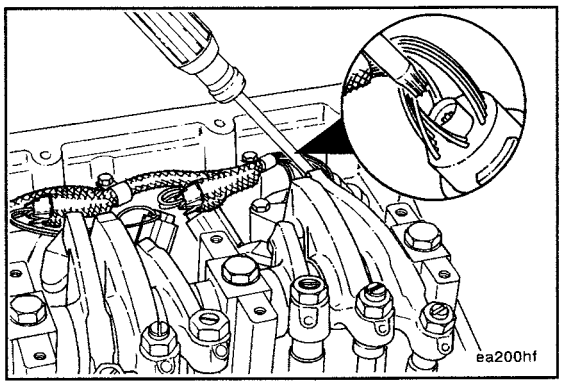
The harness and connectors **must** be clear of any moving parts, so the wires will **not** be damaged during engine operation.

Connect the 12-pin connector of the internal engine harness to the 12-pin connector of the external engine harness.

NOTE: The internal and external Metri-Pack connectors are "keyed." Make sure both connectors are correctly aligned when they are joined together.

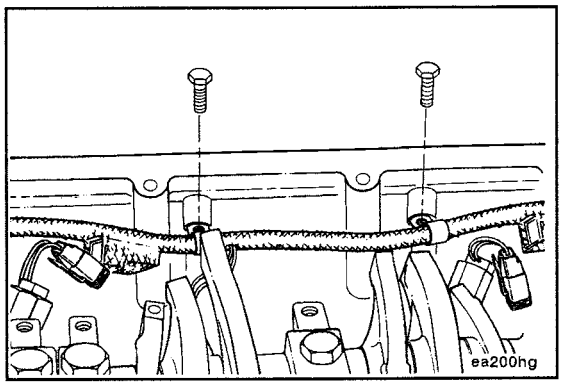
Install the locking capscrew (Torx® size T-25). Tighten the capscrew.

Torque Value: 1 N•m [11 in-lb]



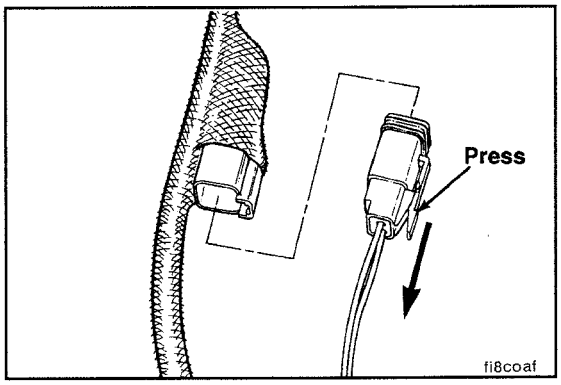
Install the holding clamps for the internal engine harness. Tighten the capscrews.

Torque Value: 20 N•m [15 ft-lb]



Lubricate the connector ends with lubricant, Part No. 3822934.

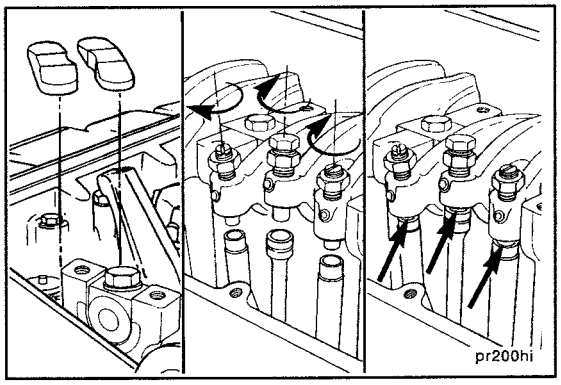
Connect the Deutsch 2-pin connectors from the internal engine harness to the fuel injectors.

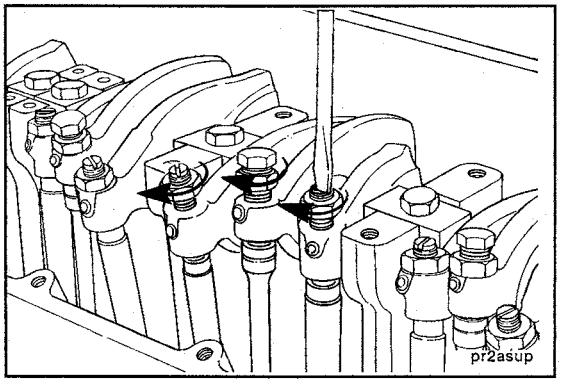


NOTE: The crossheads **must** be installed in the same position as they were removed.

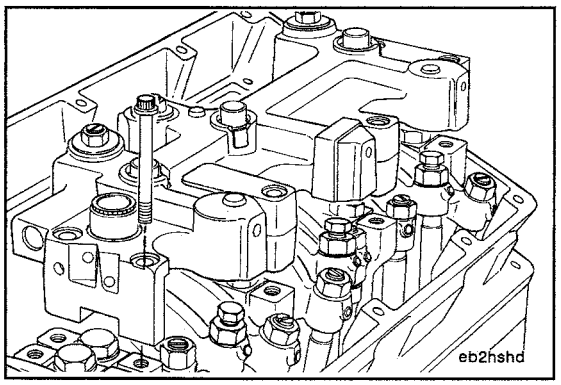
Install the crossheads.

Rotate the rocker levers up, and install the push tubes and push rods. Refer to Procedure 004-014.

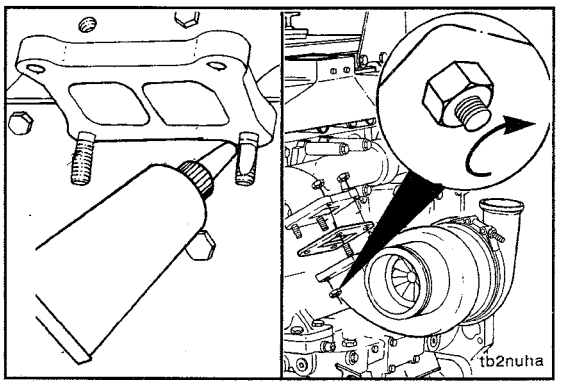




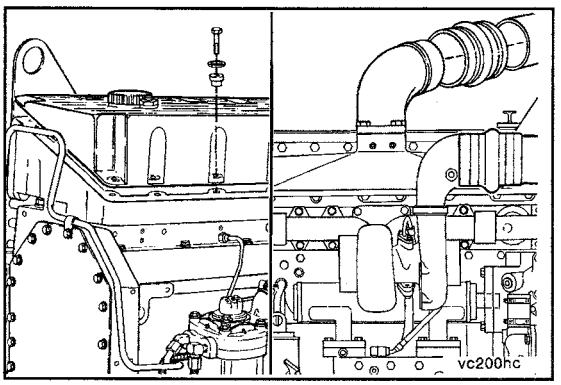
Adjust the valves and injectors. Refer to Procedure 003-004.



Install the engine brakes, if equipped. Refer to Procedure 020-001.



Install the turbocharger. Refer to Procedure 010-033.

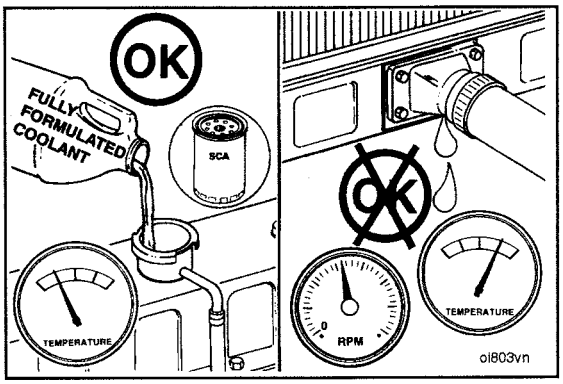


Install the rocker lever cover. Refer to Procedure 003-011.

Install the air piping to the turbocharger and the intake manifold. Refer to the manufacturer's specifications for the correct torque value.

Fill the cooling system. Refer to Procedure 008-018.

Operate the engine to normal operating temperature and check for leaks.



NOTES

Section 3 - Rocker Levers - Group 03

Section Contents

Page

Crankcase Breather (Internal) 3-2
Clean 3-2
Inspect for Reuse 3-2
Install 3-3
Remove 3-2

Overhead Set 3-3
Adjust 3-7
Measure 3-3

Rocker Lever Assembly 3-14
Assemble 3-19
Clean 3-16
Disassemble 3-15
Inspect for Reuse 3-16
Install 3-20
Remove 3-14

Rocker Lever Cover 3-23
Clean 3-23
Inspect for Reuse 3-24
Install 3-24
Remove 3-23

Rocker Lever Housing 3-25
Clean 3-27
Inspect for Reuse 3-28
Install 3-28
Remove 3-25

Service Tools 3-1
Rocker Levers 3-1

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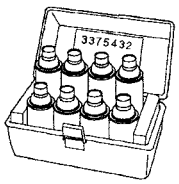
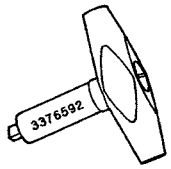
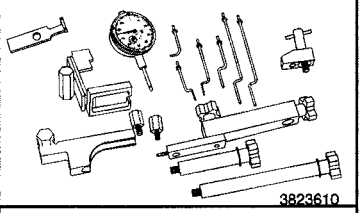
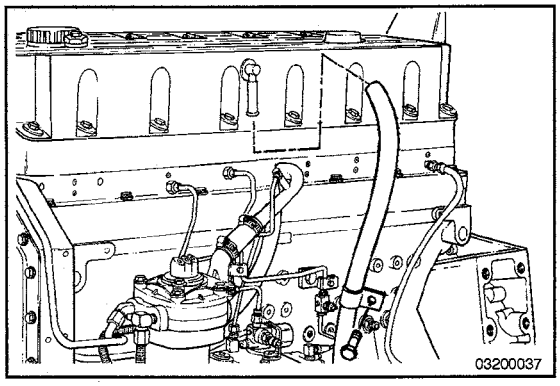
Service Tools

Rocker Levers

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3163196	**Torque Wrench Adapter** Used to tighten rocker lever adjusting screws.	
3375432	**Crack Detection Kit** Used to clean and inspect components for cracks.	 3375432
3376592	**Inch-Pound Torque Wrench** Can be used as an optional valve set. Screwdriver socket, Part No. ST-669-13, **must** be used with this tool.	 fi8togi
3823610	**Injector Travel Measurement Kit** Used to measure injector travel lash.	 3823610

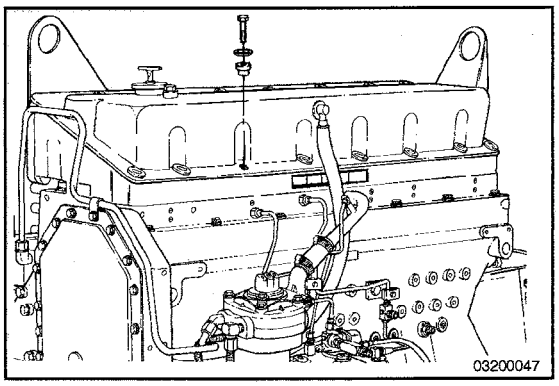


Crankcase Breather (Internal) (003-002)

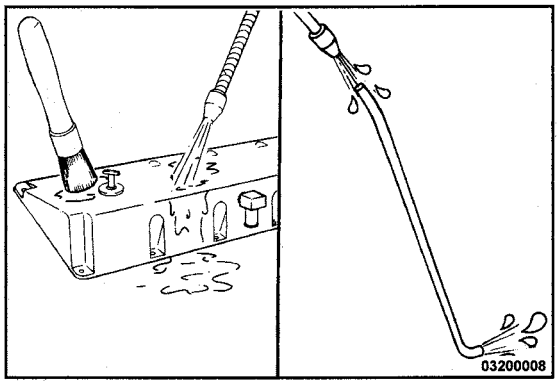
Remove (003-002-002)

Remove the tube support bracket capscrew and bracket.

Remove the tube from the engine.

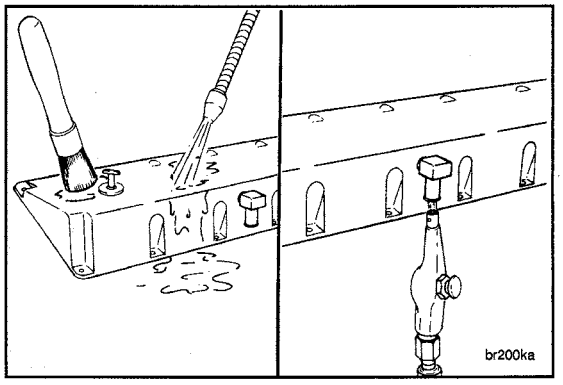


Remove the rocker lever housing cover. Refer to Procedure 003-011.



Clean (003-002-006)

Use solvent to clean the cover, breather cavity, and breather tube. Dry with compressed air.



Inspect for Reuse (003-002-007)

Use compressed air to blow through the breather cavity.

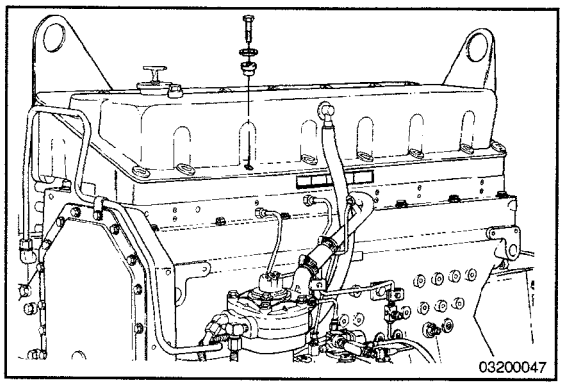
If the breather cavity is clogged and the restriction can **not** be removed by cleaning, the cover **must** be replaced.

Use air pressure to blow through the tube.

Replace the tube if it is clogged.

Install (003-002-026)

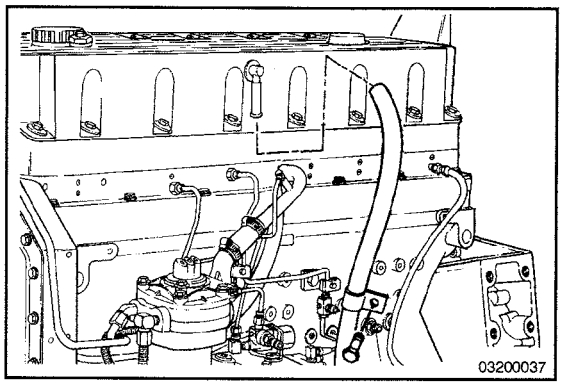
Install the rocker lever housing cover. Refer to Procedure 003-011.



Install the breather tube, bracket, and capscrew on the engine.

Tighten the bracket capscrew.

Torque Value: 27 N•m [20 ft-lb]

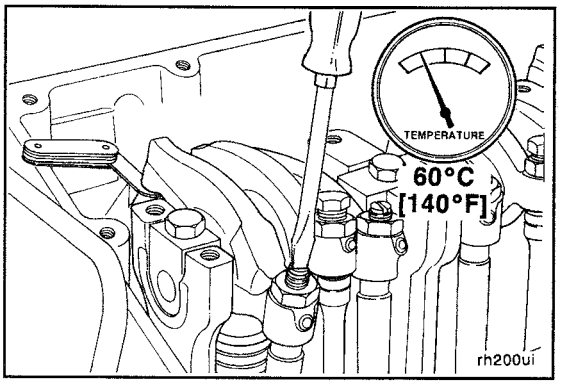


Overhead Set (003-004)

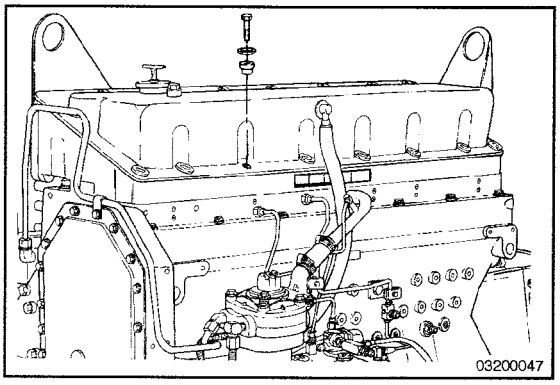
Measure (003-004-010)

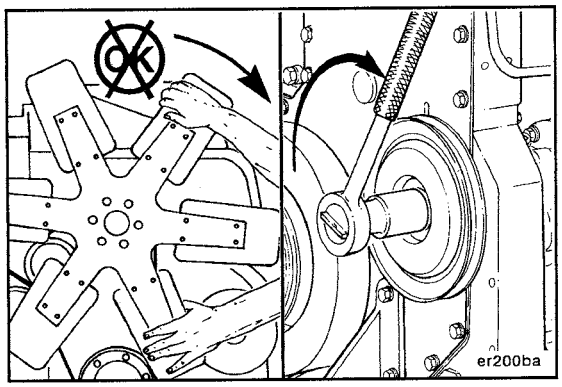
General Information

All overhead lash measurements **must** be made when the engine is cold. Stabilized coolant temperature must be at 60°C [140°F] or below.



Remove the rocker lever cover. Refer to Procedure 003-011.



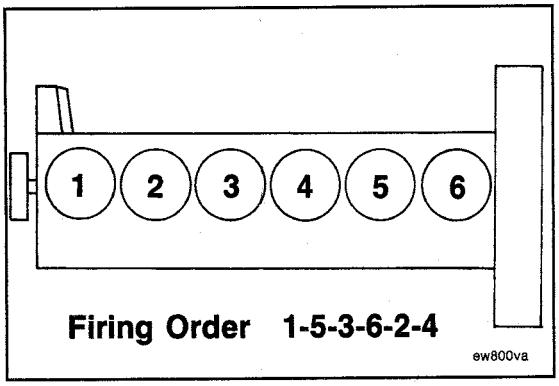


⚠ WARNING ⚠

Do not pull or pry on the fan blades to rotate the crankshaft. Doing so can damage the fan blades. Damaged fan blades can cause premature fan failures, which can result in serious personal injury or property damage.

The valve set marks are located on the accessory drive pulley. The marks align with a pointer on the gear housing.

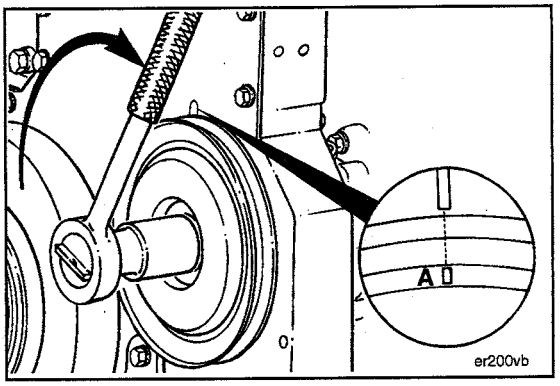
Use the accessory driveshaft to rotate the crankshaft.



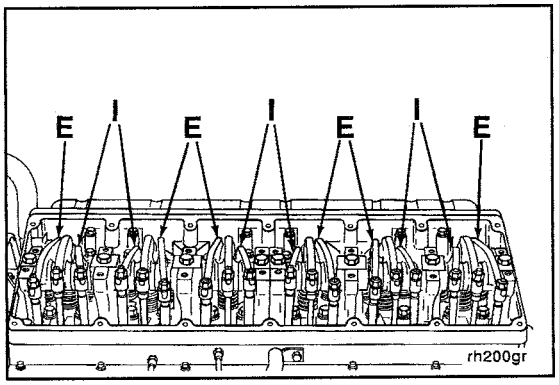
The crankshaft rotation is **clockwise** when viewed from the front of the engine.

The cylinders are numbered from the front end of the engine.

The engine firing order is 1-5-3-6-2-4.



Rotate the accessory drive **clockwise** until the "A" valve set mark on the accessory drive pulley is aligned with the pointer on the gear cover.



Each cylinder has three rocker levers:

- The long rocker lever (E) is the exhaust lever.
- The center rocker lever is the injector lever.
- The short rocker lever (I) is the intake lever.

Refer to the accompanying chart for valve rocker lever locations.

Valve and Injector Lash

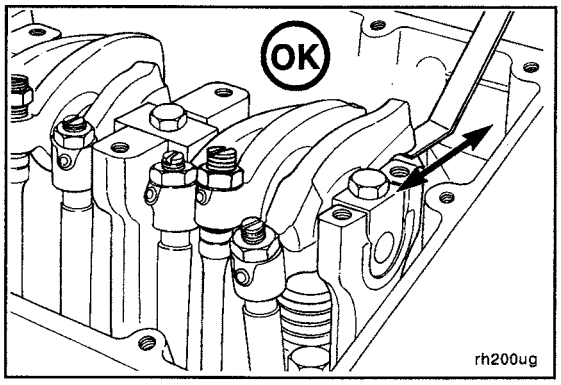
Injector and Valve Measurement Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder	
		Injector	Valve
Start	A	1	1
Advance to	B	5	5
Advance to	C	3	3
Advance to	A	6	6
Advance to	B	2	2
Advance to	C	4	4
Firing Order: 1-5-3-6-2-4			

When the "A" mark is aligned with the pointer, the intake and exhaust valves for cylinder No. 1 **must** be closed. The injector plunger for cylinder No. 1 **must** be at the bottom of its stroke. If these conditions are **not** correct, cylinder No. 6 **must** be ready to check. Check the injector and valves on the cylinder ensuring that both the intake and exhaust valve rocker levers can be "rattled" by hand or the push tubes can be freely rotated.

Valve Lash

Using a set of feeler gauges, measure the amount of clearance (lash) between the crosshead and rocker lever nose. Measure and record the intake and exhaust valve lash. If the valve lash is **not** within the specifications listed below, the valves **must** be adjusted. Refer to Procedure 003-004.

M Series Valve Lash Recheck Limits			
	mm		in
Intake	0.10	MIN	0.004
	0.41	MAX	0.016
Exhaust	0.46	MIN	0.018
	0.76	MAX	0.030

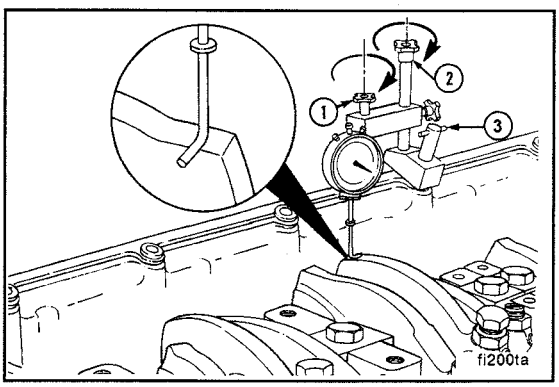


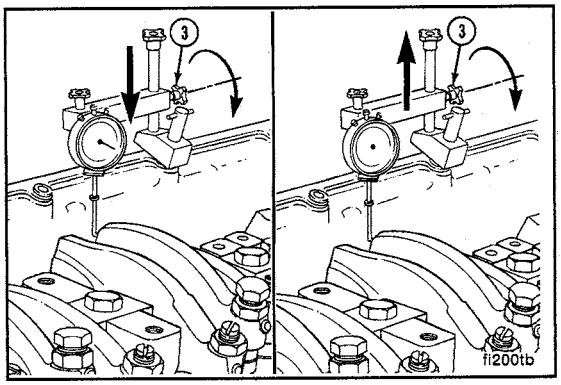
Injector Lash

Install the dial indicator and the support from injector travel measurement kit, Part No. 3823610, so the extension, Part No. 3823595, for the dial indicator is on top of the injector rocker lever, directly over the socket on the cylinder being checked.

Securely tighten the thumb screw (1) and the hold down capscrews (2 and 3).

NOTE: All adjusting screws **must** be tight to get an accurate measurement.

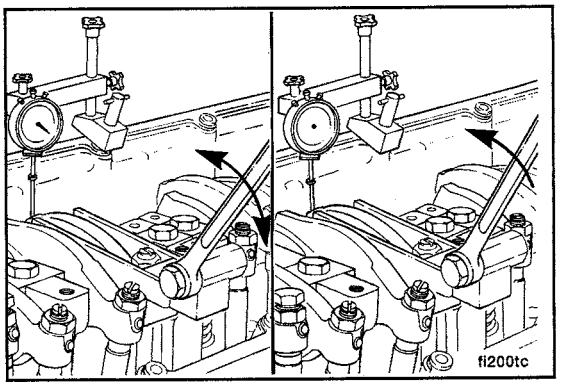




The tip of the dial indicator extension **must** rest on the rocker lever directly above the socket. If it does **not,** incorrect readings can result.

Loosen the thumb screw (3), and lower the indicator against the injector rocker lever until the stem is fully compressed.

Raise the indicator approximately 12.7 mm [0.500 in], and tighten the thumb screw (3) to hold the indicator in position.

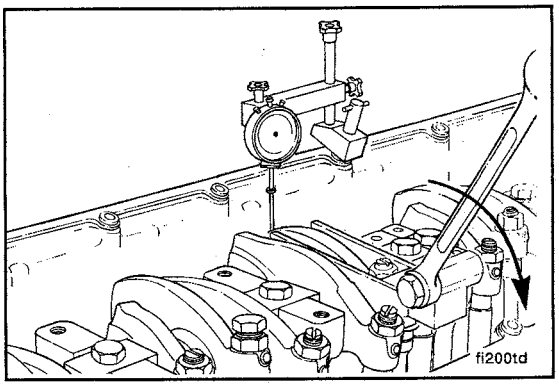


⚠ WARNING ⚠

The injector plunger is under spring-tension. Do not allow the tool to slip. Serious personal injury can result.

Actuate the injector plunger three or four times to make sure the fuel has been removed from the injector assembly. Allow the lever to return slowly to prevent damage to the dial indicator.

Actuate the lever again; set the dial indicator at zero while holding the injector plunger to the bottom of its travel.

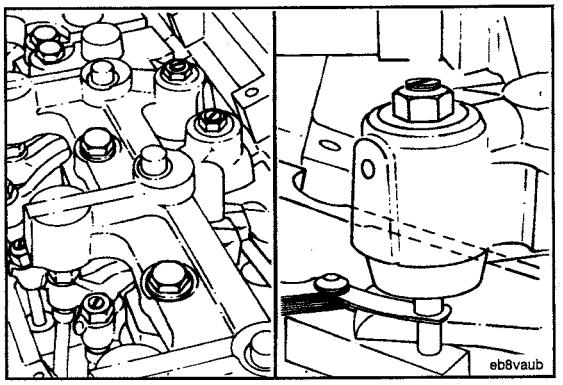


Slowly release the actuator, and check the dial indicator travel. Record the measured value.

If the injector lash setting is **not** within the specifications listed below, the injector **must** be adjusted. Refer to Procedure 003-004.

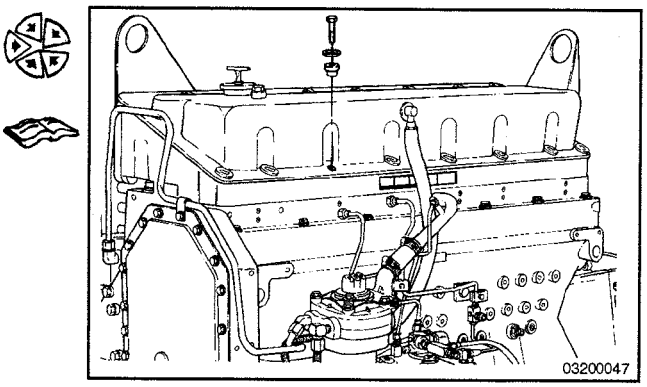
M Series Injector Lash Recheck Limits

mm		in
0.51	MIN	0.020
2.04	MAX	0.080



If the engine is equipped with engine brakes, check the brake piston clearance. Refer to Procedure 020-001.

Install the rocker lever cover. Refer to Procedure 003-011.



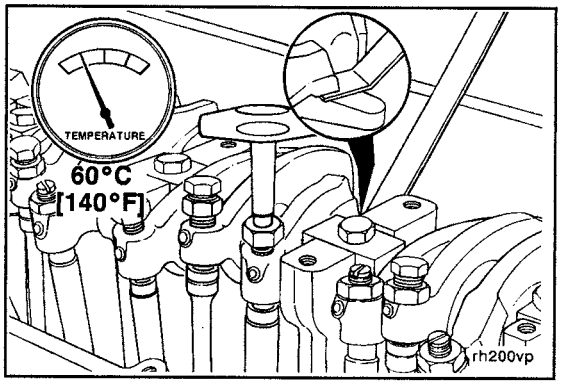
Adjust (003-004-029)

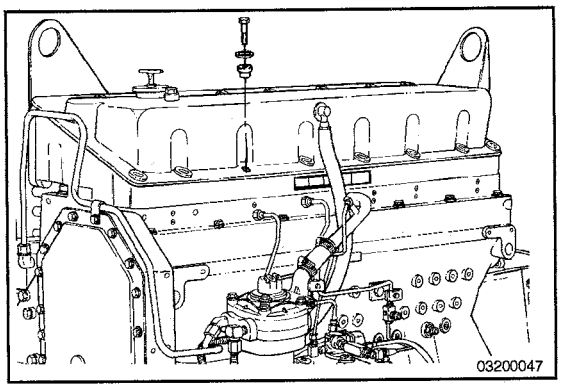
General Information

Valves, injectors, and engine brakes **must** be correctly adjusted for the engine to operate efficiently. Valve, injector, and engine brake adjustment **must** be performed using the values listed in this section. The accompanying table gives the adjustment specifications.

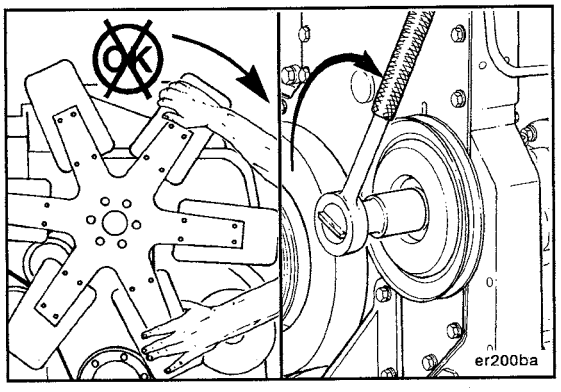
Valve, Injector, and Engine Brake Adjustment Specifications		
	mm	in
Intake Valve	0.36	0.014
Exhaust Valve	0.69	0.027
Engine Brake	0.38	0.015

All valve and injector adjustments **must** be made when the engine is cold (any stabilized coolant temperature at 60°C [140°F] or below).





Remove the rocker lever cover and gasket. Refer to Procedure 003-011.

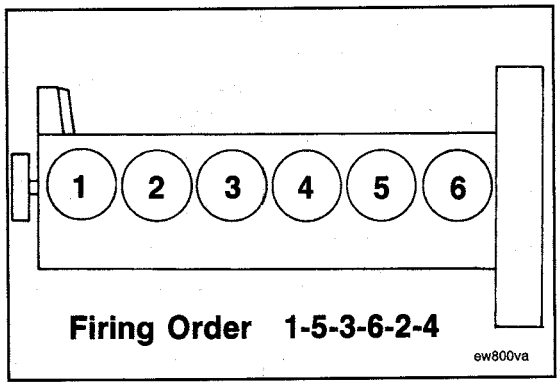


⚠ WARNING ⚠

Do not pull or pry on the fan to rotate the crankshaft. Doing so can damage the fan blades. Damaged fan blades can cause premature fan failures that can result in serious personal injury or property damage.

The valve set marks are located on the accessory drive pulley. The marks align with a pointer on the gear cover.

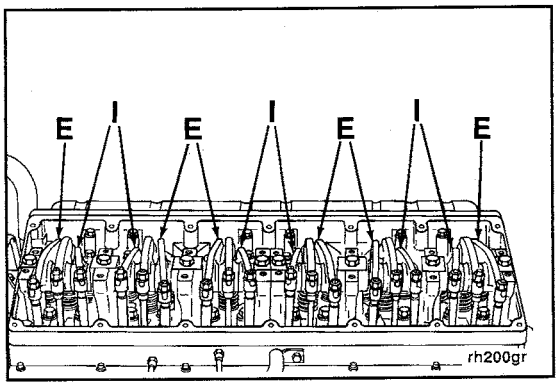
Use the accessory driveshaft to rotate the crankshaft.



The crankshaft rotation is **clockwise** when viewed from the front of the engine.

The cylinders are numbered from the front gear housing end of the engine.

The engine firing order is 1-5-3-6-2-4.



Each cylinder has three rocker levers:

- The long rocker lever (E) is the exhaust lever.
- The center rocker lever is the injector lever.
- The short rocker lever (I) is the intake lever.

Refer to the accompanying graphic for valve rocker lever locations.

The valves and injectors on the same cylinders are adjusted at the same index mark on the accessory drive pulley.

One pair of valves and one injector are adjusted at each pulley index mark before rotating the accessory drive to the next index mark.

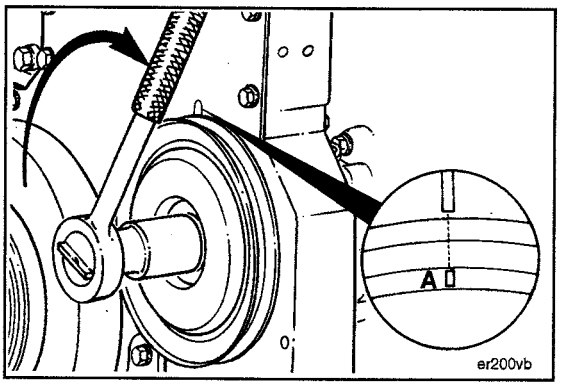
Two crankshaft revolutions are required to adjust all the valves and injectors.

NOTE: See the example before attempting to begin the adjusting procedure.

NOTE: Set injectors on cylinder before setting valves.

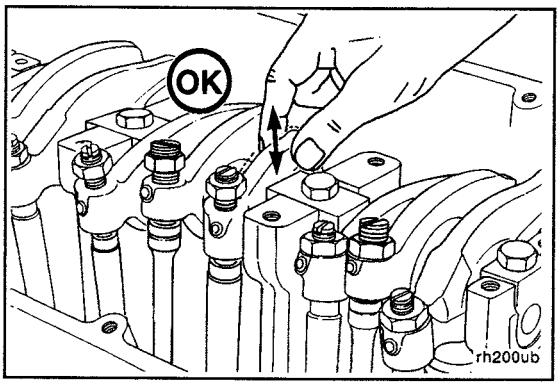
Injector and Valve Measurement Sequence			
Bar Engine in Direction of Rotation	**Pulley Position**	**Set Cylinder**	
		Injector	**Valve**
Start	A	1	1
Advance to	B	5	5
Advance to	C	3	3
Advance to	A	6	6
Advance to	B	2	2
Advance to	C	4	4
Firing Order: 1-5-3-6-2-4			

The adjustment can begin on any valve set mark. In the following example, the adjustment will begin on the "A" valve set mark with cylinder No. 1 valves closed and ready for adjustment.

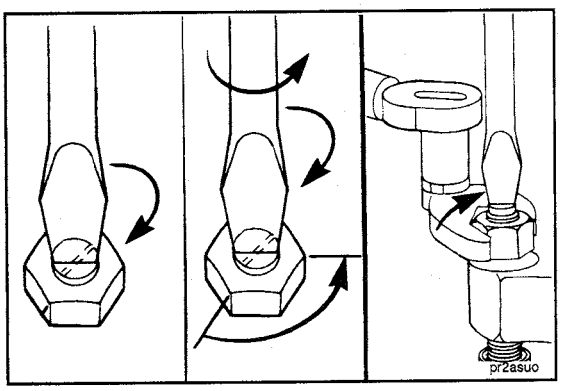


Rotate the accessory drive **clockwise** until the "A" valve set mark on the accessory drive pulley is aligned with the pointer on the gear cover.

When the "A" mark is aligned with the pointer, the intake and exhaust valves for cylinder No. 1 **must** be closed. If these conditions are **not** correct, cylinder No. 6 injector and valves **must** be ready to set. Set the injector and valves on the cylinder so that both the intake and exhaust valve rocker lever arms are loose and can be moved from side to side.



Both valves are closed when both rocker levers are loose and can be moved from side to side.



Injector Adjustment

Loosen the injector adjusting screw locknut. Using a screwdriver (box-end wrench if equipped with engine brakes) and the adjusting screw, bottom the injector plunger three or four times to remove the fuel.

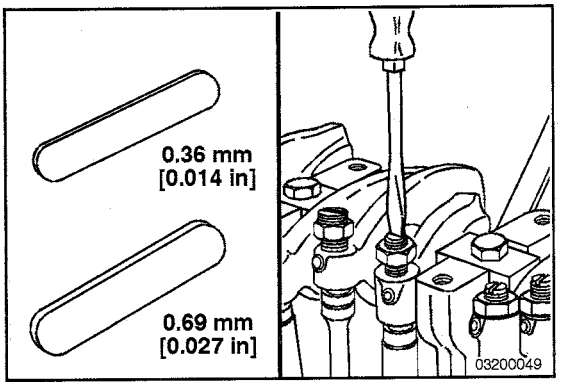
Turn the adjusting screw in until you can feel it lightly bottom the plunger.

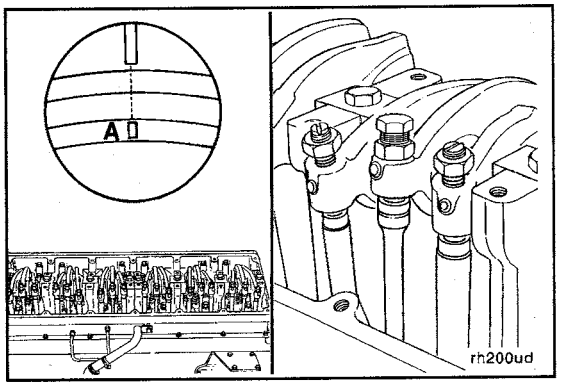
NOTE: Do **not** use excessive force when bottoming the plunger.

Back out the adjusting screw two flats, 120 degrees. Hold the adjusting screw, and tighten the locknut.

Torque Value: 61 N•m [45 ft-lb]

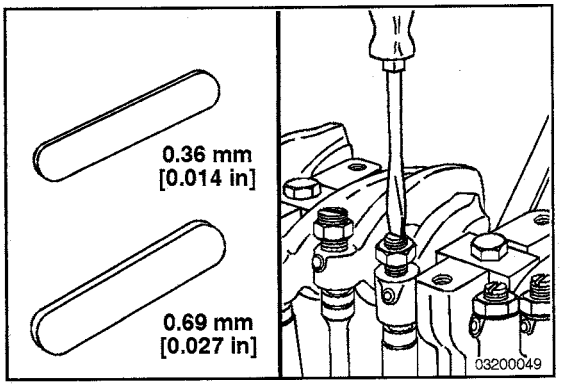
After setting the injector, set the valves on the same cylinder.





Valve Adjustment

With the "A" valve set mark aligned with the pointer on the gear cover and both valves closed on the cylinder to be adjusted, loosen the adjusting screw locknuts on the intake and exhaust valves.



Select a feeler gauge for the correct valve lash specification.

Valve Lash Specification

	mm	in
Intake	0.36	0.014
Exhaust	0.69	0.027

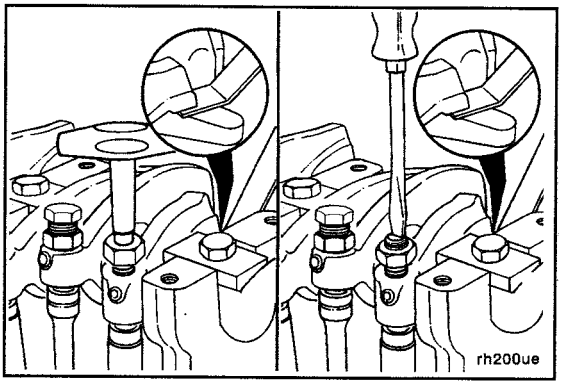
Insert the feeler gauge between the top of the crosshead and the rocker lever pad.

Two different methods for establishing valve lash clearance are described below. Either method can be used; however, the torque wrench method has proven to be the most consistent. It eliminates the need to feel the drag on the feeler gauge.

- **Torque Wrench Method:** Use the inch-pound torque wrench, Part No. 3376592, normally used to set preload on top-stop injectors, and tighten the adjusting screw.

Torque Value: 0.7 N•m [6 in-lb]

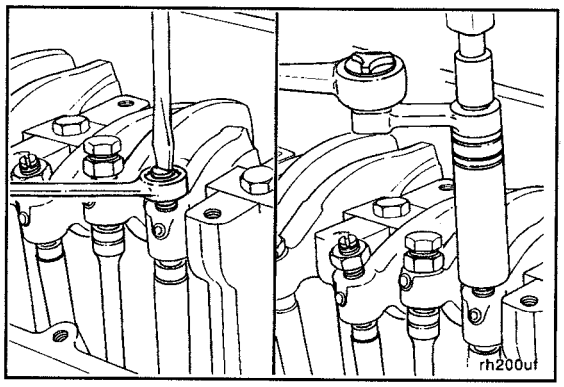
- **Touch Method:** Tighten the adjusting screw until a slight drag is felt on the feeler gauge.



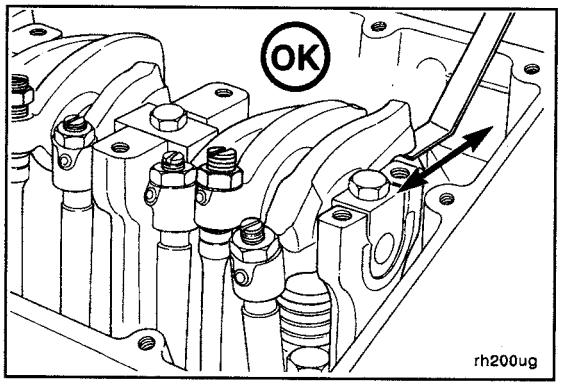
Hold the adjusting screw in this position. The adjusting screw **must not** turn when the locknut is tightened.

Torque Value:

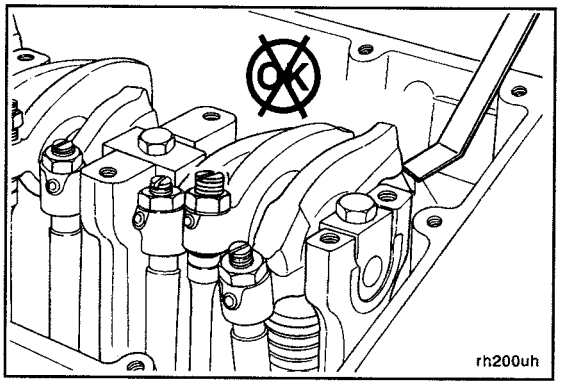
- **Without** torque wrench adapter: 61 N•m [45 ft-lb]
- **With** torque wrench adapter, Part No. 3163196: 47 N•m [35 ft-lb]

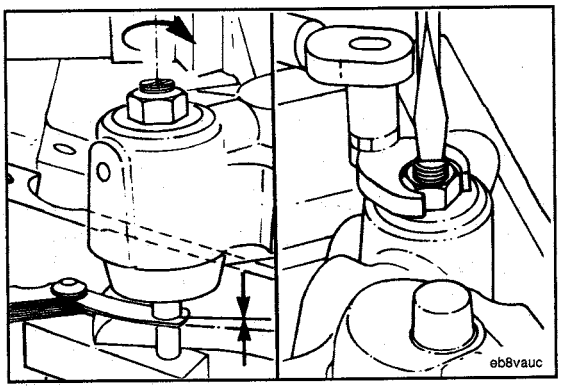


After tightening the locknut to the correct torque value, check to make sure the feeler gauge will slide backward and forward between the crosshead and the rocker lever with **only** a slight drag.

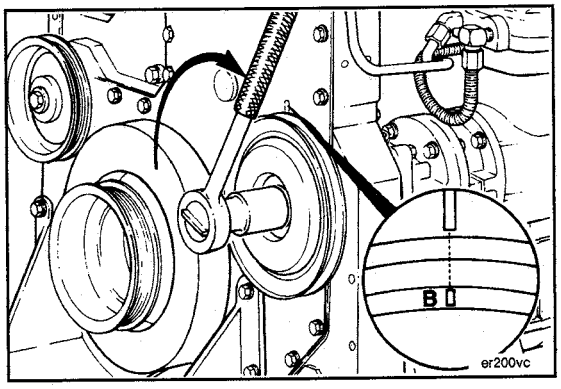


If using the touch method, attempt to insert a feeler gauge that is 0.03-mm [0.001-in] thicker between the crosshead and the rocker lever pad. The valve lash is **not** correct when a thicker feeler gauge will fit.





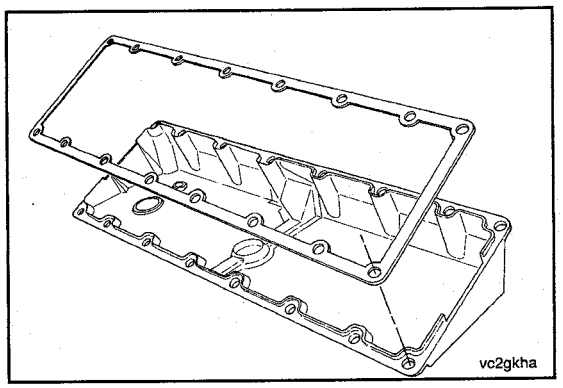
If the engine is equipped with an engine brake, refer to Engine Brake - Adjust, which appears later in this procedure.



After adjusting the injector, valves, and engine brakes (if equipped) on the appropriate cylinder, rotate the accessory drive pulley, and align the next valve set mark with the pointer on the gear cover.

Adjust all of the injectors, valves, and brakes (if equipped) following the injector and valve adjustment sequence chart.

Injector and Valve Measurement Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder	
		Injector	Valve
Start	A	1	1
Advance to	B	5	5
Advance to	C	3	3
Advance to	A	6	6
Advance to	B	2	2
Advance to	C	4	4
Firing Order: 1-5-3-6-2-4			



If the valve cover gasket was **not** damaged, it can be used again. If the gasket was damaged, it **must** be discarded and a new one used.

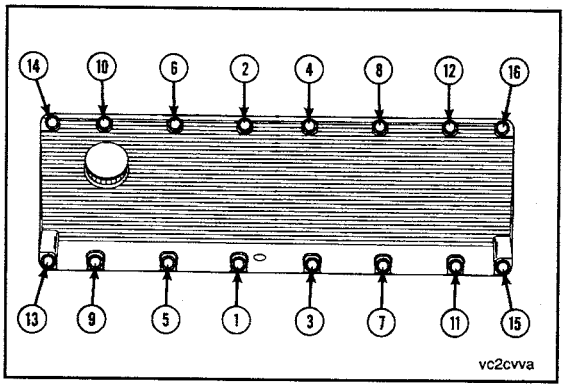
Install the gasket on the cover.

Install the cover on the rocker lever housing.

Install the 16 isolators, spacers, and capscrews in the cover.

Tighten the capscrews in the sequence shown.

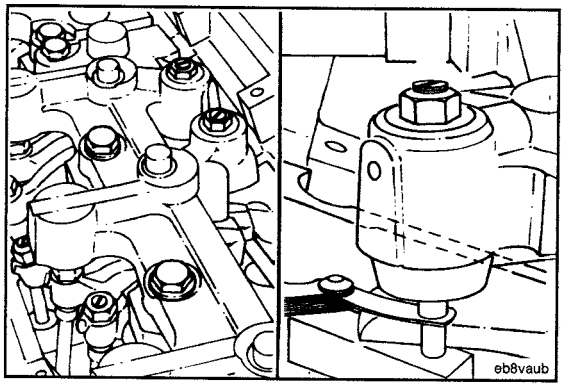
Torque Value: 15 N•m [130 in-lb]



Engine Brake - Adjust

NOTE: To obtain maximum brake operating efficiency and prevent engine damage by piston-to-valve contact, complete the following instructions carefully.

After adjusting the exhaust valves on the appropriate cylinder, insert a feeler gauge 0.38 mm [0.015 in] between the slave piston and the actuating pin in the crosshead.



△ CAUTION △

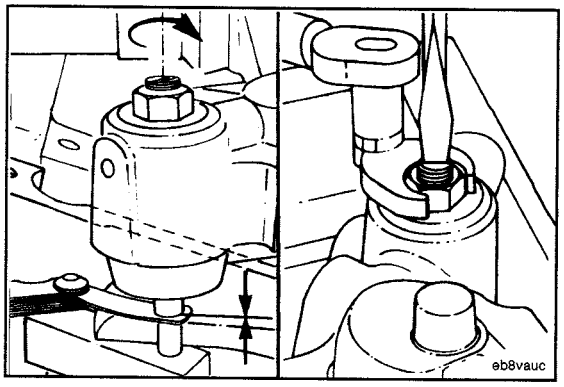
Do not tighten the adjusting screws too tightly. The engine can be damaged.

Turn the slave piston adjusting screw down until it touches the feeler gauge.

Hold the screw in position, and tighten the locknut.

Torque Value:

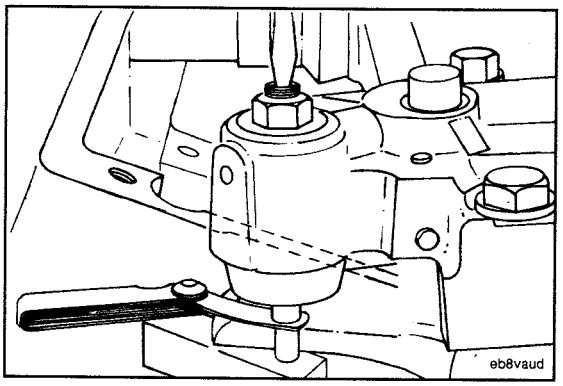
- **Without** torque wrench adapter: 34 N•m [25 ft-lb]
- **With** torque wrench adapter, Part No. 3163196: 30 N•m [22 ft-lb]

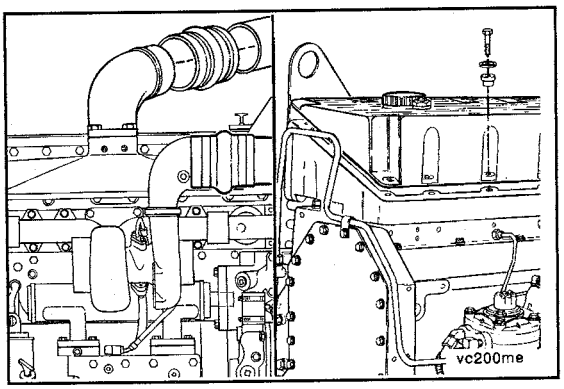


△ CAUTION △

Failure to have the correct clearance can damage the engine.

After the slave piston adjusting screw locknut is tightened to the correct torque value, check the clearance with the feeler gauge again.



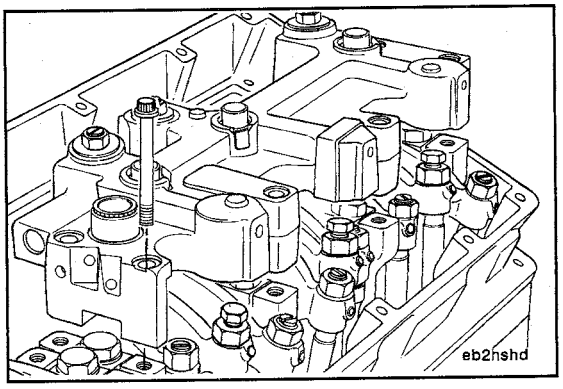


Rocker Lever Assembly (003-009)

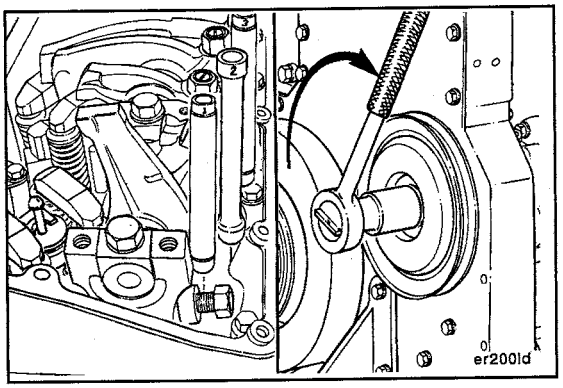
Remove (003-009-002)

Remove the air piping from the intake manifold.

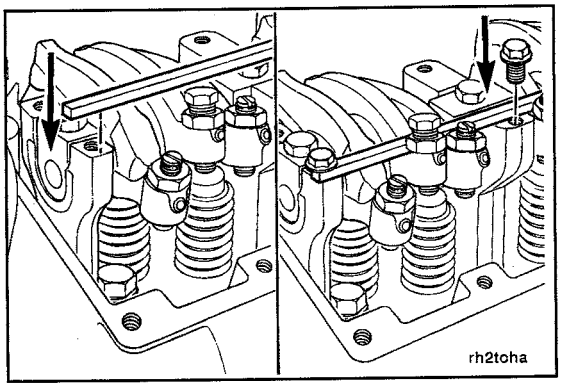
Remove the rocker lever cover. Refer to Procedure 003-011.



Remove the engine brakes, if equipped. Refer to Procedure 020-001.



Remove the push rods and push tubes. Refer to Procedure 004-014.



NOTE: This action applies **only** to engines built with the cast iron supports.

Install a piece of 1/4-inch key stock 457-mm [18-in] long on top of the four front rocker lever assembly supports. Use four M10 - 1.50 x 25 flange head capscrews to secure the bar stock to the supports.

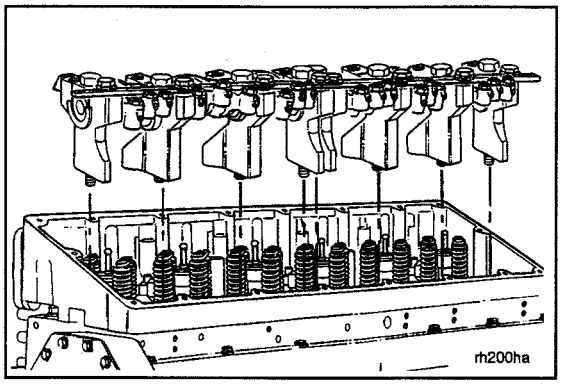
The capscrews on the two end supports will fasten to the engine brake mounting holes on one side of the bar stock. The capscrews on the two center supports will fasten to the engine brake mounting holes on the opposite side of the bar stock.

Loosen, but do **not** remove, the eight rocker shaft capscrews. The capscrews hold the rocker lever assemblies together.

On engines with the cast-iron supports, grasp hold of the bar stock and lift the front rocker lever assembly from the engine. Do **not** lift the assemblies by grasping the rocker levers and shaft. The shaft and levers can lift out of the supports allowing the levers to slide off the shaft.

On engines with the aluminum supports, grasp hold of the assembly by the rocker levers and shaft, and lift them from the engine.

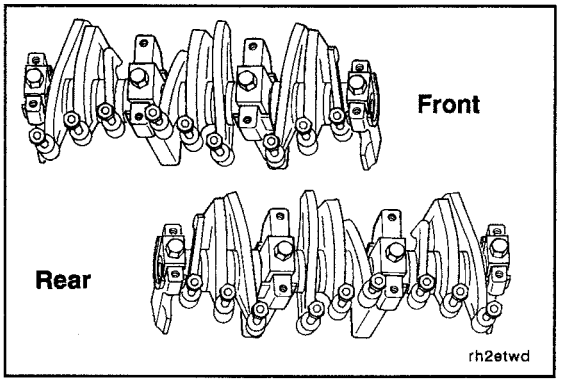
Repeat the process to remove the rear rocker lever assembly.



Disassemble (003-009-003)

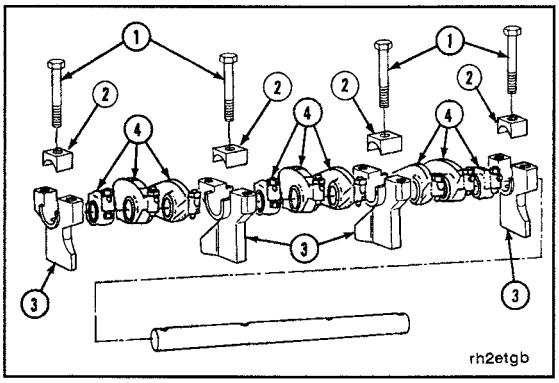
Mark each rocker lever, shaft, and support with their relative position in the engine.

The rocker lever assemblies **must** be installed in the same position they were removed from.

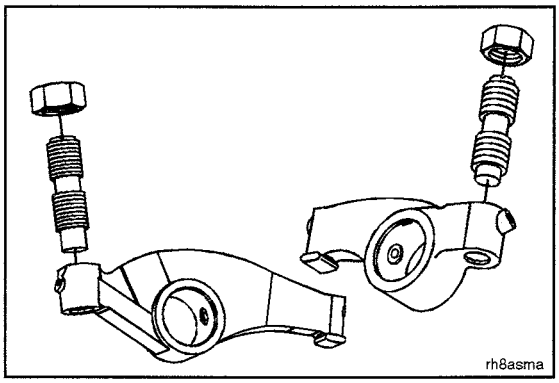


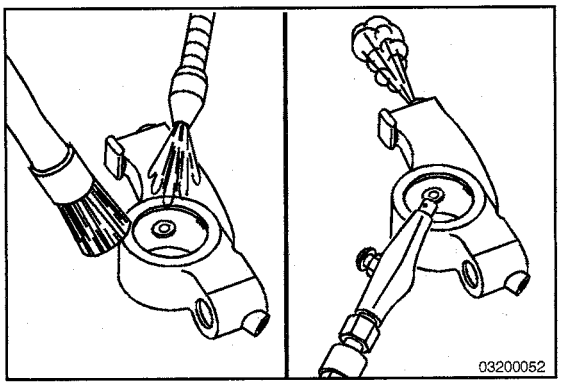
Remove the rocker shaft capscrews (1) and retaining blocks (2). Lift the shaft and levers out of the supports (3).

Remove the rocker levers (4) from both shaft assemblies.



Remove the locknuts and the adjusting screws from each rocker lever.





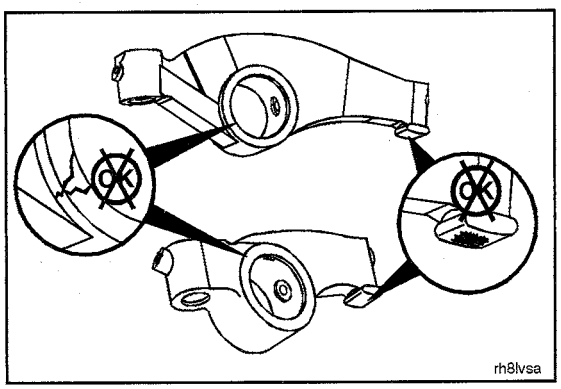
Clean (003-009-006)

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

Use steam or solvent to clean the parts. Dry with compressed air.

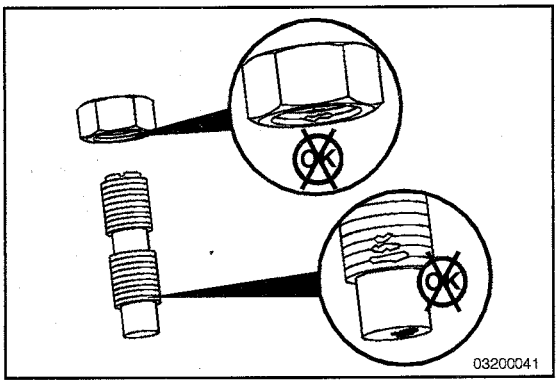
Be sure to blow out the oil passages.



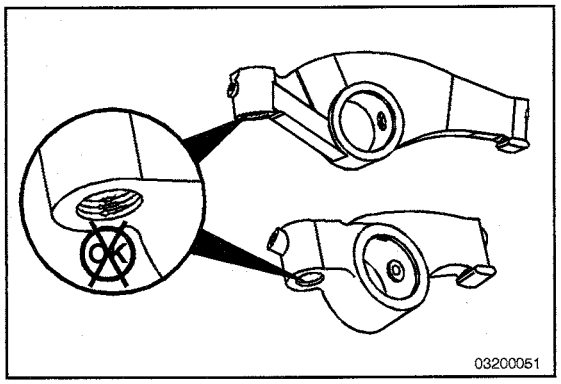
Inspect for Reuse (003-009-007)

Inspect the rocker levers for cracks, excessive pitting, or unusual wear.

Refer to the Overhead Reuse Guidelines, Bulletin No. 3810388, to identify wear patterns and excessive wear.



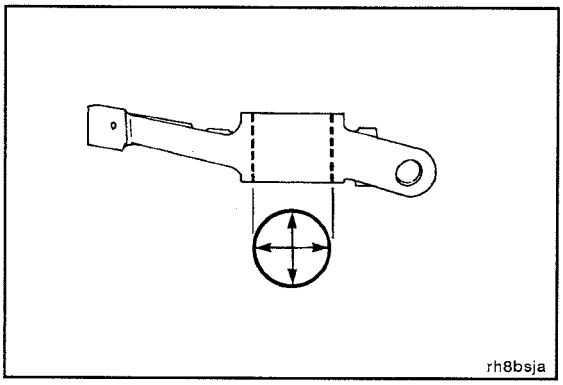
Inspect the adjusting screws and locknuts for damaged threads.



Inspect the adjusting screw threads in the rocker levers for damaged threads.

Measure each rocker lever bushing bore inside diameter.

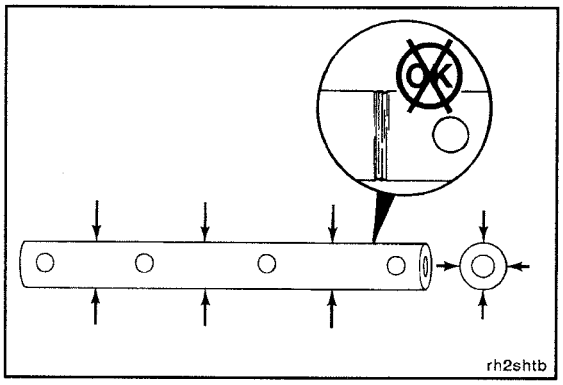
Rocker Lever Bushing Inside Diameter (Installed)		
mm		in
34.887	MIN	1.3735
34.990	MAX	1.3776



Inspect the rocker lever shafts for pitting, scoring, or other damage.

Measure each rocker lever shaft outside diameter.

Rocker Lever Shaft Outside Diameter		
mm		in
34.837	MIN	1.3715
34.864	MAX	1.3726



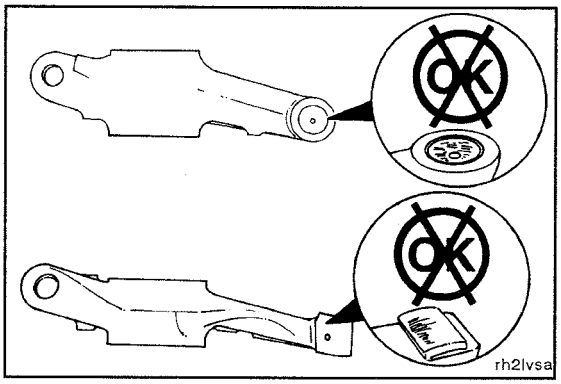
Refer to the Overhead Reuse Guidelines, Bulletin No. 3810388, to identify wear patterns and excessive wear.

If worn or damaged parts are found, or the rocker lever bushings or shafts are **not** within the specifications given, the rocker lever assemblies **must** be rebuilt. Refer to the M11 Shop Manual, Bulletin No. 3666075.

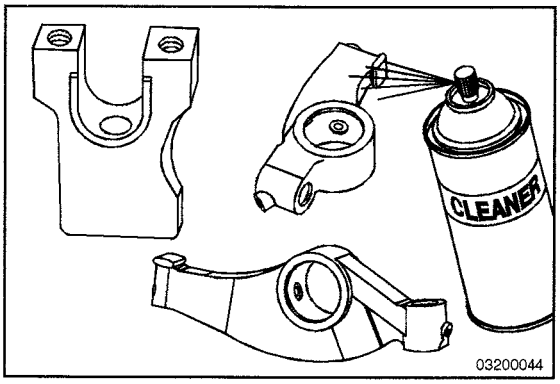
Inspect the sockets in the injector rocker levers for wear or damage.

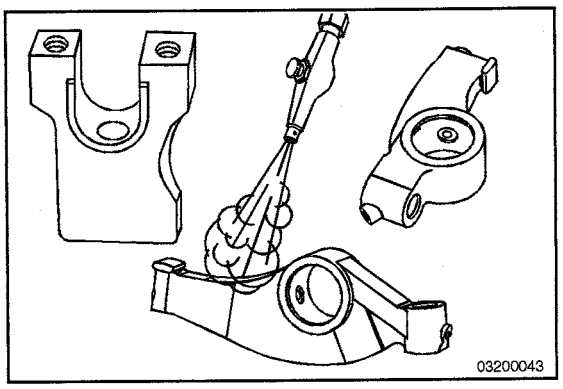
Inspect the valve rocker lever pads for wear, cracks, or other damage.

If wear, cracks, or other damage is found, the rocker lever **must** be replaced.

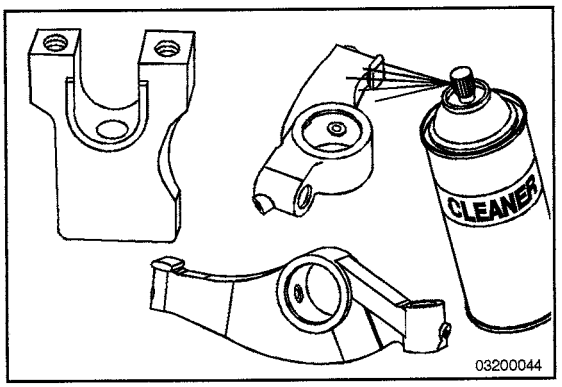


Use crack detection kit, Part No. 3375432, to inspect the rocker lever supports for cracks or damage.



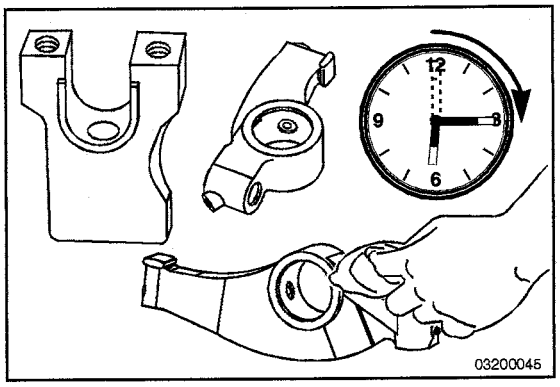


Use crack detection cleaner, Part No. 3375433, to clean the rocker levers and shaft supports. Dry with compressed air.



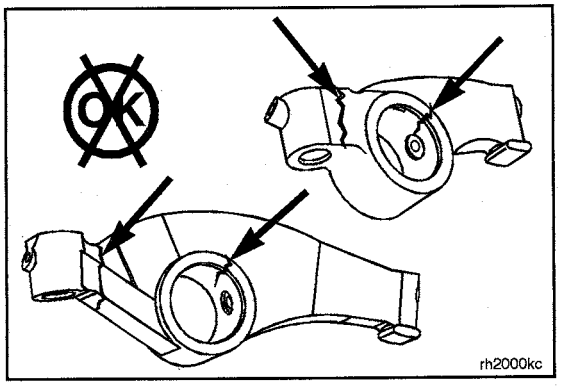
Use crack detection penetrant, Part No. 3375435, to spray the rocker levers and shaft supports.

NOTE: Do **not** dry with compressed air.



Allow the penetrant to dry for 15 minutes.

Remove the excess penetrant with a dry cloth.



Use crack detection developer, Part No. 3375434, to spray the rocker levers and shaft supports.

Inspect the levers and supports.

Cracks will appear as a solid, bright line.

Cavitation in the casting will appear as a small round mark.

If cracks or cavitation are found, the part **must** be replaced.

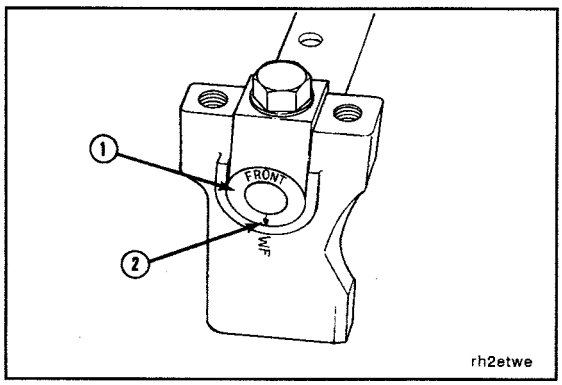
Assemble (003-009-025)

Cast-Iron Supports

⚠ CAUTION ⚠

Make sure the rocker lever shafts are installed with the arrow on the end of the shafts pointing DOWN. When the arrow points up, crossdrillings to the rocker levers are orientated differently, which has an adverse affect to rocker lever oiling.

The rocker lever shafts are labeled front and rear on the end of the shafts (1). The arrows on the shafts (2) **must** be pointed downward to maintain an oil flow to the rocker levers.

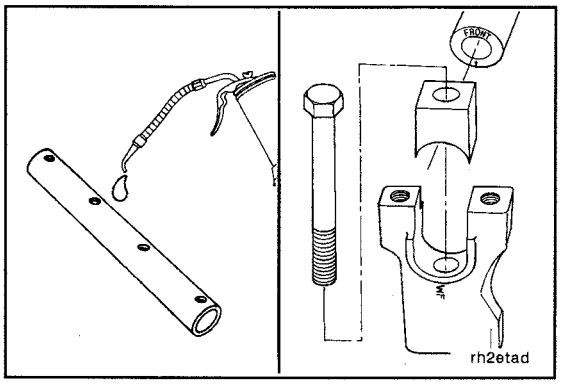


The shaft end supports are **not** interchangeable.

Use clean 15W-40 oil to lubricate both shafts.

Install the front end support on each shaft.

Install the retaining blocks, washers, and capscrews through the end supports.

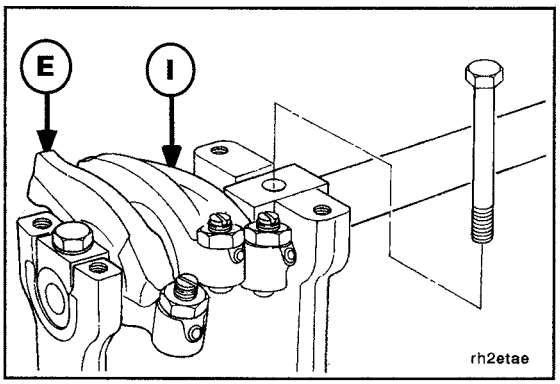


Install the rocker levers in the correct sequence, as shown.

NOTE: The rocker levers **must** be installed so they will be in the same position in the engine as when they were removed.

Install one of the two shaft center supports on the shaft.

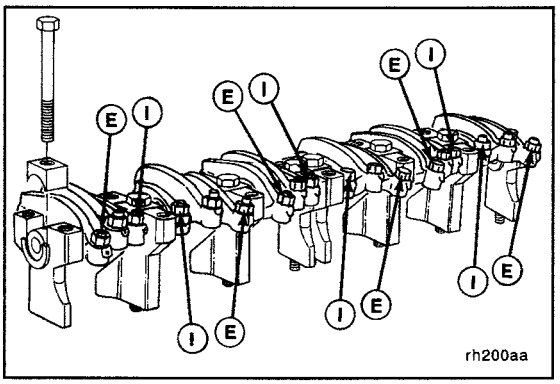
Install the retaining block, washer, and capscrew through the center support.

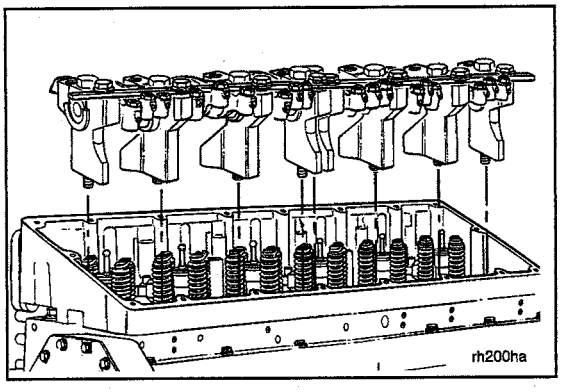


Install the remaining levers and supports with the intake (I) and exhaust (E) valve levers in the correct position, as shown.

Install the remaining retaining blocks, washers, and capscrews.

Install the key stock used to remove the rocker levers on top of the supports.





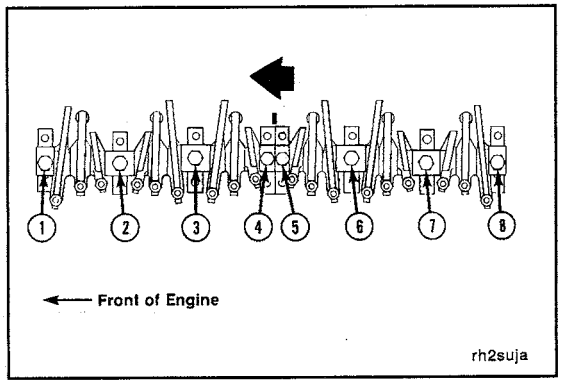
Install (003-009-026)

The rocker lever assemblies **must** be installed in the engine so they are in the same position as they were removed from.

Install the assemblies on the engine.

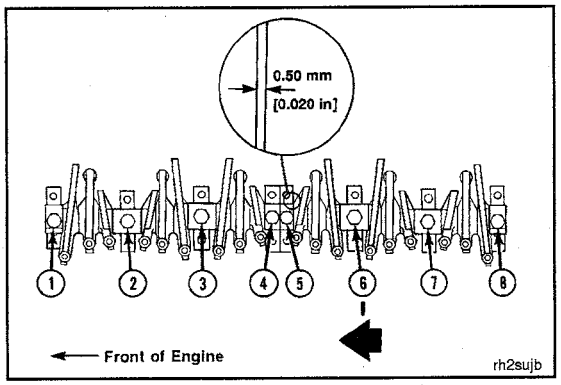
Hand-tighten the mounting capscrews at this time. The rocker lever side clearance **must** be adjusted before the capscrews are tightened to their final torque value.

Rocker Lever Installation Side Clearance		
mm		in
0.50	NOMINAL	0.020



Push or use a hammer to tap the number five rocker lever support toward the front of the engine.

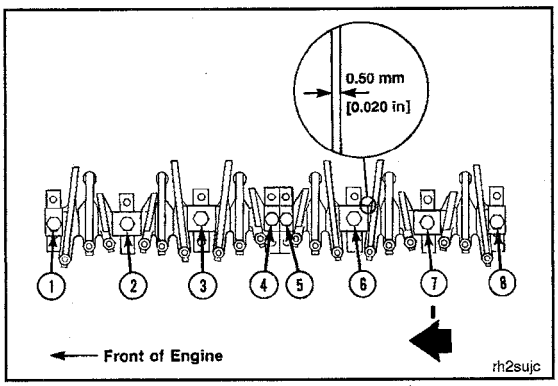
Torque the mounting capscrews to 5 N•m [45 in-lb] at this time.



Install a 0.50-mm [0.020-in] feeler gauge between the number five support and the intake lever for the number four cylinder.

Push or use a hammer to tap the number six support toward the front of the engine.

Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.



Install a 0.50-mm [0.020-in] feeler gauge between the number six support and the exhaust lever for the number five cylinder.

Push or use a hammer to tap the number seven support toward the front of the engine.

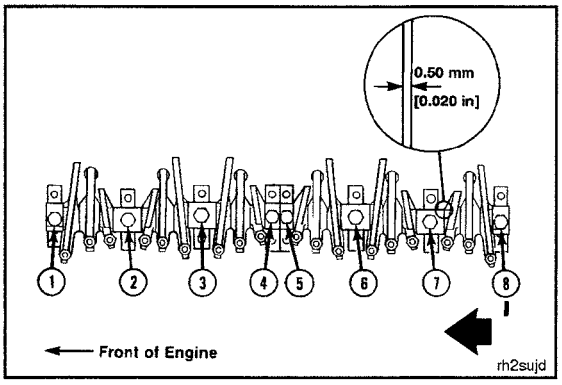
Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.

Install a 0.5-mm [0.020-in] feeler gauge between the number seven support and the intake lever for the number six cylinder.

Push or use a hammer to tap the number eight support toward the front of the engine.

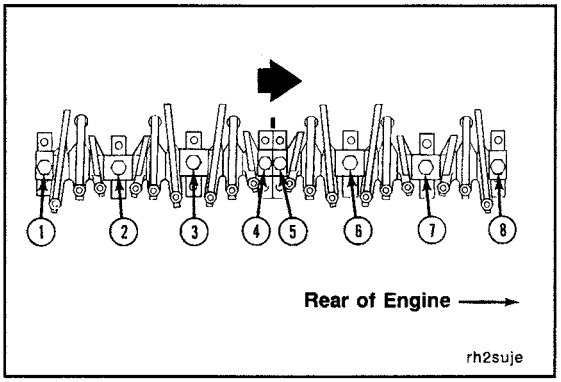
Tighten the No. 5, 6, 7, and 8 support capscrews to their final torque.

Torque Value: 183 N•m [135 ft-lb]



Push or use a hammer to tap the number four support toward the rear of the engine.

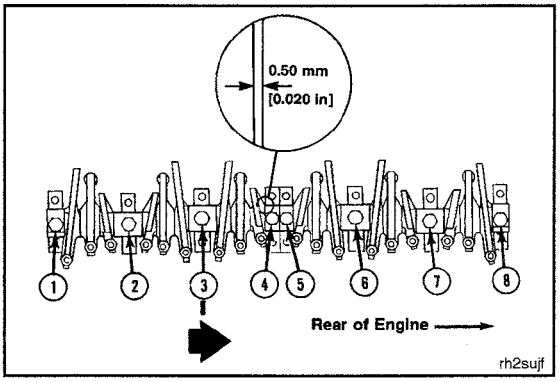
Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.



Install a 0.50-mm [0.020-in] feeler gauge between the number four support and the intake lever for the number three cylinder.

Push or use a hammer to tap the number three support toward the rear of the engine.

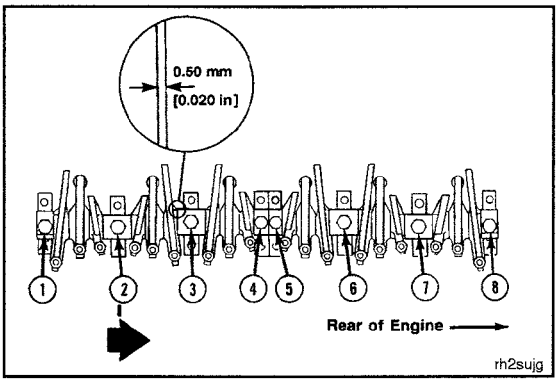
Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.

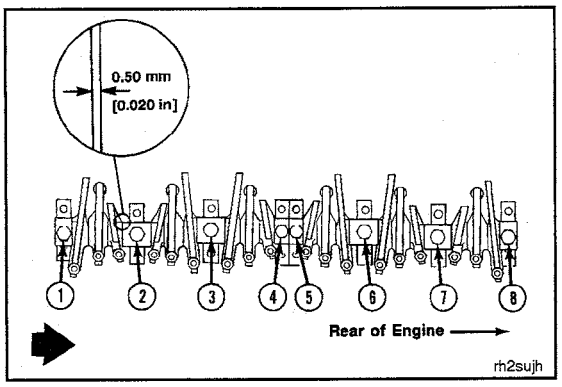


Install a 0.50-mm [0.020-in] feeler gauge between the number three support and the exhaust lever for the number two cylinder.

Push or use a hammer to tap the number two support toward the rear of the engine.

Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.





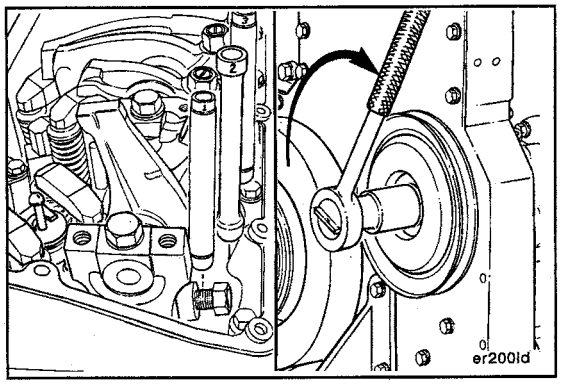
Install a 0.50-mm [0.020-in] feeler gauge between the number two support and the intake lever for the number one cylinder.

Push or use a hammer to tap the number one support toward the rear of the engine.

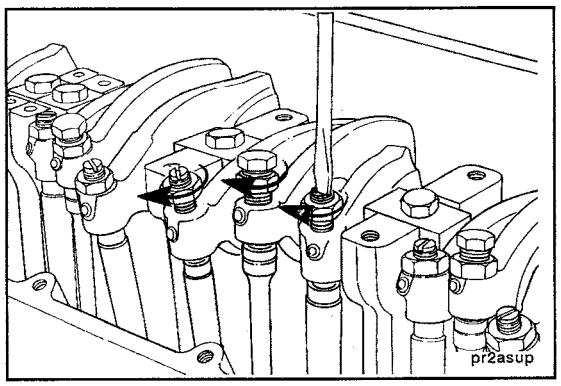
Tighten the No. 1, 2, 3, and 4 support capscrews to their final torque.

Torque Value: 183 N•m [135 ft-lb]

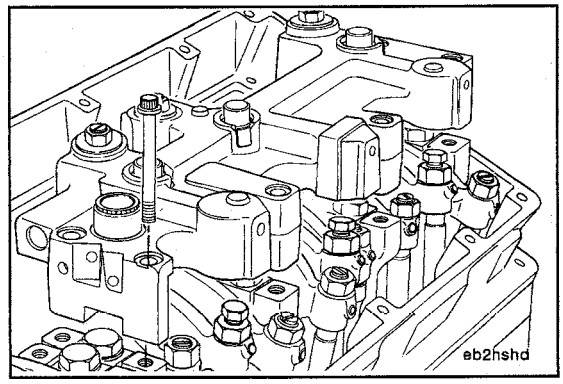
Check the front and rear assemblies for correct clearance. Check the support capscrews for the correct torque value.



Install the push rods and push tubes. Refer to Procedure 004-014.



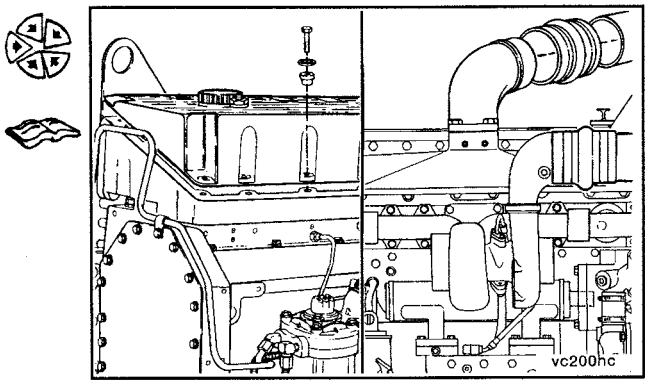
Adjust the valves and injectors. Refer to Procedure 003-004.



Install the engine brakes, if applicable. Refer to Procedure 020-001.

Install the rocker lever cover. Refer to Procedure 003-011.

Install the air piping to the intake manifold. Refer to the manufacturer's specifications for the correct torque value.

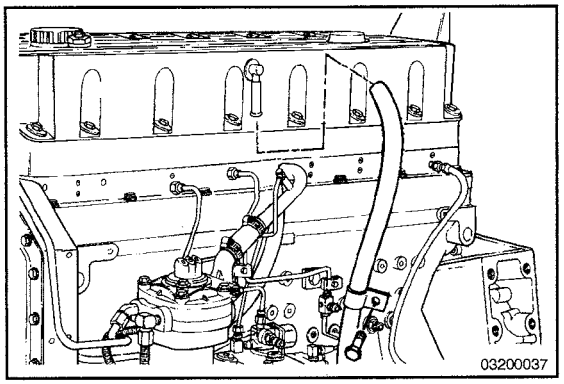


Rocker Lever Cover (003-011)

Remove (003-011-002)

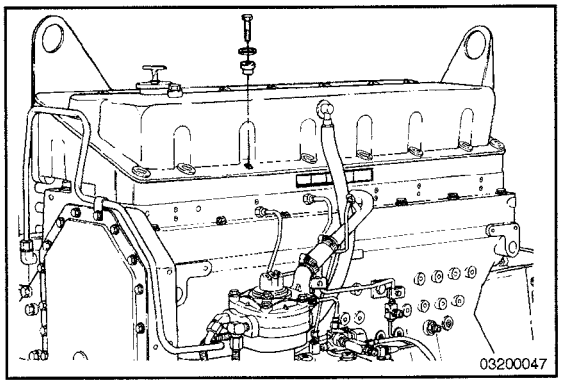
Remove the air piping from the intake manifold.

Remove the hose from the crankcase breather.



Remove the 16 capscrews and the rocker lever cover.

Remove the 16 isolators from the cover.



Clean (003-011-006)

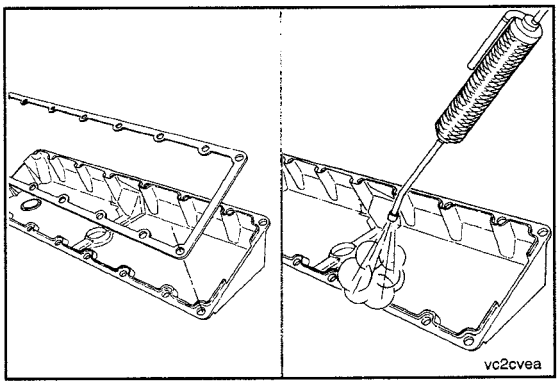
⚠ WARNING ⚠

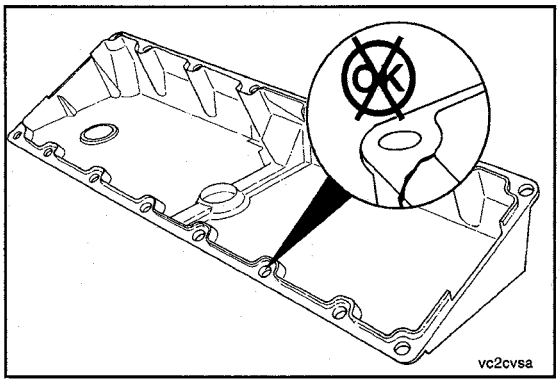
When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

NOTE: The gasket can be reused if it is **not** damaged.

Remove the gasket and inspect for damage.

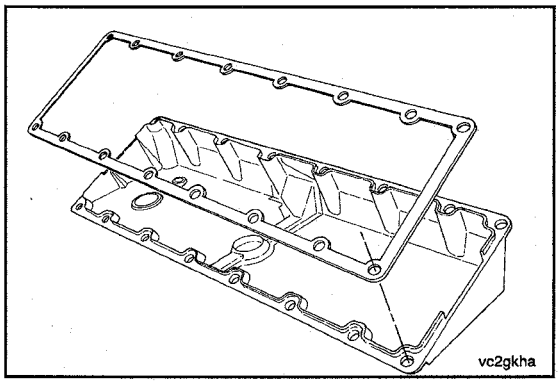
Steam clean and dry with compressed air.





Inspect for Reuse (003-011-007)

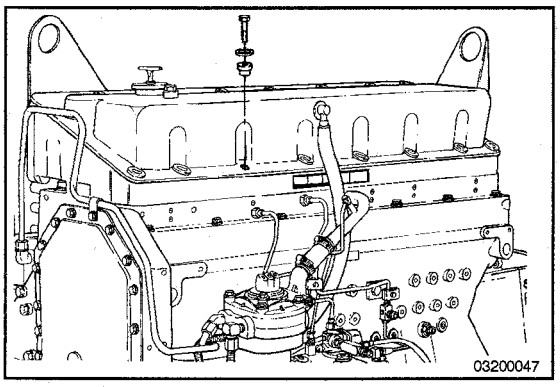
Inspect the cover for cracks or damage and replace if necessary.



Install (003-011-026)

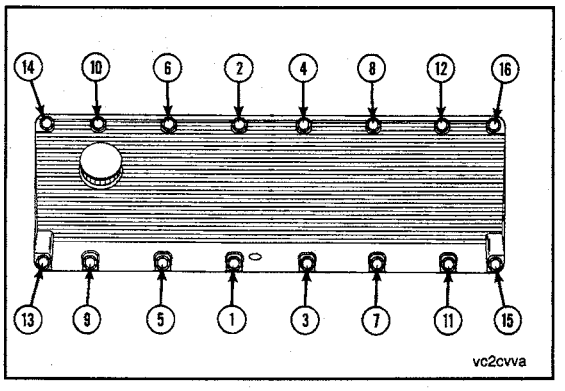
If the gasket was **not** damaged, it can be used again. If the gasket was damaged, it **must** be discarded and a new one used.

Install the gasket on the cover.



Install the cover on the rocker lever housing.

Install the 16 isolators, spacers, and capscrews in the cover.

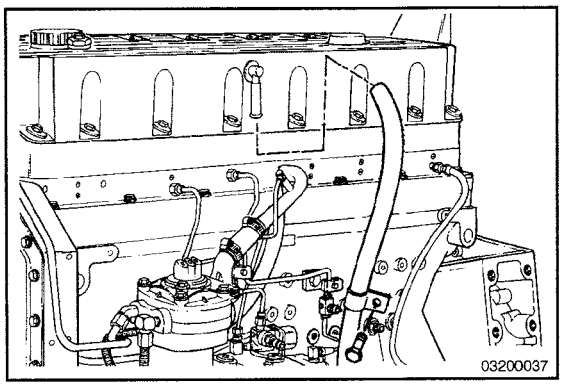


Tighten the capscrews in the sequence shown.

Torque Value: 15 N•m [130 in-lb]

Install the hose on the crankcase breather.

Install the air piping to the intake manifold. Refer to the manufacturer's specifications for the correct torque values.

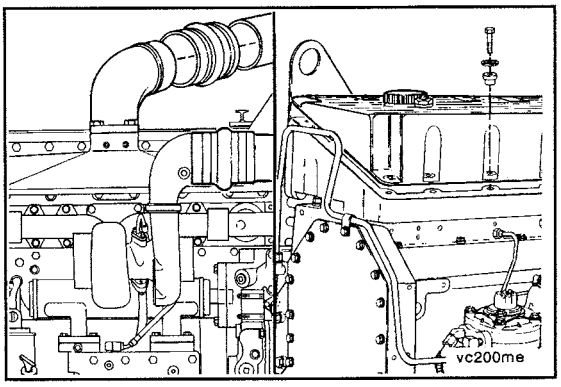


Rocker Lever Housing (003-013)

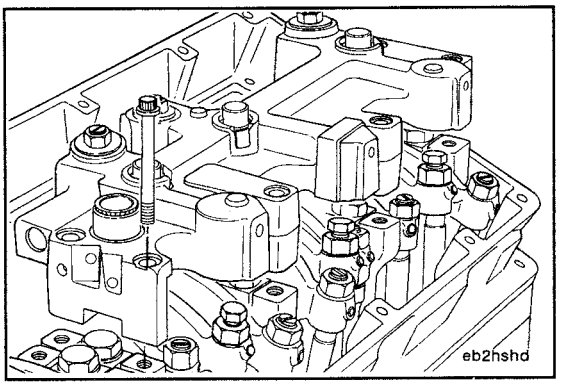
Remove (003-013-002)

Remove the air piping from the intake manifold.

Remove the rocker lever cover. Refer to Procedure 003-011.



Remove the engine brakes, if applicable, from the engine. Refer to Procedure 020-001.

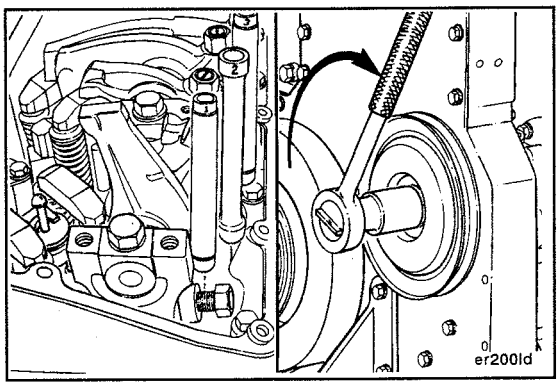


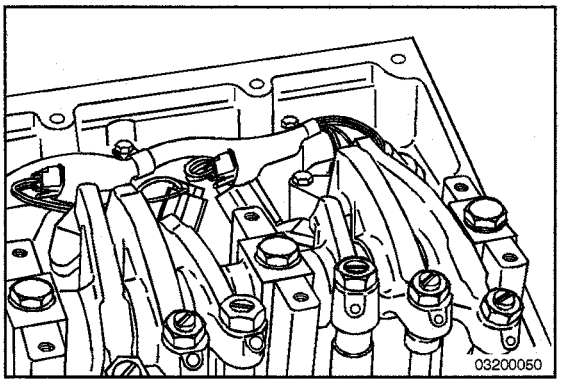
Remove all valve push tubes and injector push rods from the engine. Refer to Procedure 004-014.

Rotate the rocker levers up.

NOTE: Mark the position of the crossheads as they are removed. They **must** be installed in the same position as from which they were removed.

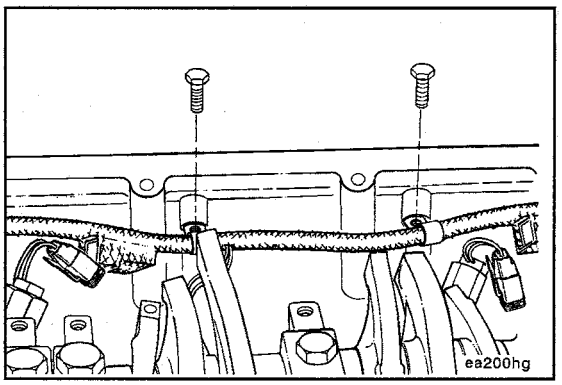
Remove the crossheads to prevent them from falling into the lower area of the engine.



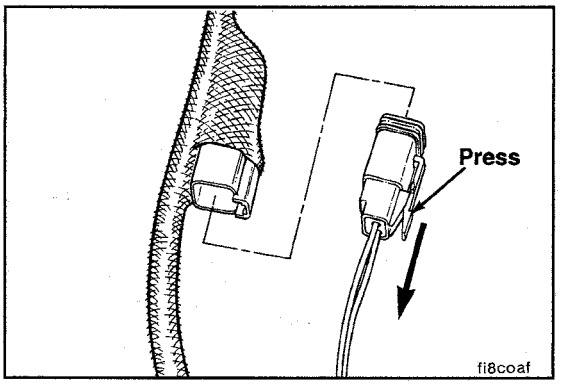


The internal engine harness is located inside the rocker housing.

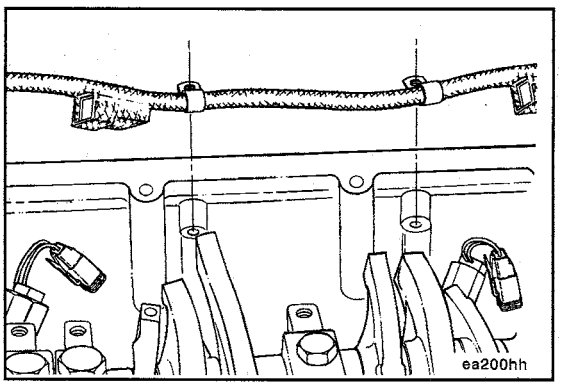
A pass through connector joins the internal and external engine harness. This connector has two clips that can manually be opened to allow separation of the two harnesses. Engines with pass through connectors in the front of the engine have clips on the outside, engines with pass through connections in the rear of the engine have clips on the inside of the rocker housing that require the valve cover to be removed to access.



Remove the internal engine harness holding clamp capscrews.

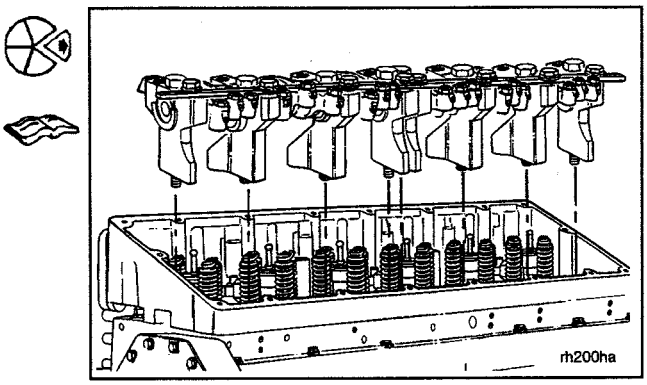


Separate the Deutsch 2-pin connectors from the internal engine harness to the fuel injectors.

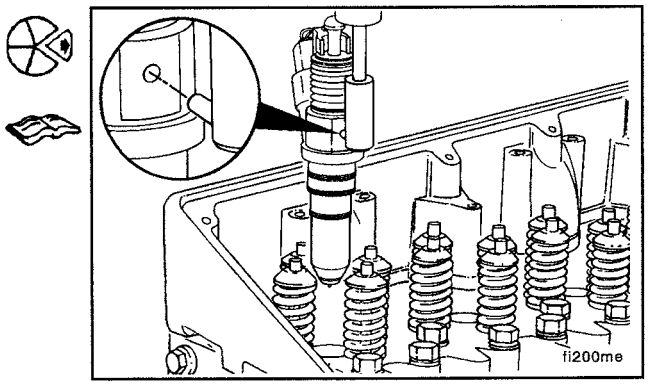


Remove the internal engine harness from the engine.

Remove the rocker lever assemblies. Refer to Procedure 003-009.



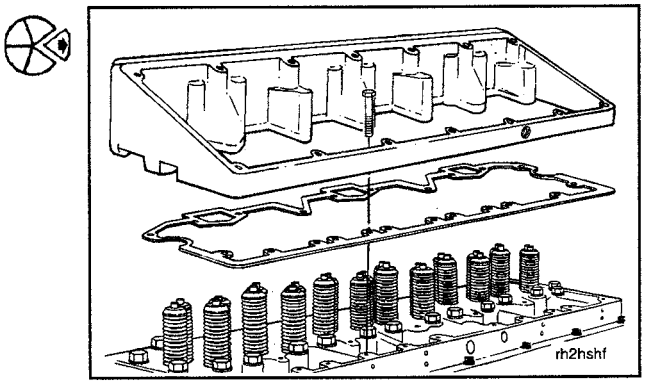
Remove the injectors. Refer to Procedure 006-026.



Remove the rocker housing mounting capscrews.

Remove the rocker housing and the intake manifold as a complete unit.

NOTE: If you are troubleshooting high blowby, the rocker housing gasket **must** be inspected before it is removed from the cylinder head.



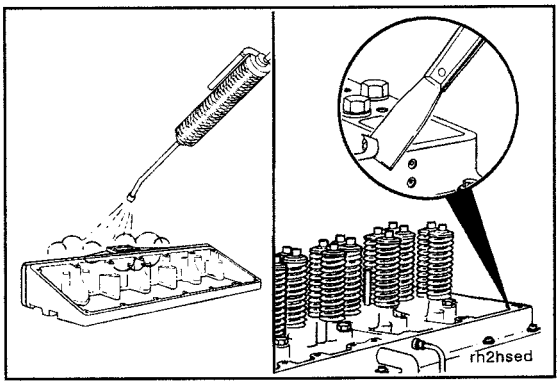
Clean (003-013-006)

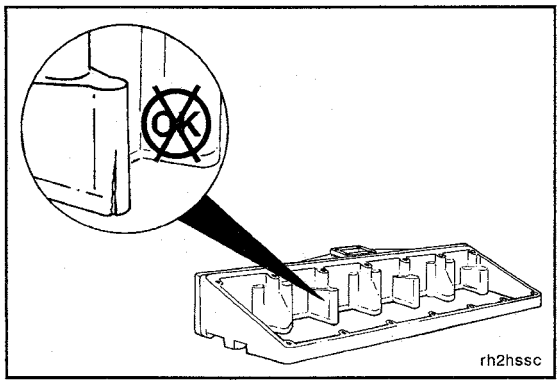
⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

Use steam to clean the rocker lever housing. Dry with compressed air.

Clean the cylinder head gasket surface.



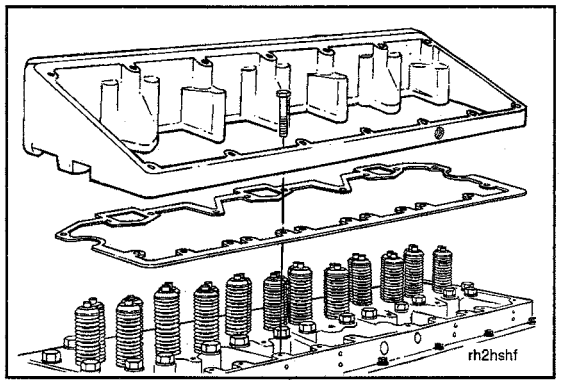


Inspect for Reuse (003-013-007)

Inspect the rocker housing gasket for cuts or damage on the portion of the gasket that seals around the intake ports. Damage to the gasket can cause high blowby.

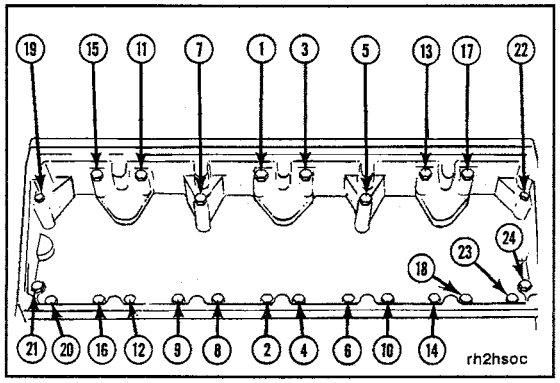
Inspect the housing for cracks or damage.

If the housing is cracked, it **must** be replaced.



Install (003-013-026)

Use a new gasket, and install the rocker lever housing.



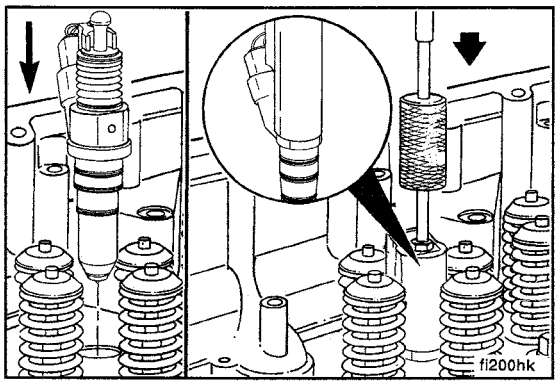
Step 1: Snug all bolts.

Step 2: Tighten the 24 capscrews in the sequence shown.

Torque Value: 34 N•m [25 ft-lb]

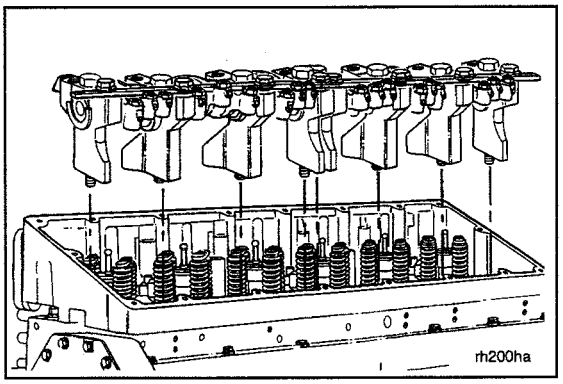
Step 3: Tighten the 24 capscrews in the sequence shown.

Torque Value: 61 N•m [45 ft-lb]



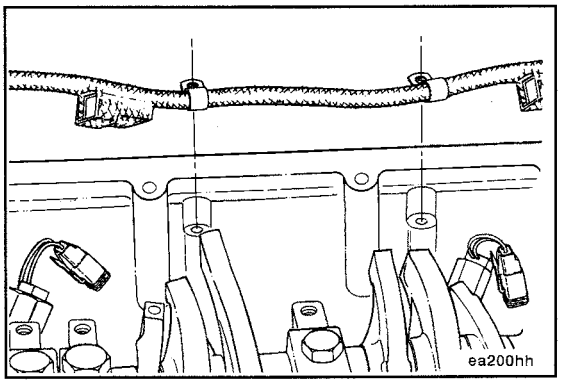
Install the injectors. Refer to Procedure 006-026.

Install the rocker lever assemblies. Refer to Procedure 003-009.



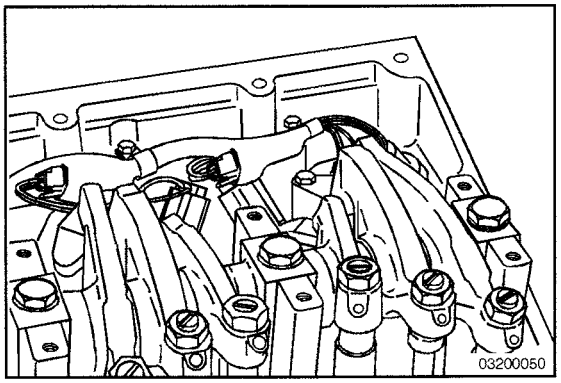
Install the internal engine wiring harness on the engine.

The harness and connectors **must** be clear of any moving parts, so the wires will **not** be damaged during engine operation.



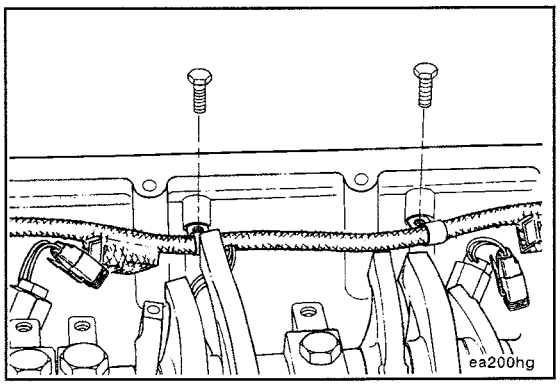
Connect the 15-pin connector of the internal engine harness to the 15-pin connector of the external engine harness.

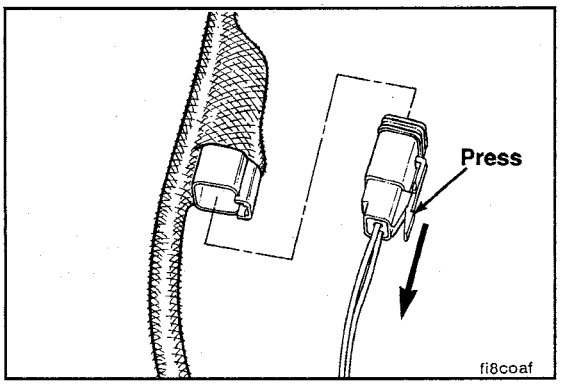
NOTE: The internal and external Metri-Pack connectors are "keyed." Make sure both connectors are correctly aligned when they are joined together.



Install the holding clamps for the internal engine harness. Tighten the capscrews.

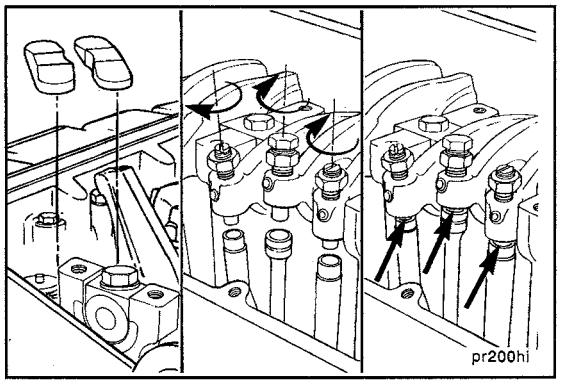
Torque Value: 20 N•m [15 ft-lb]





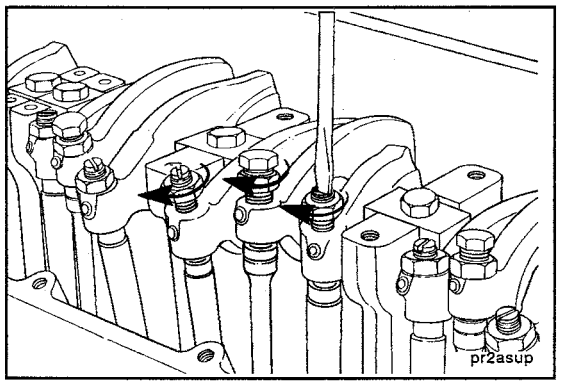
Lubricate the connector ends with lubricant, Part No. 3822934.

Connect the Deutsch 2-pin connectors from the internal engine harness to the fuel injectors.

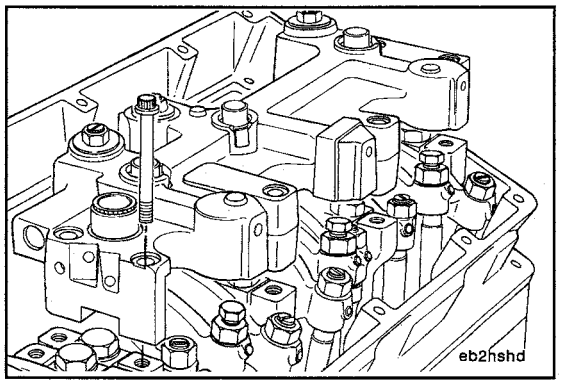


Install the crossheads in the same position they were removed from, and rotate the rocker levers down.

Install the push rods and push tubes. Refer to Procedure 004-014.



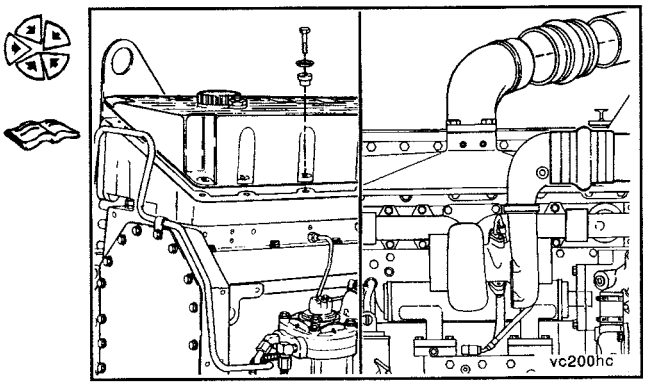
Adjust the valves and injectors. Refer to Procedure 003-004.



Install the engine brakes, if applicable. Refer to Procedure 020-001.

Install the rocker lever cover. Refer to Procedure 003-011.

Install the air piping to the intake manifold. Refer to the manufacturer's specifications for the correct torque value.



NOTES

Section 4 - Cam Followers/Tappets - Group 04

Section Contents

Page

Cam Follower Assembly 4-2
Assemble 4-5
Clean 4-3
Disassemble 4-3
Inspect for Reuse 4-3
Install 4-6
Remove 4-2

Push Rods or Tubes 4-8
Inspect for Reuse 4-9
Install 4-10
Remove 4-8

Service Tools 4-1
Cam Followers/Tappets 4-1

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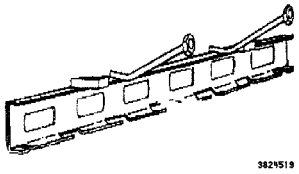
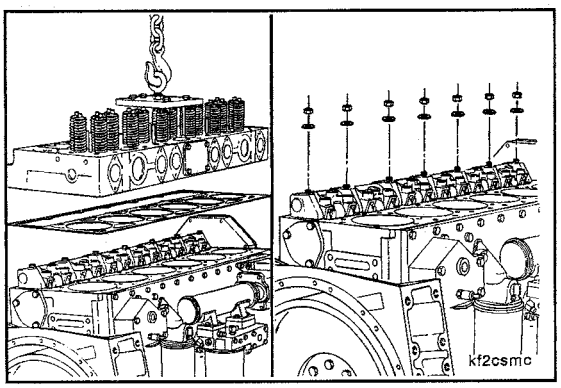
Service Tools

Cam Followers/Tappets

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3824519	**Cam Follower Assembly Removal and Installation Tool** Used to remove and install the cam follower assemblies.	

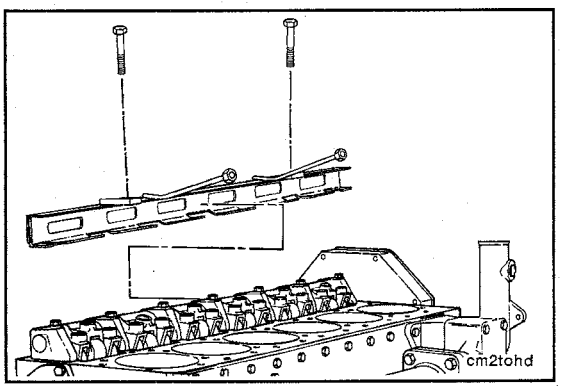


Cam Follower Assembly (004-001)

Remove (004-001-002)

Remove the cylinder head. Refer to Procedure 002-004.

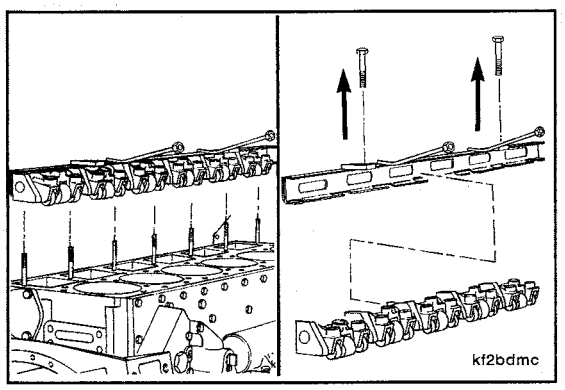
Remove the nuts and washers from the cam follower assembly supports.



Install the cam follower assembly installation and removal tool, Part No. 3824519. Slide the tool under the assemblies with the supports located in the cutouts on the bottom surface of the tool.

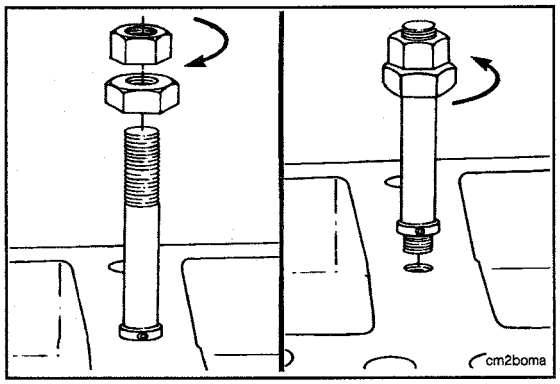
NOTE: The cam follower assembly consists of two shaft assemblies with a common center support.

Secure the tool to the assemblies by hand-tightening the screws on top of the tool.



Lift both ends of the cam follower assemblies to remove them from the engine.

Set the assemblies on a flat surface. Loosen the two screws on top of the tool, and remove the tool from the cam follower assemblies.



Install two M10 x 1.50 nuts on each stud.

Tighten the nuts together.

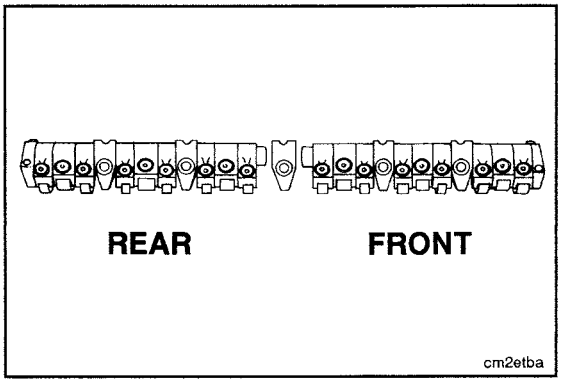
Turn the bottom nut **counterclockwise** to remove the stud.

NOTE: The cam follower studs have an internal oil passage to supply the cam followers with lubricating oil. The studs **must** be removed and checked.

Disassemble (004-001-003)

Separate the two shafts from the center support.

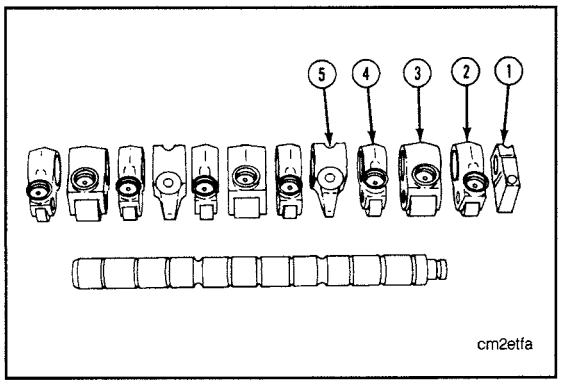
NOTE: The cam follower levers **must** be installed in the same position they were removed from. Mark both of the end supports, the center support, and all of the cam followers to identify their location when they are removed. The end supports are **not** interchangeable. The center support is **not** interchangeable with any of the other inner supports.



Remove the end supports (1) from the shafts.

Remove the cam followers and supports from both shafts.

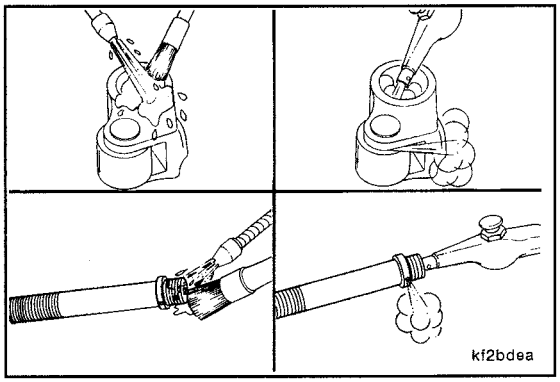
- Valve cam follower (2)
- Injector cam follower (3)
- Valve cam follower (4)
- Shaft support (5).



Clean (004-001-006)

Clean the cam follower parts with solvent and dry with compressed air.

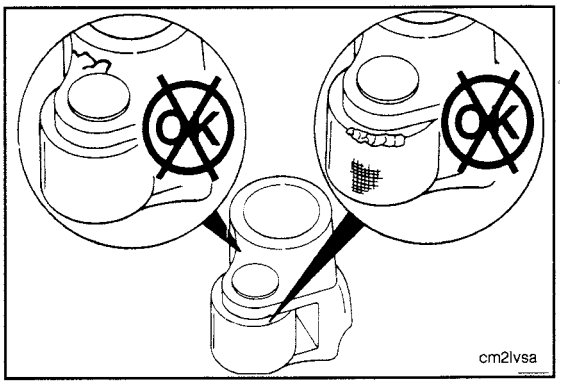
Make sure the oil passages in the cam followers and the cam follower studs are clean.

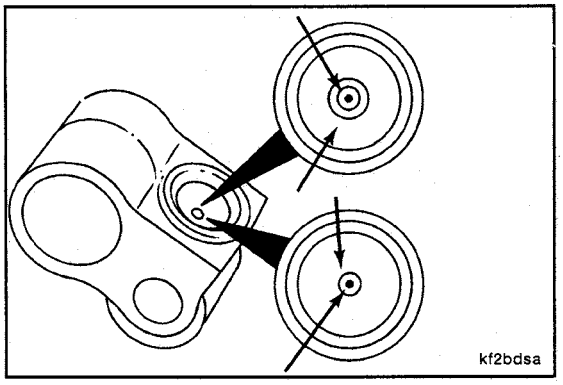


Inspect for Reuse (004-001-007)

Inspect the cam followers for cracks or other damage.

Refer to Camshaft Reuse Guidelines, Bulletin No. 3666052, for inspection criteria of cam follower rollers.

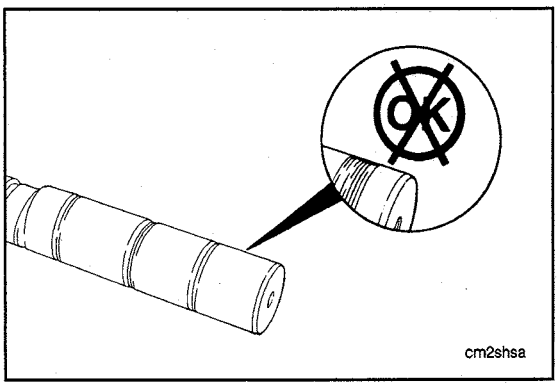




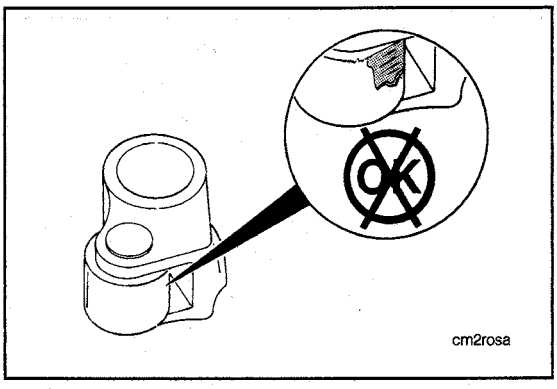
Inspect the cam follower sockets for excessive wear.

If excessive wear is found in the cam follower sockets, the push rods **must** be inspected. Refer to Procedure 004-014. Refer to the Overhead Reuse Guidelines, Bulletin No. 3810388, to identify wear patterns and excessive wear.

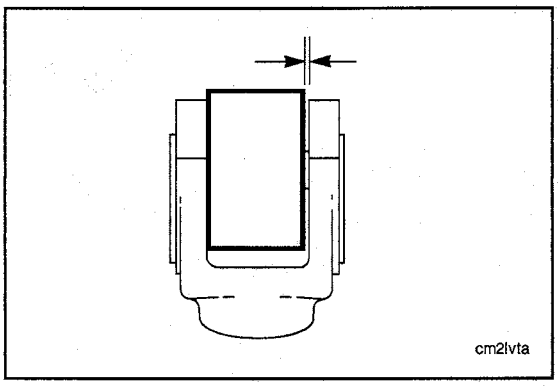
Replace all parts that do **not** meet the reuse guidelines.



Inspect the cam follower shafts for scores or damage.



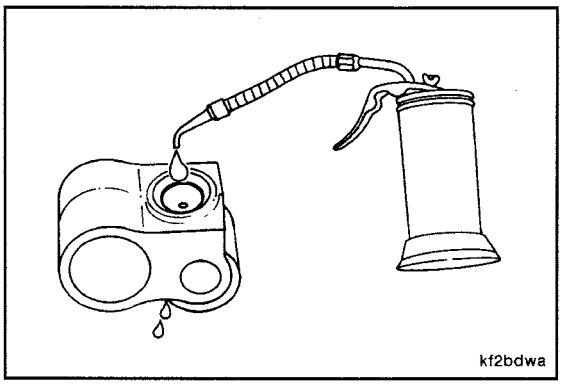
Inspect the cam follower rollers for flat spots, freedom of rotation, or other damage.



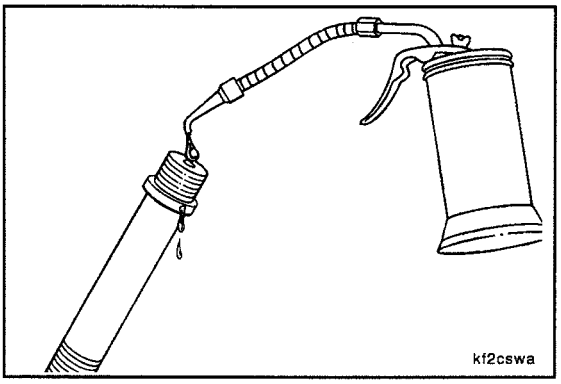
Measure the cam follower roller side clearance.

Cam Follower Roller Side Clearance		
mm		in
0.19	MIN	0.007
0.65	MAX	0.026

Use clean 15W-40 oil to check the oil flow through the cam followers.

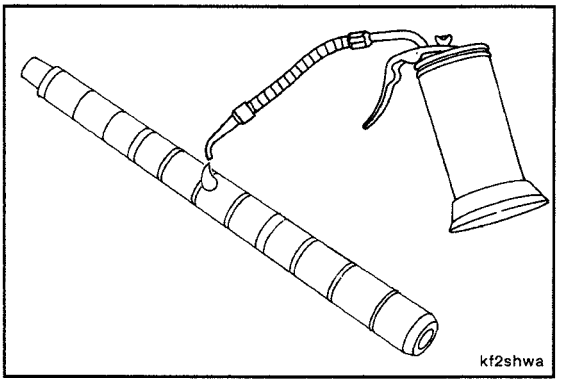


Use clean 15W-40 oil to check the oil flow through the cam follower studs.



Assemble (004-001-025)

Use clean 15W-40 oil to lubricate the cam followers and shafts.

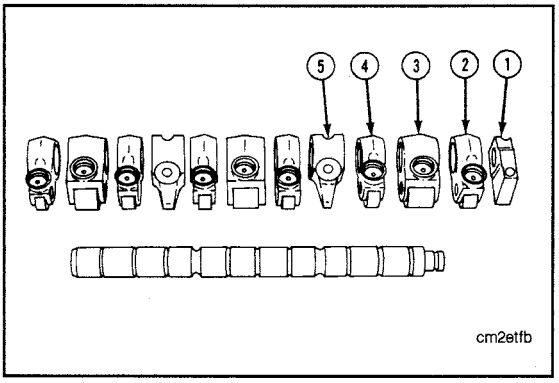


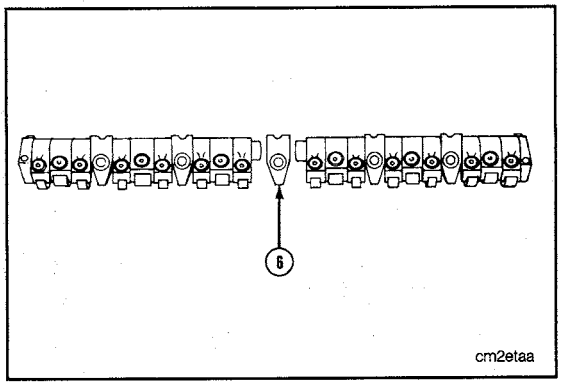
The cam followers, supports, and shafts **must** be installed in the same position from which they were removed. The shaft end supports are **not** interchangeable.

Install the end support (1) on the shaft.

Install the cam followers on the shaft in the following sequence:

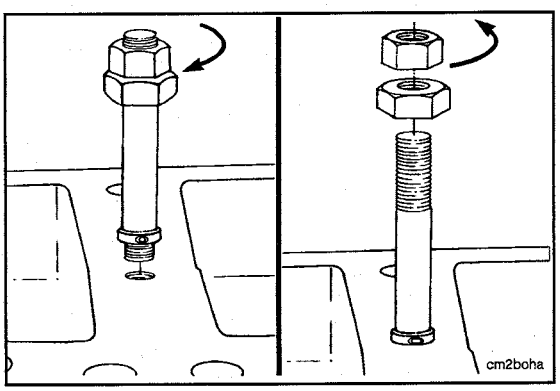
- Valve cam follower (2)
- Injector cam follower (3)
- Valve cam follower (4)
- Shaft support (5).





Install the two cam follower shaft assemblies in the common center support (6).

NOTE: The common center support (6) has a locating dowel hole. The other inner supports do **not** have this hole.



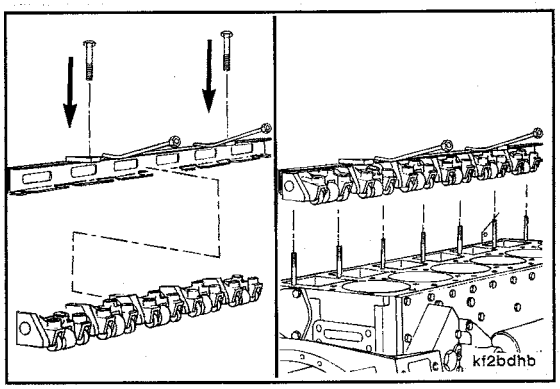
Install (004-001-026)

Install the cam follower studs with two M10 x 1.50 nuts tightened together.

Tighten the studs.

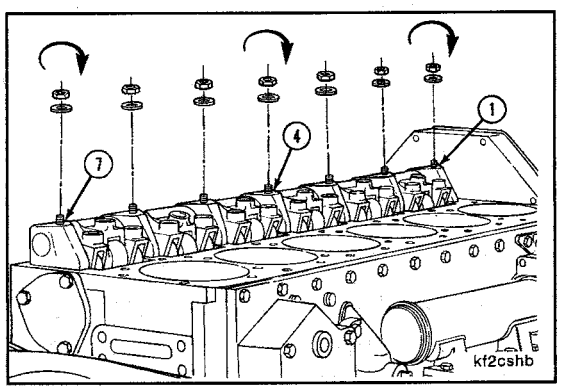
Torque Value: 34 N•m [25 ft-lb]

Remove the two nuts.



Install cam follower assembly installation and removal tool, Part No. 3824519, onto the cam follower assemblies.

NOTE: Before installing the cam follower assemblies, the cylinder head deck **must** be cleaned. Refer to Procedure 002-004.



Supports one, four, and seven are doweled. The supports **must** align with the dowel pins in the cylinder block.

Install the cam follower assemblies on the studs.

Remove the service tool.

Install the washers and nuts on each stud.

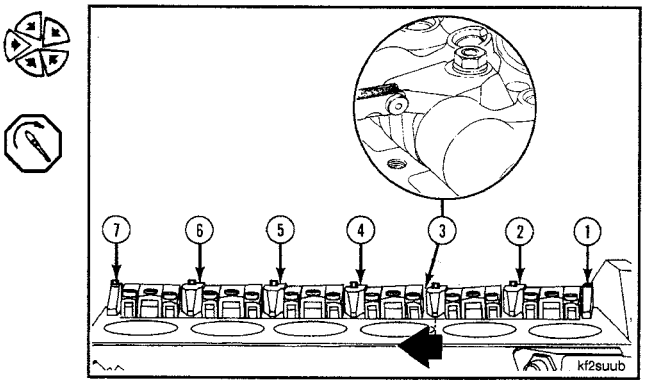
Tighten the nuts on supports one, four, and seven.

Torque Value: 47 N•m [35 ft-lb]

Install a 0.76-mm [0.030 in] feeler gauge between the No. three support and the exhaust lever for cylinder No. three. Push the No. three support toward the No. four support.

Tighten the No. three support nut.

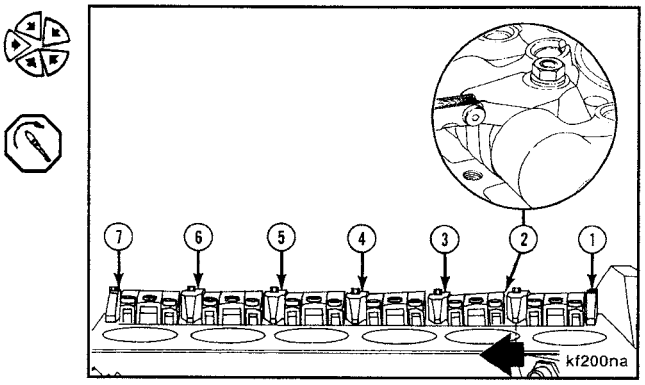
Torque Value: 47 mm [35 ft-lb]



Install a 0.76-mm [0.030 in] feeler gauge between the No. two support and the intake lever for cylinder No. two. Push the No. two support toward the No. three support.

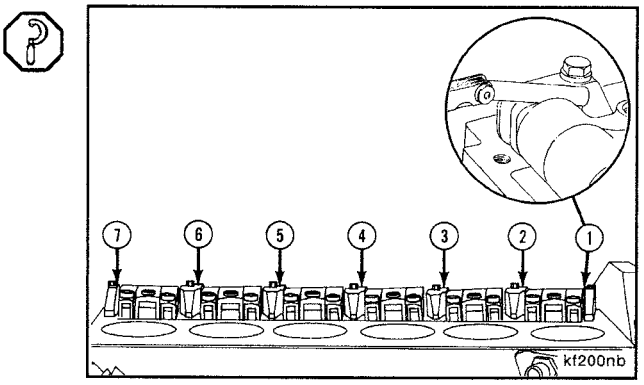
Tighten the No. two support nut.

Torque Value: 47 N•m [35 ft-lb]



Measure side clearance between the No. one and two supports.

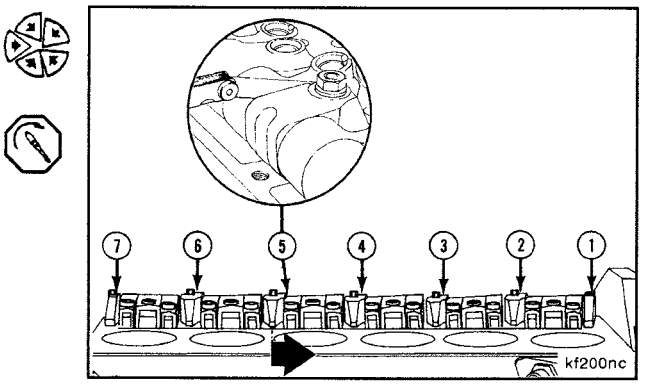
Cam Follower Side Clearance Between Supports		
mm		in
0.76	MIN	0.030

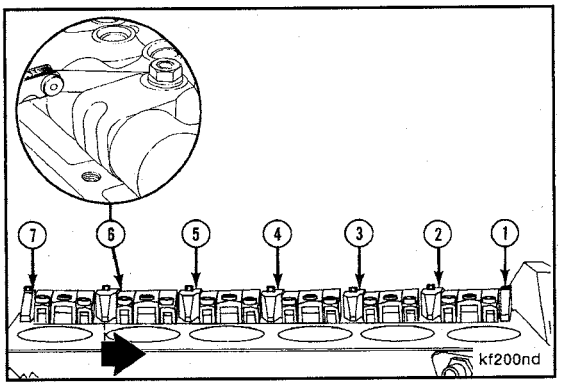


Install the 0.76-mm [0.030 in] feeler gauge between the No. five support and the exhaust lever for cylinder No. four. Push the No. five support toward the No. four support.

Tighten the No. five support nut.

Torque Value: 47 N•m [35 ft-lb]

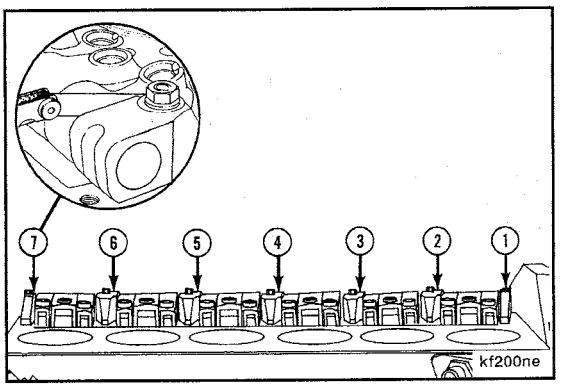




Install the 0.76-mm [0.030 in] feeler gauge between the No. six support and the intake lever for cylinder No. five. Push the No. six support toward the No. five support.

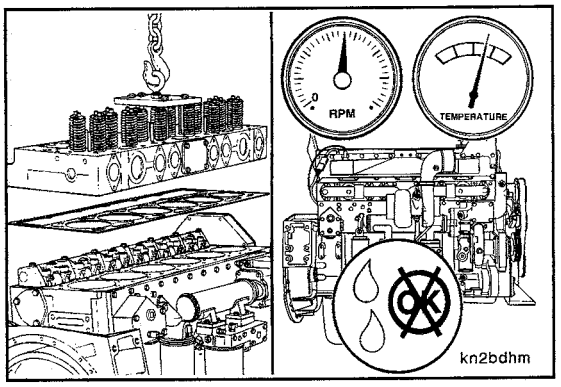
Tighten the No. six support nut.

Torque Value: 47 N•m [35 ft-lb]



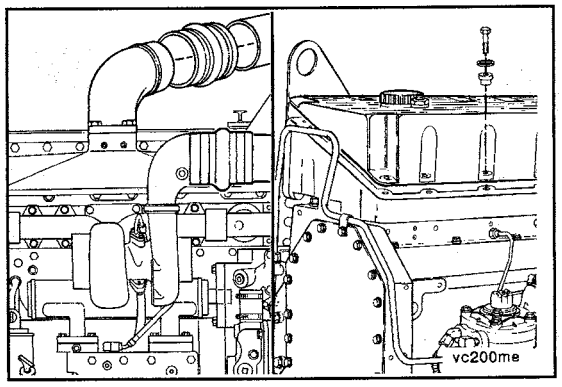
Measure the side clearance between the No. six and seven supports.

Cam Follower Side Clearance Between Supports		
mm		in
0.76	MIN	0.030



Install the cylinder head. Refer to Procedure 002-004.

Operate the engine and check for leaks.



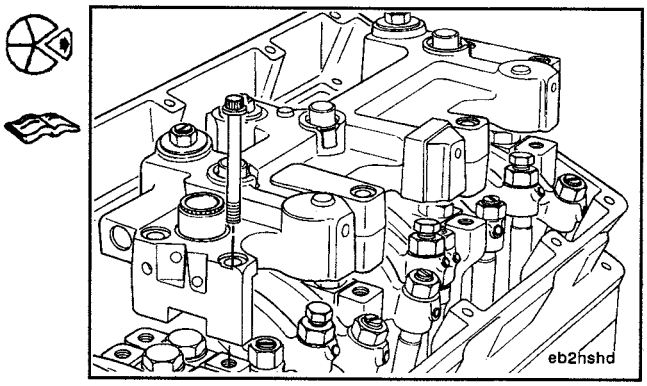
Push Rods or Tubes (004-014)

Remove (004-014-002)

Remove the air piping from the intake manifold.

Remove the rocker lever cover. Refer to Procedure 003-011.

Remove the engine brakes, if applicable. Refer to Procedure 020-001.

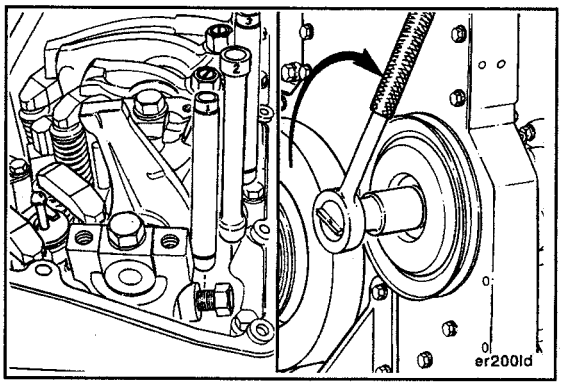


NOTE: Mark the position of the valve push tubes and injector push rods as they are removed. The push tubes and push rods **must** be installed in the same positions when the engine is assembled.

Loosen the rocker lever adjusting screws, and remove the valve push tubes and injector push rods.

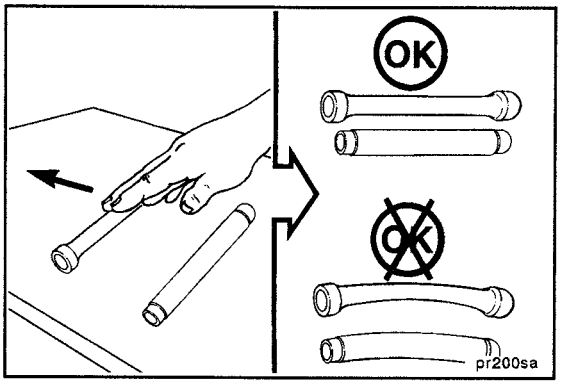
Hold the push tubes and push rods while loosening the adjusting screws. Do **not** let them fall into the engine while rotating the accessory drive pulley.

NOTE: Some push tubes and rods are under compression because the valves are open. Rotate the crankshaft **clockwise** with the accessory drive pulley to relieve the spring tension.



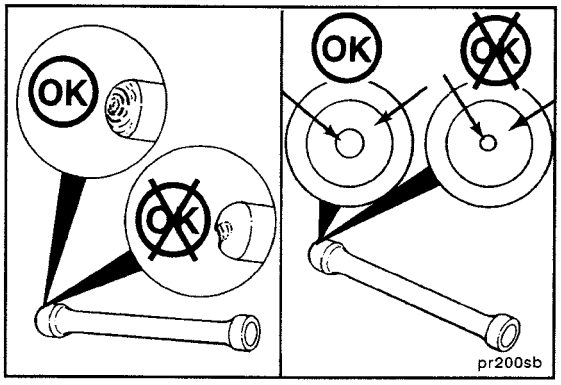
Inspect for Reuse (004-014-007)

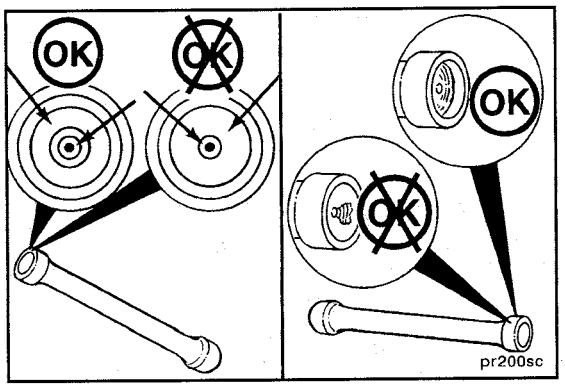
Inspect the straightness of the push tubes and push rods by rolling them on a level bench. If any push tube or push rod is bent, it **must** be replaced.



Inspect the ball-and-socket ends for uneven wear or scratches.

Check the push tubes for oil. If the push tubes are filled with oil, they **must** be replaced.



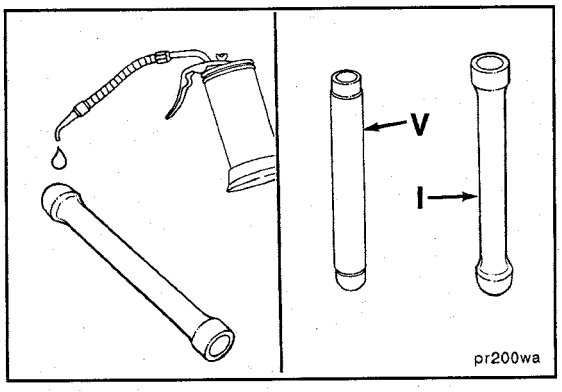


Inspect the seating pattern in the socket for excessive wear.

Inspect the ball end for excessive wear.

If excessive wear is found on the ball end, the cam follower sockets **must** be inspected. Refer to Procedure 007-009. Refer to the Overhead Reuse Guidelines, Bulletin No. 3810388, to identify wear patterns and excessive wear.

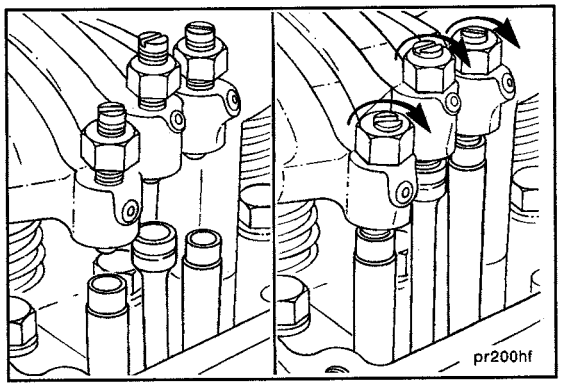
Replace all parts that do **not** meet the reuse guidelines.



Install (004-014-026)

Use clean 15W-40 oil to coat the ball end of the push tubes and push rods.

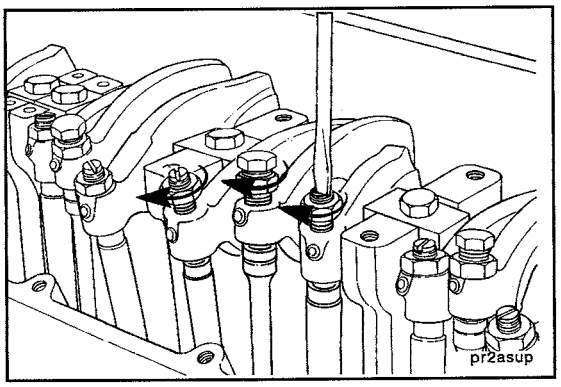
NOTE: The injector push rods (I) are smaller in diameter and longer than the valve push tubes (V).



Install the valve push tubes and injector push rods.

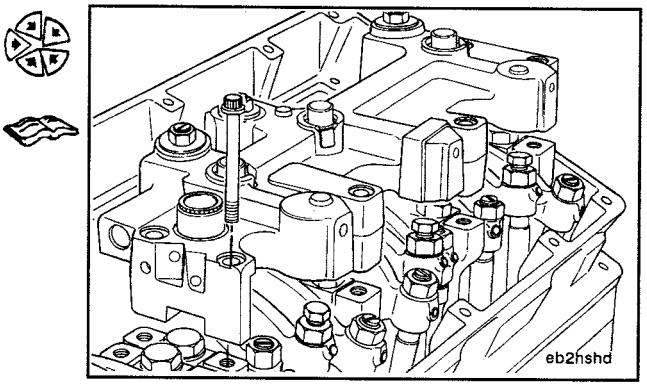
Position the push tubes and push rods under the rocker lever adjusting screws.

Tighten the adjusting screws enough to hold the push tubes and push rods in position.



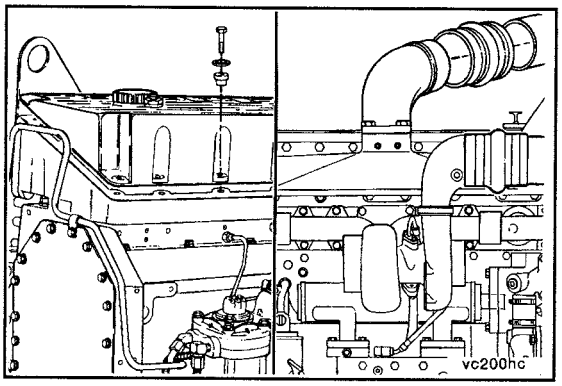
Adjust the valves and injectors. Refer to Procedure 003-004.

Install the engine brakes, if applicable. Refer to Procedure 020-001.



Install the rocker lever cover. Refer to Procedure 003-011.

Install the air piping to the intake manifold. Refer to the manufacturer's specifications for the correct torque.



NOTES

Section 5 - Fuel System - Group 05

Section Contents

Page

Flow Diagram, Fuel System 5-4
Fuel System 5-4

Fuel Consumption 5-9
Measure 5-9

Fuel Flow 5-12
Initial Check 5-12
Leak Test 5-13
Pressure Test 5-13

Fuel Pump 5-14
Clean 5-15
Inspect for Reuse 5-15
Install 5-16
ISM 5-16
Prime 5-16
General Information 5-16
ISM 5-17
Remove 5-14
Rotation Check 5-18

Fuel Pump Gear Pump Check Valve 5-19
Install 5-19
Remove 5-19

Fuel Pump Pressure Regulator 5-26
Initial Check 5-26

Fuel Pump Pulsation Damper 5-20
Inspect for Reuse 5-20

Fuel Shutoff Valve (FSOV) 5-21
Inspect for Reuse 5-21

Fuel System - General Information 5-1
Installation Recommendations 5-1

Service Tools 5-7
Fuel System 5-7

Specifications 5-5
Fuel Recommendations 5-5
Fuel System 5-5

Stall Speed Check List 5-27
If the Stall Speed is too High, Check the Following: 5-28
If the Stall Speed is Too Low, Check the Following: 5-27

Stall Speed Test 5-22
Stall Speed Check 5-22
Time Speed Check 5-25

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Fuel System - General Information

Installation Recommendations

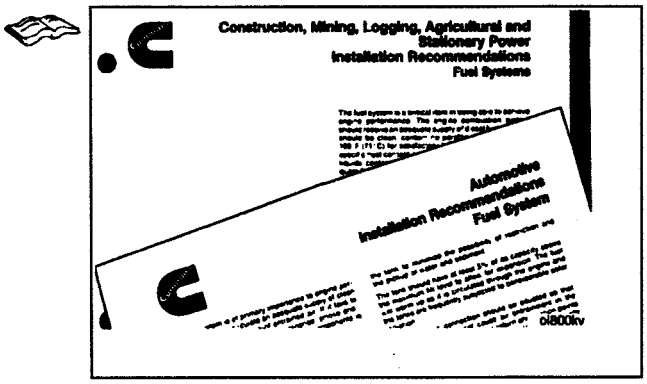
Installation Publications

The following publications are available to provide fuel system installation recommendations approved by Cummins Engine Co., Inc.:

Automotive Installation Recommendations (Fuel System), Bulletin No. 3382707.

Construction, Mining, Logging, and Agriculture Installation Recommendations (Fuel System), Bulletin No. 3382015.

Contact the nearest Cummins Authorized Repair Location for engine fuel system specifications and requirements provided on the Engine Data Sheet for your specific engine and application.

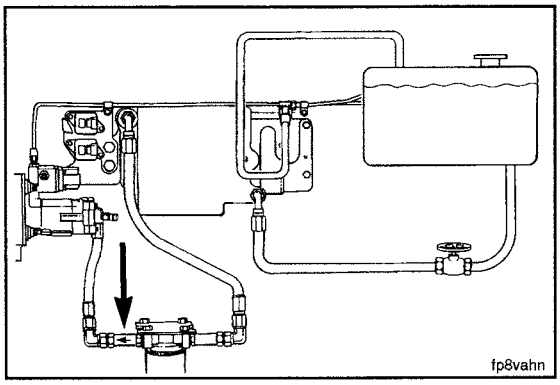


Overhead Fuel Tank Requirements

If the fuel filter is lower than the fuel pump, install a check valve in the filter outlet fuel line. Refer to the Installation Recommendations.

The check valve on the outlet side of the fuel filter prevents gear pump fuel drainback during filter removal.

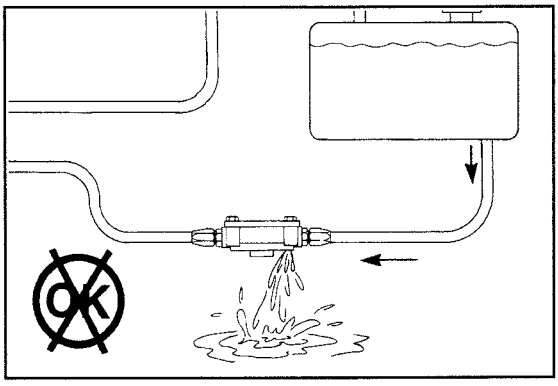
Install a shutoff valve between the filter and the fuel tank.

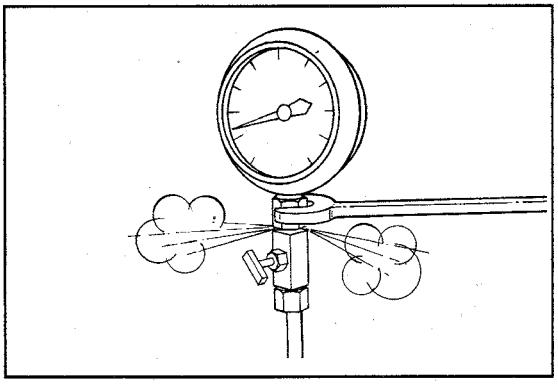


⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flamex, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to avoid severe personal injury or death when working on the fuel system.

If the fuel line valve is not used, the overhead tank can drain when the fuel filter is changed. Spilled fuel is a fire hazard.



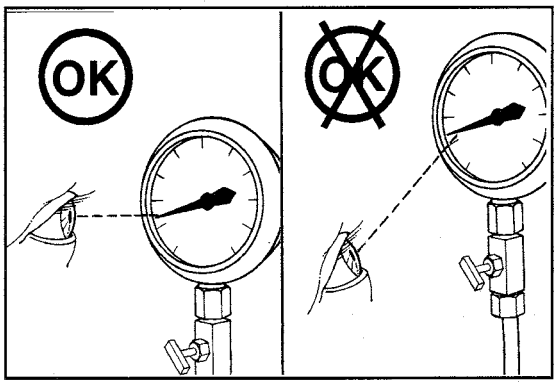


Proper Use of Fuel System Gauges

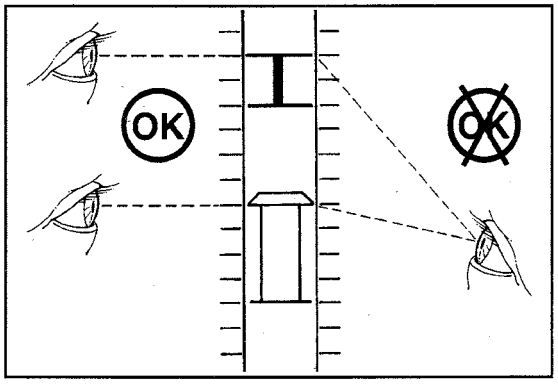
NOTE: To be sure the reading is correct, always remove the air from the pressure gauge line before taking a reading.

Loosen the connection at the gauge to remove the air.

NOTE: Do **not** loosen the vacuum gauge connections when the engine is operating.

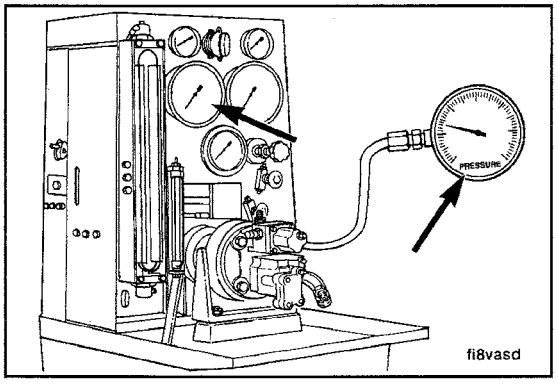


Read the gauge in direct alignment with the gauge hand.



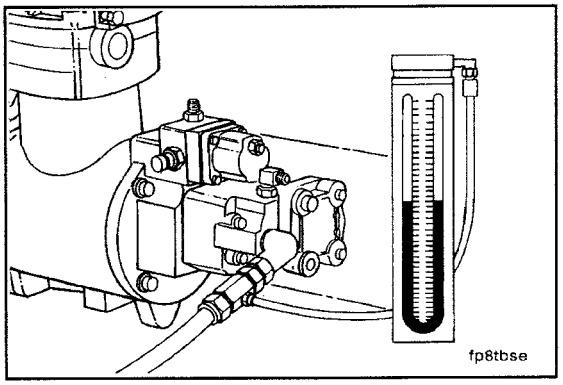
Read the flow meter in direct alignment with the float.

NOTE: Read the level of the floats where indicated.

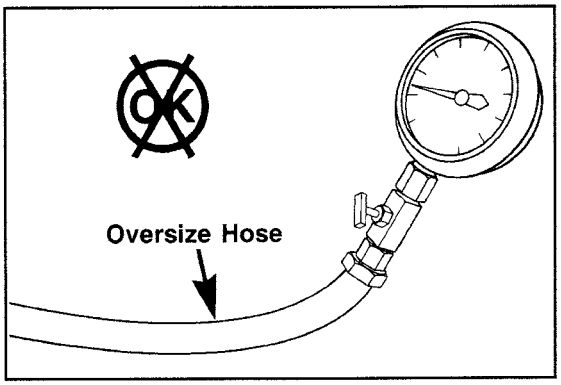


Portable fuel pressure gauges **must** be checked regularly against a reference gauge or against the gauge on the fuel pump test stand. Adjust the valve on the gauge until the gauge needle stops vibrating.

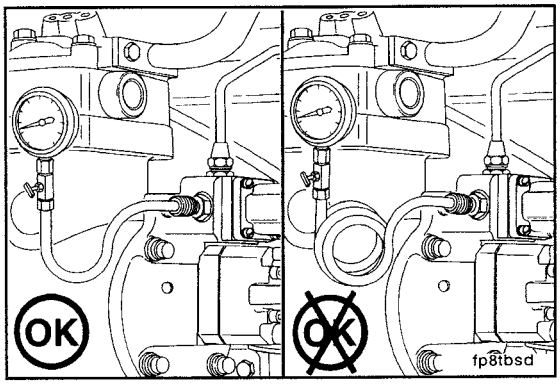
When measuring the fuel inlet and drain line restriction, the manometer or gauges **must** be on the same level as the connection point.



NOTE: Always use the same size and material of line or hoses as was originally supplied with the gauge.

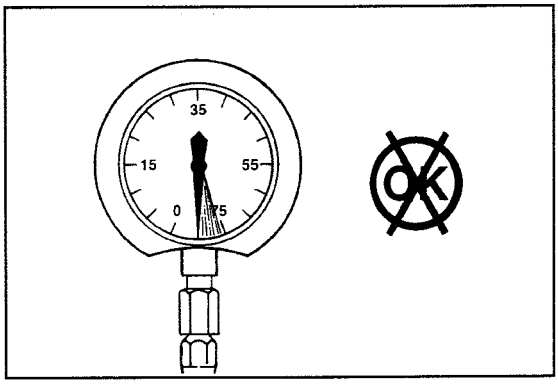


The distance from the gauge to the connection point **must** be as short as possible.



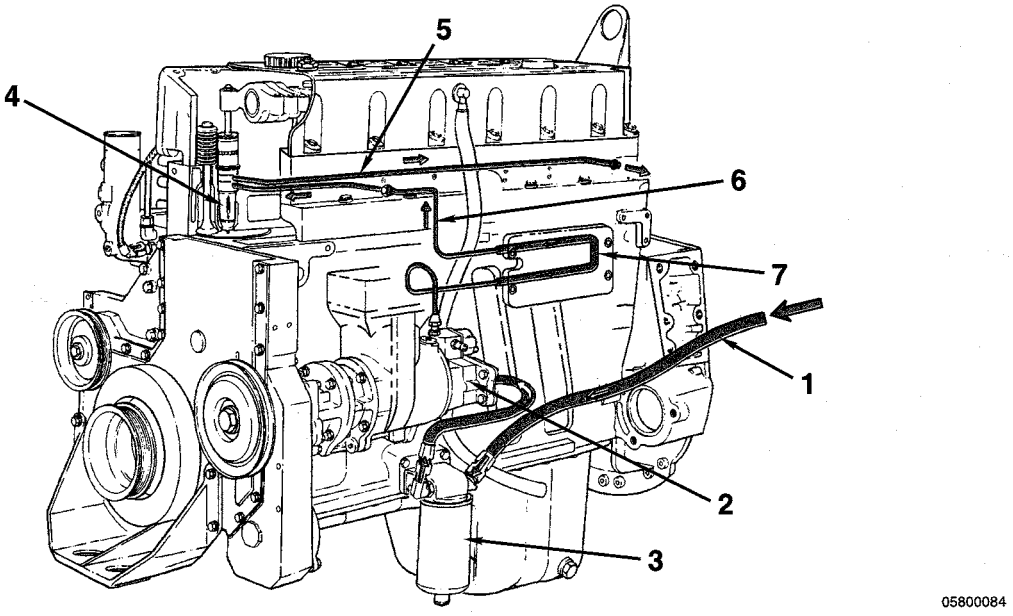
⚠ CAUTION ⚠

Never exceed the maximum capacity of the gauge or flow meter. If the maximum is exceeded, check the gauge against a reference gauge.



Flow Diagram, Fuel System

Fuel System



1. Fuel Inlet Supply
2. Fuel Pump
3. Fuel Filter
4. Injector
5. Fuel Drain Return
6. Fuel to Injector
7. ECM Cooling Plate

Specifications

Fuel System

For performance and fuel rate values, refer to the engine data sheet or the fuel pump code for the particular model involved.

Engine Idle Speed ..... 600 to 800 rpm

Fuel Inlet Maximum Restriction:
- Clean Fuel Filter ..... 152 mm Hg [6 in Hg]
- Dirty Fuel Filter ..... 254 mm Hg [10 in Hg]

Fuel Drain Line Maximum Restriction ..... 89 mm Hg [3.5 in Hg]

Minimum Fuel Pressure:
- During Cranking ..... 172 kPa [25 psi]
- 1200 rpm ..... 827 kPa [120 psi]
- Governed rpm ..... 1034 to 1241 kPa [150 to 180 psi]

Fuel Inlet Maximum Temperature ..... 71°C [160°F]

Engine Minimum Cranking Speed ..... 150 rpm

Shutoff Valve Solenoid Coil Resistance
- 12 VDC ..... 7.0 to 8.0 ohms

Fuel Recommendations

⚠ WARNING ⚠

Do not mix gasoline, alcohol, or gasohol with diesel fuel. This mixture can cause an explosion.

△ CAUTION △

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

△ CAUTION △

Do not use diesel fuel blended with lube oil in engines equipped with a catalytic converter. Damage to the converter will result.

Cummins Engine Company, Inc. recommends the use of ASTM No. 2D fuel. The use of No. 2 diesel fuel will result in optimum engine performance.

At operating temperatures below 0°C [32°F], acceptable performance can be obtained by using blends of No. 2D and No. 1D.

NOTE: Lighter fuels can reduce fuel economy.

The viscosity of the fuel **must** be kept above 1.3 cSt at 40°C [104°F] to provide adequate fuel system lubrication.

The following chart lists acceptable alternate fuels for M series engines.

Acceptable Substitute Fuels - Cummins CELECT™ Plus Fuel System

No. 1D Diesel	No. 2D Diesel	No. 1K Kerosene	Jet-A	Jet-A1	JP-5	JP-8	Jet-B	JP-4	CITE
1	OK	1	1	1	OK	OK	**NOT** OK	**NOT** OK	**NOT** OK

1. OK - **ONLY** if fuel lubricity is adequate. Refer to Fuel for Cummins Engines, Bulletin No. 3379001.
2. **NOTE:** Any adjustment to compensate for reduced performance with a fuel system using substitute fuel is **not** warrantable.

Additional information for fuel recommendations and specifications can be found in Fuel for Cummins Engines, Bulletin No. 3379001. See ordering information in the back of this manual.

Fuel Oil Recommended Properties:

Cummins diesel engines are designed to operate on No. 2 diesel fuel. These engines will also operate satisfactorily on fuels that meet the following specifications:

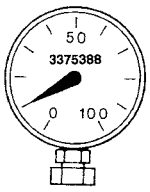
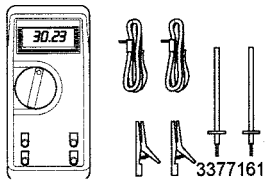
Property	Recommended Specifications
Viscosity (ASTM D445)	1.3 to 5.8 centistokes [1.3 to 5.8 mm per second] at 104°F [40°C].
Cetane Number (ASTM D613)	40 minimum above 32°F. 45 minimum below 32°F.
Sulfur Content (ASTM D129 or 1552)	**Not** to exceed 1.0 mass percent*.
Active Sulfur (ASTM D130)	Copper strip corrosion **not** to exceed No. 2 rating after 3 hours at 122°F [49°C].
Water and Sediment (ASTM D1796)	**Not** to exceed 0.1 volume %.
Carbon Residue (Rams-bottom, ASTM D524 or Conradson, ASTM D189)	**Not** to exceed 0.35 mass % on 10 volume % residuum.
Density (ASTM D287)	42 to 30° API gravity at 60°F [0.816 to 0.876 g/cc at 15°C].
Cloud Point (ASTM D97)	10°F [6°C] below lowest ambient temperature at which the fuel is expected to operate.
Ash (ASTM D482)	**Not** to exceed 0.02 mass % (0.05 mass % with lubricating oil blending).
Distillation (ASTM D86)	The distillation curve must be smooth and continuous.
Acid Number (ASTM D664)	**Not** to exceed 0.1 mg KOA per 100 ml.

NOTE: Effective October 1, 1993, the Environmental Protection Agency requires maximum sulfur content **not** to exceed 0.05 mass percent.

Service Tools

Fuel System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3375388	**Pressure Gauge (0 to 100 psi)** Used to measure fuel pressure during cranking.	 3375388
3377462	**Digital Tachometer Kit** Used to measure engine rpm.	
3375932	**Pressure Gauge and Hose (0 to 300 psi)** Used to measure oil pressure or measure fuel pump pressure. Includes necessary hoses and hardware to attach to a fuel pump. Part No. ST-435-1 is the hose and Part No. ST-435-6 is the pressure gauge.	 eg8togh
3376375	**Fuel Measurement Device** Used to measure fuel rate on the engine.	 eg8togf
3376506	**Remote Starter Switch** Used to turn engine on and off from a remote location.	 3376506
3377161	**Digital Multimeter** Used to measure electrical circuits: voltage (volts), resistance (ohms), and current (amps).	 3377161

Tool No.	Tool Description	Tool Illustration
3824510	**Safety Solvent** Used to clean parts and tools safely.	

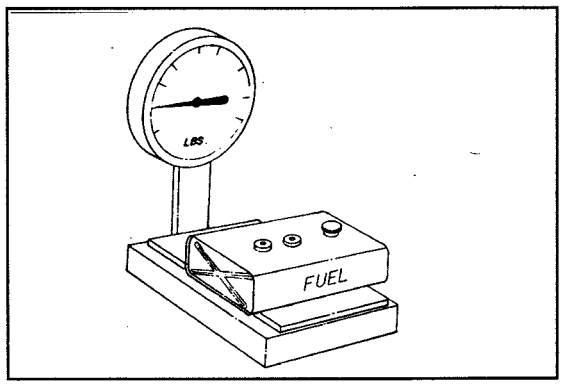
Fuel Consumption (005-010)

Measure (005-010-010)

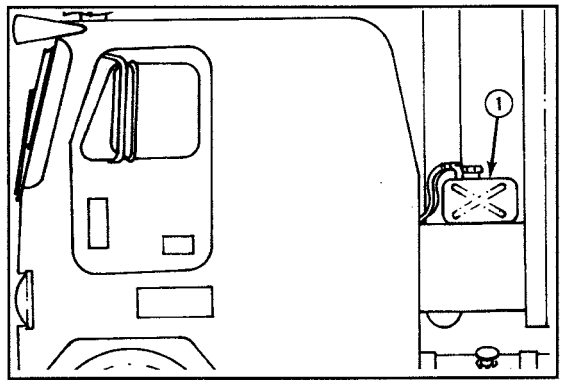
Refer to the fuel consumption check list sheets in the back of Section TS.

NOTE: The most accurate method to check the fuel consumption is to weigh the fuel used. Use a scale capable of measuring within 0.045 kg [0.1 lb] to weigh the fuel tank. Use a remote mount tank with enough capacity to run 80 km [50 mi].

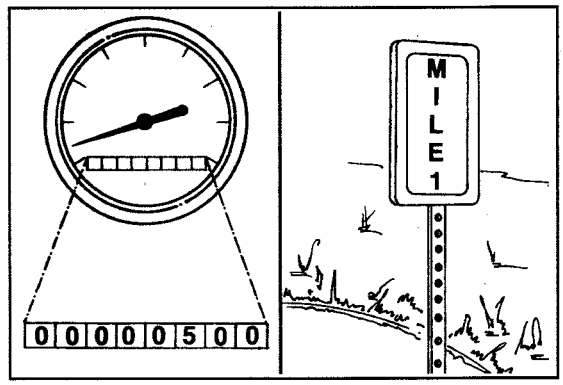
Fill the fuel tank. Weigh the tank with the fuel. The weight on No. 2 diesel fuel is nominally 0.844 kg per liter [7.03 lb per gallon].



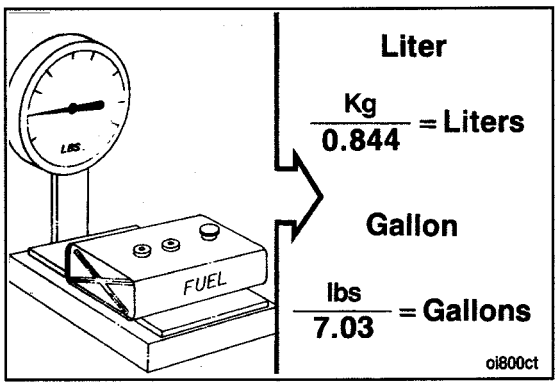
Install the remote tank (1).



Measure the distance traveled with an accurate odometer. The odometer accuracy can be checked by using measured miles or kilometers.



After traveling the route, remove the tanks, and weigh the remaining fuel. Compute the fuel used in liters [gallons] as required.



Compute the kilometers per liter or miles per gallon.

$$\frac{\text{Miles}}{\text{Gallons}} = \text{MPG}$$

$$\frac{\text{Kilometers}}{\text{Liters}} = \text{KPL}$$

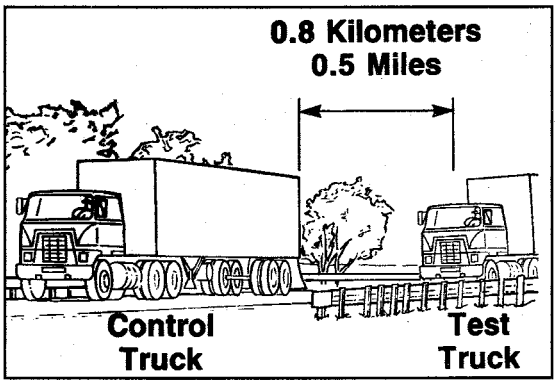
In addition to the measurement of the fuel used, the following factors provide points for running a test similar to the recognized Type II Society of Automotive Engineers Fuel Test.

These procedures are helpful in determining differences in fuel consumption between two vehicles under the same environmental, road, and test conditions.

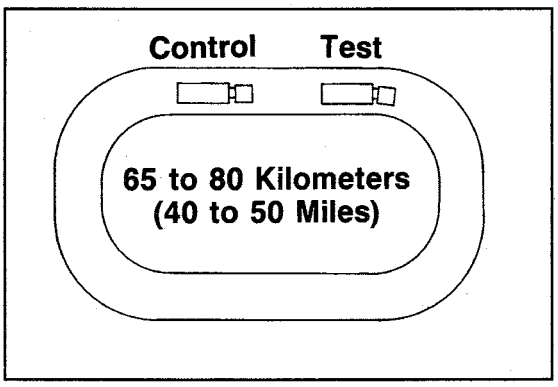
Type II
Fuel Test
SAE
RCCC
ATA

Perform the test with the test vehicle and a control vehicle. The control vehicle compensates for changes in traffic conditions.

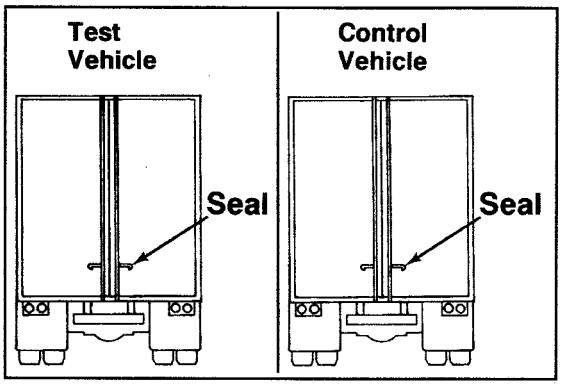
The vehicles **must** stay close together to experience the same varying traffic and weather conditions, but **not** so close as to affect each other's driving or headwind.



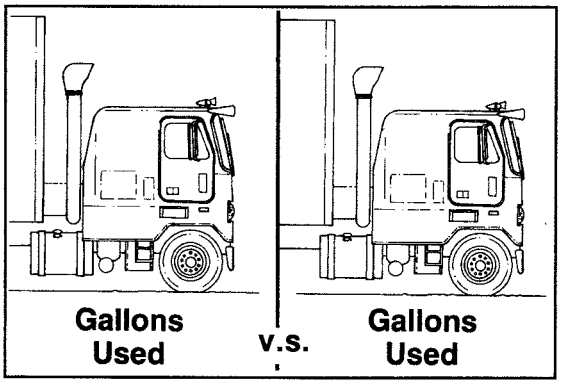
The test course **must** be 65 to 80 km [40 to 50 mi] long.



This test route and truck weights **must not** change during the test.

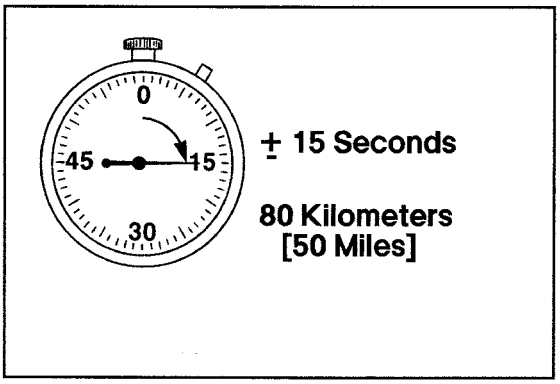


All of the test results are based on comparing the fuel used by the test truck to the fuel used by the control truck.



Drive the truck on a warm-up test run. Drive enough tests to achieve:

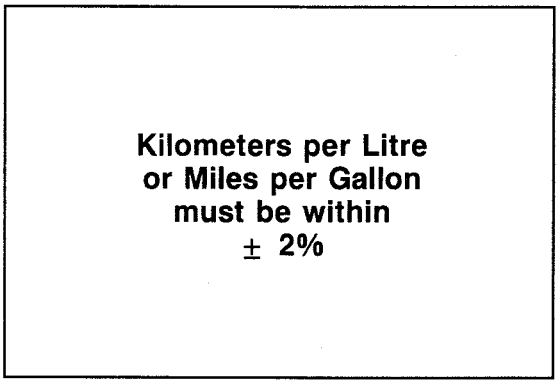
- Difference in elapsed time between each test run can **only** be plus or minus 0.5 percent. This will be ±15 seconds on 80 km [50 mi] at 60 mph.

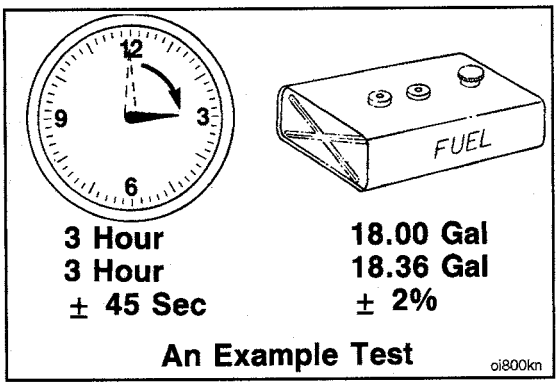


The fuel usage of the test truck between test drives **must** fall within a 2-percent range (6.00 mpg vs. 6.12 mpg).

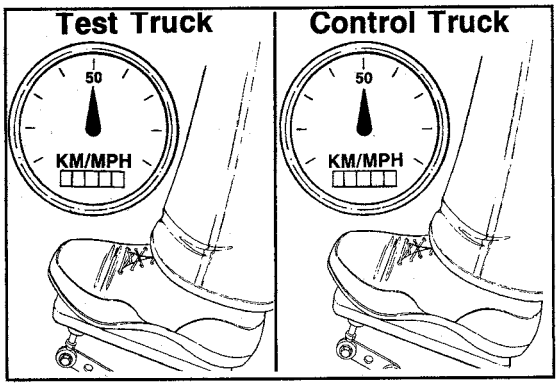
The same range also applies between drives of the control truck.

NOTE: The differences in traffic and driving practices can make the test drive fall out of the 2-percent range.



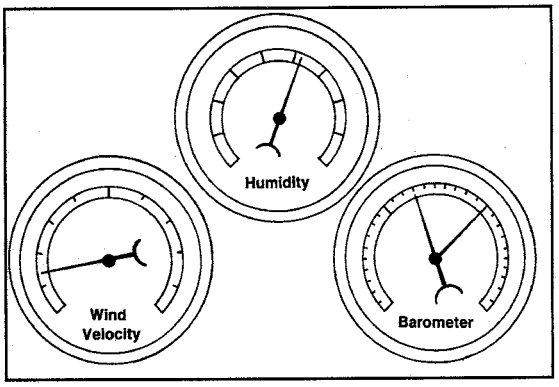


A minimum of three test drives that meet these conditions make a valid test. A single test drive is unreliable.



Use the same experienced drivers for all of the tests.

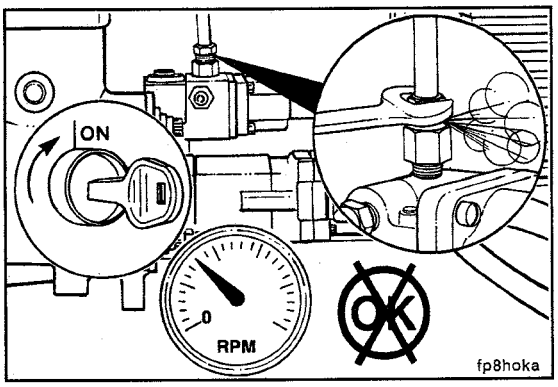
NOTE: The vehicle speeds **must** be representative of a typical operation.



During the test, record the following:

- Ambient temperature
- Humidity
- Barometric pressure
- Wind velocity
- Wind direction.

NOTE: Avoid testing under any extreme conditions.



Fuel Flow (005-011)

Initial Check (005-011-001)

Loosen the fuel line at the shutoff valve while the engine is cranking. If fuel does **not** come out of the connection, the pump **must** be primed.

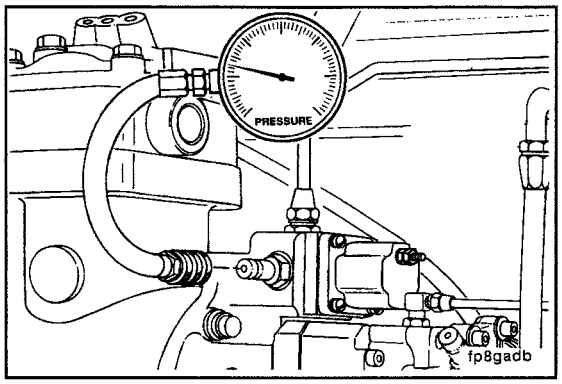
Pressure Test (005-011-013)

Connect a pressure gauge to the quick disconnect fitting of the fuel pump.

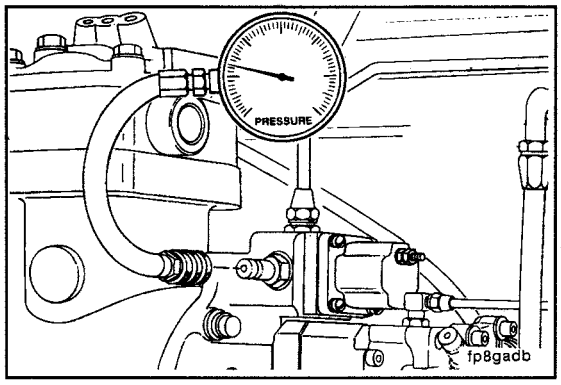
Start cranking the engine, and observe the cranking fuel pressure.

Minimum Cranking Fuel Pressure		
kPa		psi
172	MIN	25

If the fuel pressure is below the specification, check to be sure there is a fuel supply to the pump and that it is **not** restricted. Refer to Procedure 006-020. Prime the fuel pump if necessary. Refer to Procedure 005-016.



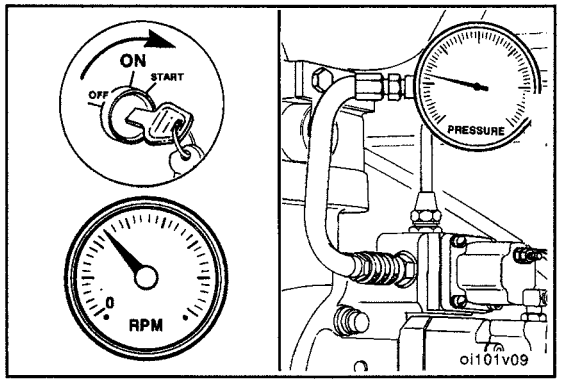
Connect a 0 to 300 psi pressure gauge to the quick disconnect fitting to the fuel pump.



Start the engine and operate it at 1200 rpm with no load applied.

Record the fuel pressure.

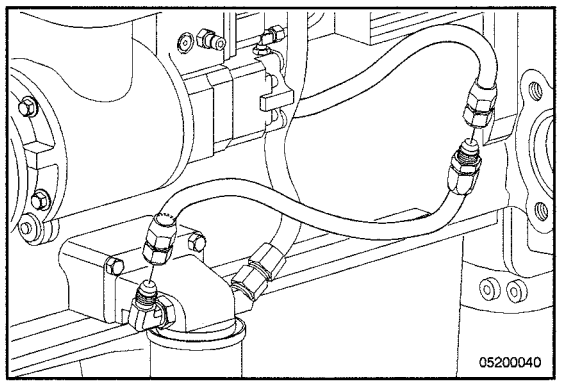
Minimum Fuel Pressure at 1200 rpm		
kPa		psi
827	MIN	120

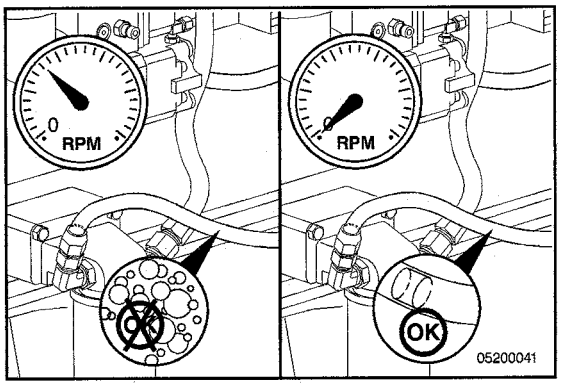


Leak Test (005-011-014)

Install an 18-inch piece of clear tubing on the suction side of the gear pump or the fuel filter head. Tygon R-3603 is the correct size for use with standard Stratoflex No. 10 hose fittings.

NOTE: Add the 18-inch piece of clear tubing to the existing fuel suction line. Do **not** replace any portion of the suction line to install the 18-inch piece of clear tubing.

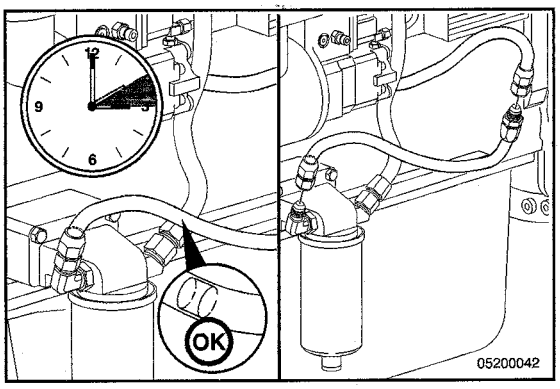




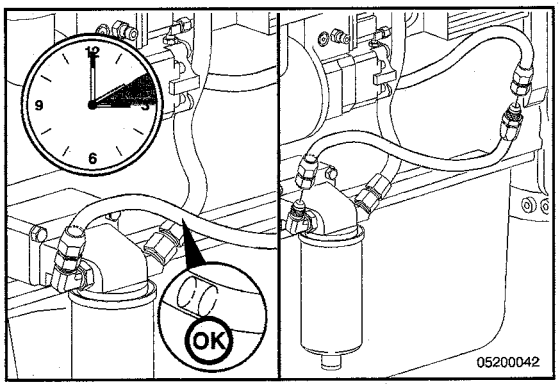
Start the engine and allow the air to purge from the clear tubing. No air bubbles can appear.

Shut off the engine, and observe the clear tubing.

NOTE: Generally, an air space will appear in the clear tubing that is drawn from the top of the fuel filter.

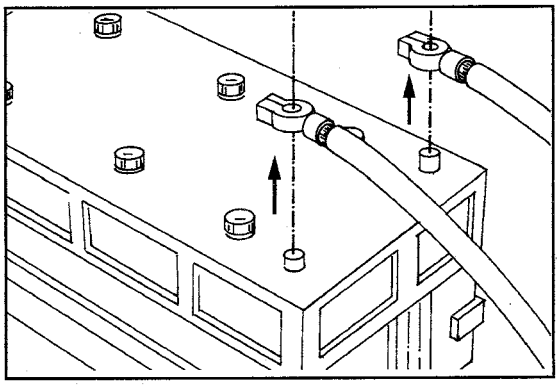


Observe the fuel in the clear tubing. It should stop moving within 1 minute if the system is leak free. If the fuel continues to move toward the fuel tank, there is a leak in the system. Observe from which direction air bubbles are coming into the clear tubing. If they are coming from the fuel tank side, then the leak is in the cooling plate, fittings, fuel line, or fuel tank.



If the fuel did **not** move immediately, let the vehicle sit for about 1 hour. If there is no movement of the fuel, the system is sealed and should **not** cause a hard start due to drainback of the suction lines.

Remove the clear tubing, and connect the suction line back to its original connection.



Fuel Pump (005-016)

Remove (005-016-002)

Disconnect the battery cables, negative (-) cable first.

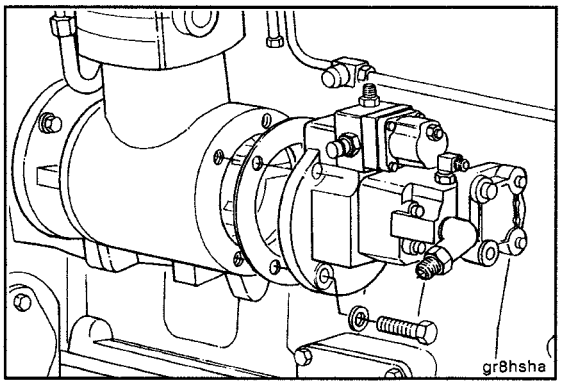
Clean the supply pump and the surrounding area.

Remove the electric wire to the fuel shutoff solenoid.

Remove the fuel plumbing.

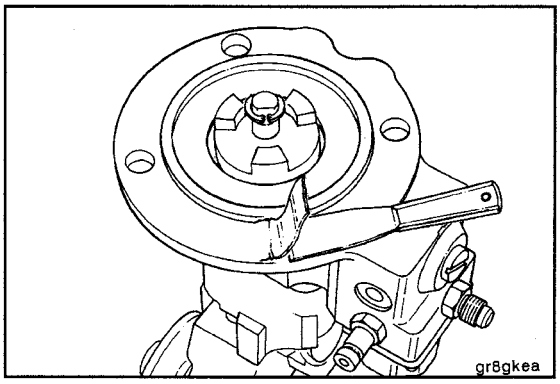
Remove the two support bracket capscrews from the cylinder block bracket.

Remove the four fuel pump mounting capscrews and remove the fuel pump.



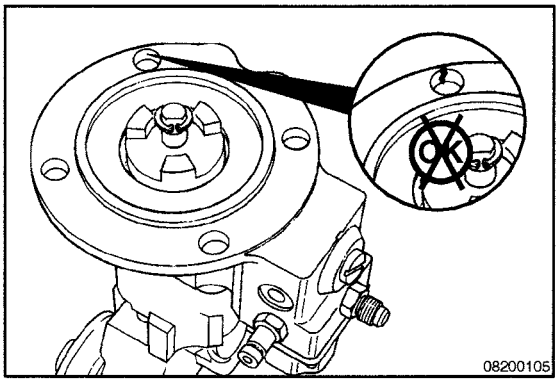
Clean (005-016-006)

Clean the gasket surfaces of the fuel pump and the air compressor or accessory drive.

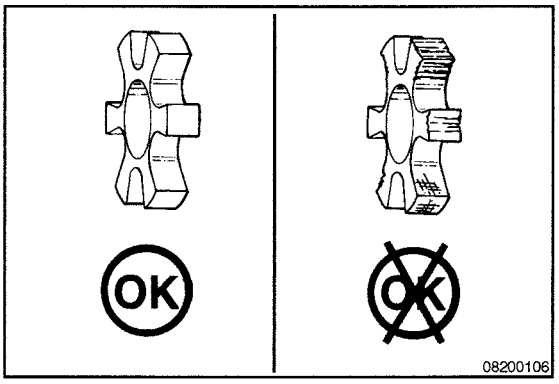


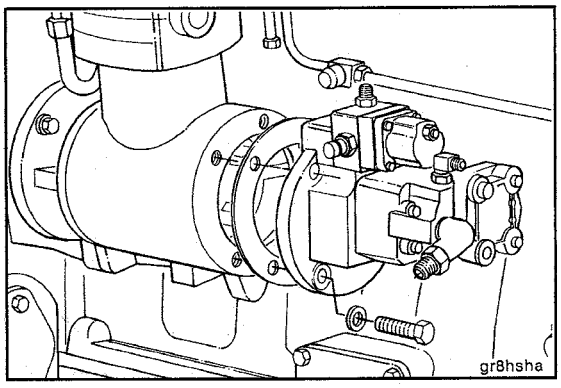
Inspect for Reuse (005-016-007)

Inspect the mounting surfaces for damage.



Inspect the jaw coupling spider and the jaw coupling hub for damage or wear.



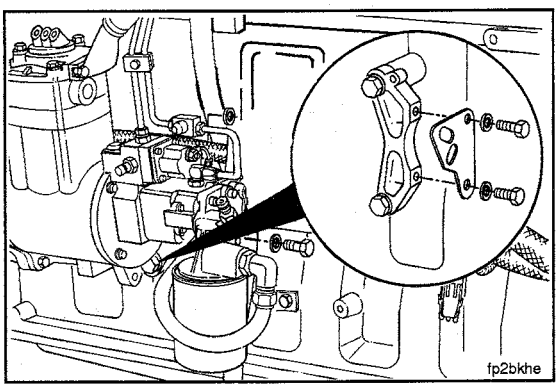


Install (005-016-026)

ISM

Install the jaw coupling spider, the mounting gasket, and the fuel pump.

Install the two outside mounting capscrews.



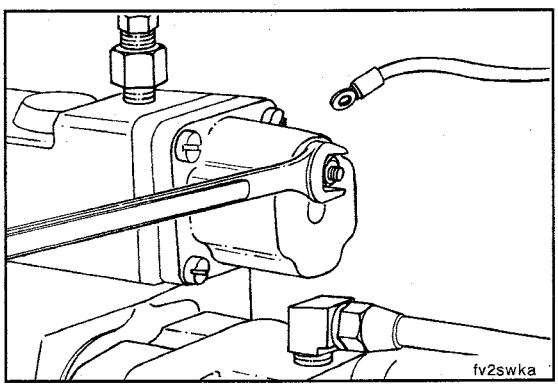
Install the two fuel pump support brackets to cylinder block bracket capscrews.

Tighten the support bracket to engine mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]

Tighten the fuel pump mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]

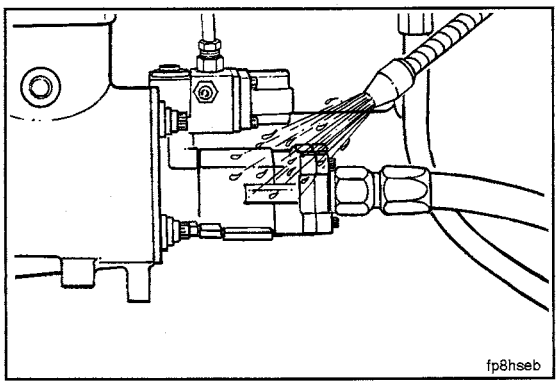


Connect the fuel plumbing.

Connect the electric wire to the shutoff solenoid.

Connect the battery cables.

Start the engine and check for leaks.



Prime (005-016-050)

General Information

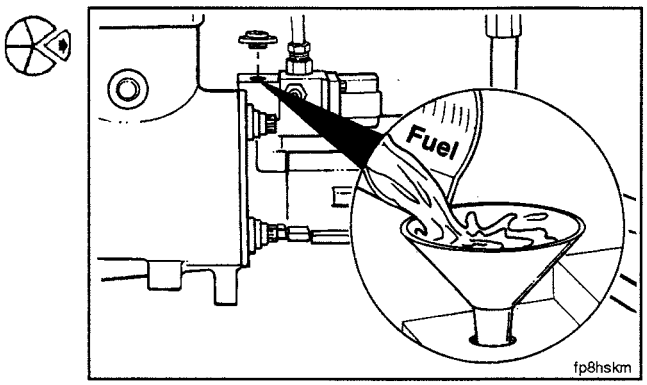
To reduce engine cranking time, prime the fuel supply pump.

NOTE: If the fuel supply pump is dirty, clean the outside of the pump.

ISM

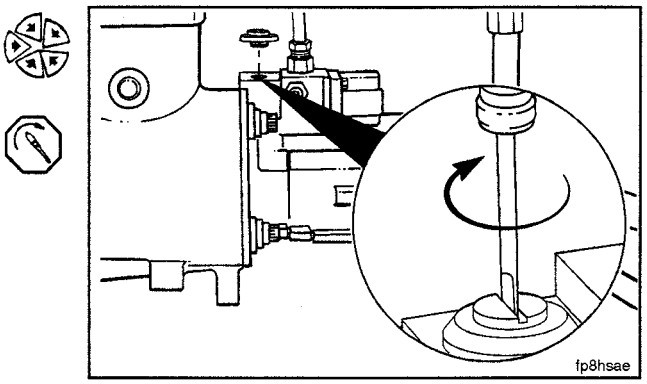
Remove the filter cap from the top of the front support.

Fill the pump with clean fuel oil.



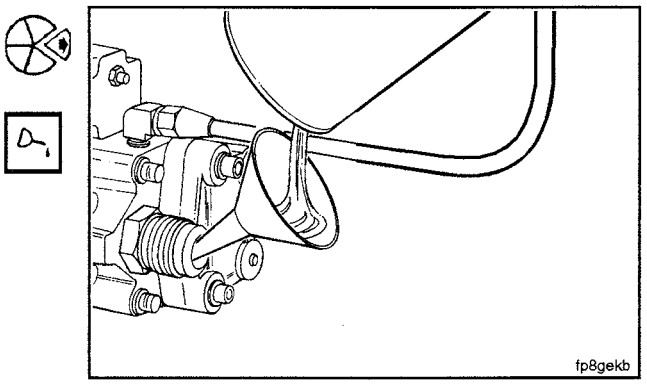
Install and tighten the filter cap.

Torque Value: 16 N•m [12 ft-lb]

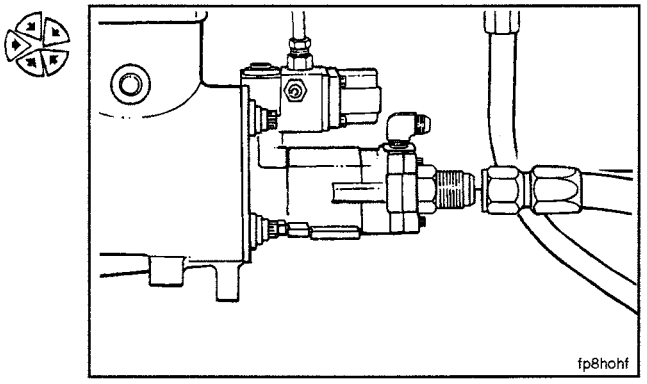


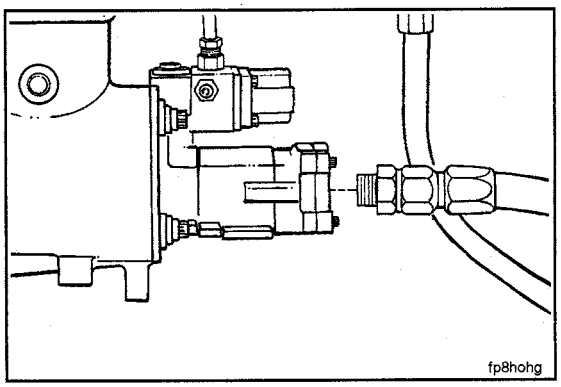
If the filter cap opening **cannot** be used, remove the fuel supply hose to the gear pump.

Fill the pump with clean fuel.



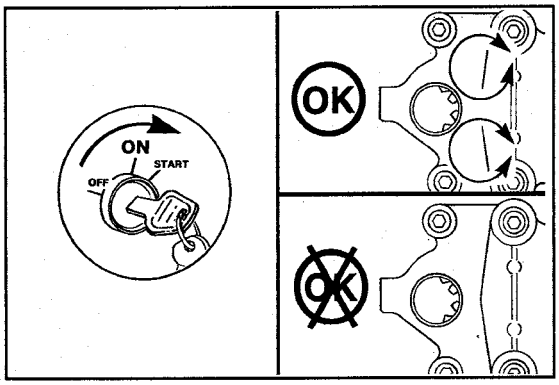
Install the fuel supply hose to the gear pump.



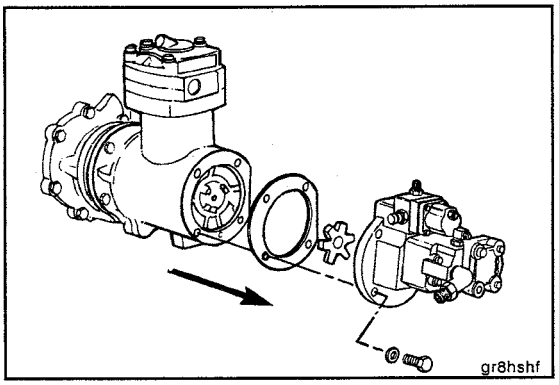


Rotation Check (005-016-052)

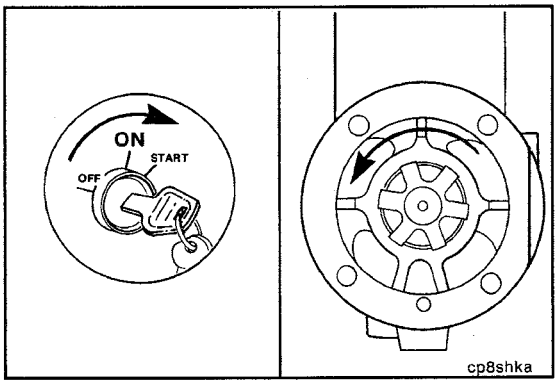
Remove the fuel supply hose and the fuel inlet fitting from the gear pump.



Look into the gear pump and crank the engine. The gear pump gears **must** turn.



If the supply pump gears do **not** turn, remove the fuel pump. Refer to Procedure 005-016.



Crank the engine, and check the air compressor or the accessory drive shaft for rotation.

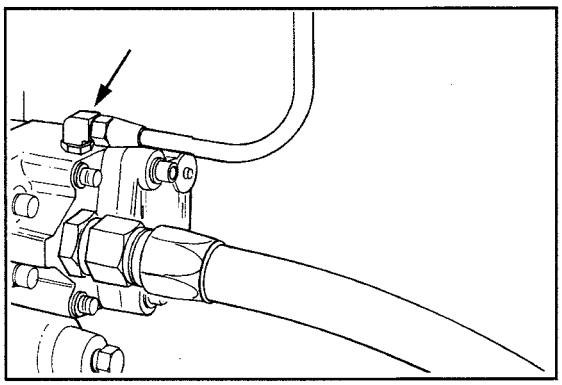
If the shaft turns, the fuel pump is damaged and **must** be replaced or repaired. Refer to the M11 Shop Manual, Bulletin No. 3666075, for rebuilding instructions.

If the shaft does **not** turn, remove the air compressor, and check the accessory drive for rotation. If the accessory driveshaft turns, the air compressor or air compressor coupling is damaged and **must** be replaced.

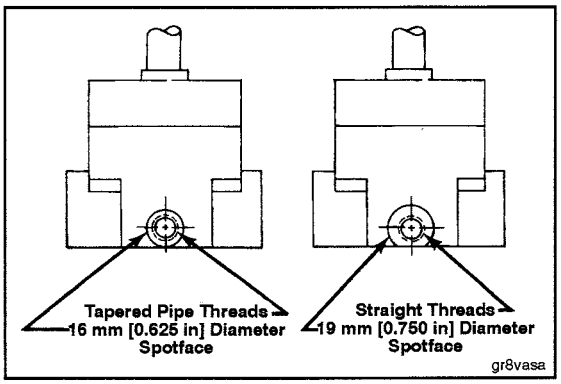
Fuel Pump Gear Pump Check Valve (005-026)

Remove (005-026-002)

If the check valve in the gear pump return elbow stays open or closed, replace the elbow.

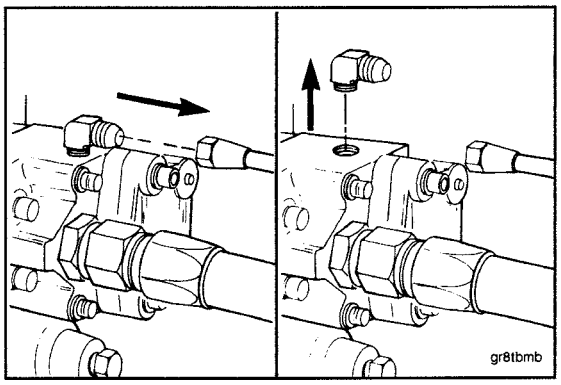


NOTE: Check the elbow threads. Do **not** install an elbow that has straight machine threads in a hole that has a pipe tap thread. A gear pump that has a straight thread will have a 19-mm [0.750-in] spotface in the valve area. A gear pump that has a pipe tap thread will have a 16-mm [0.625-in] spotface or no spotface.



Remove the drain line.

Remove the check valve elbow.



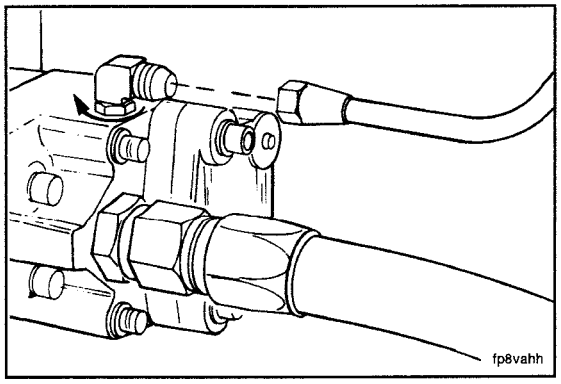
Install (005-026-026)

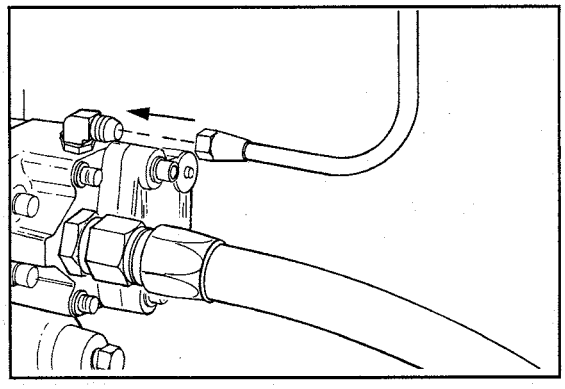
Install the check valve elbow.

- If the check valve elbow has machine threads to the maximum thread depth, turn the elbow out until it is pointed toward the drain line. Tighten the jam nut.

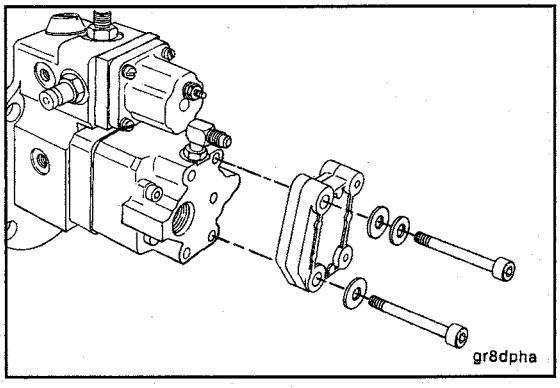
Torque Value: 6 N•m [50 in-lb]

- If the check valve has a pipe thread, install the elbow until it is tight and pointed toward the drain line.





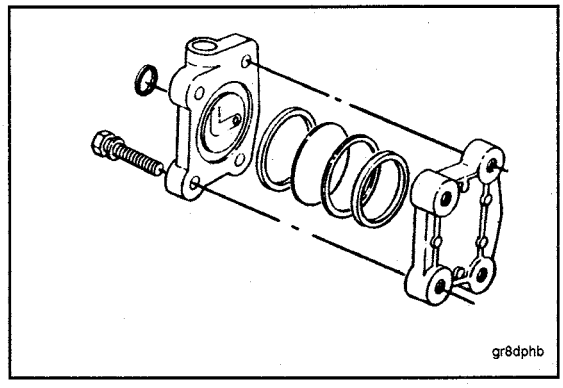
Install the drain line.



Fuel Pump Pulsation Damper (005-031)

Inspect for Reuse (005-031-007)

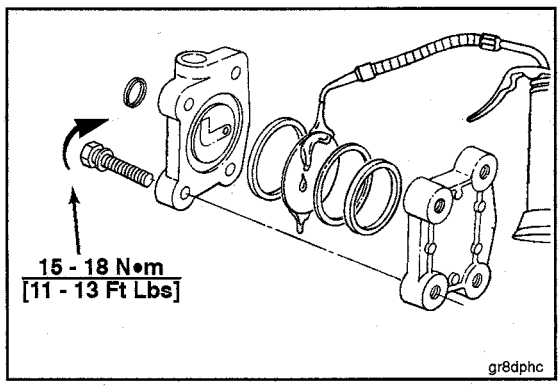
Remove the fuel inlet connection and pulsation damper or the filter head damper assembly. Discard the rubber o-rings.



Remove the housing from the cover. Remove the spring steel diaphragm. Discard the o-rings. Inspect the nylon washer and discard it, if it is damaged.

Check for corrosion, wear, or cracks in the cover or the diaphragm. Replace the damaged parts.

To check the diaphragm for hidden cracks, drop it on a flat hard surface. It **must** have a clear ring. If it has a flat sound, replace the diaphragm.



Install new o-rings in the grooves and a new nylon washer.

Clean the diaphragm. Coat the diaphragm with clean engine oil. Install the diaphragm in the cover.

Assemble the cover to the housing. Tighten the capscrews.

Torque Value: 18 N•m [13 ft-lb]

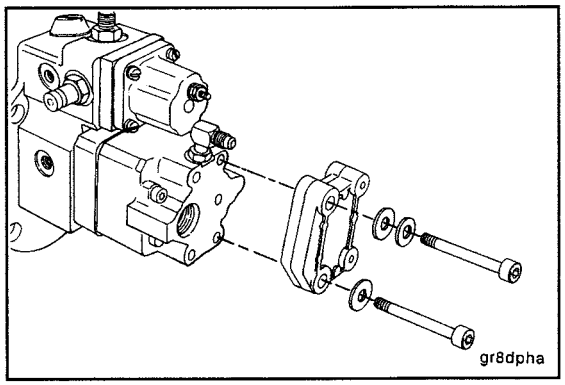
Remove the two damper mounting capscrews. Install the damper assembly with a new o-ring on the gear pump. Tighten the capscrews.

Torque Value: 18 N•m [13 ft-lb]

NOTE: If a fuel filter and damper assembly are mounted on the gear pump, remove the four mounting capscrews.

Install the fuel inlet connection. Be careful **not** to let dirt enter the fuel pump.

Check for free rotation of the gear pump.



Fuel Shutoff Valve (FSOV) (005-043)

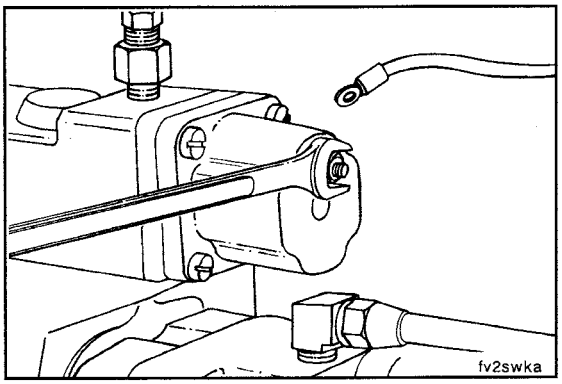
Inspect for Reuse (005-043-007)

Remove the wire. Make sure the remaining wire connection nut is tight. Tighten the nut.

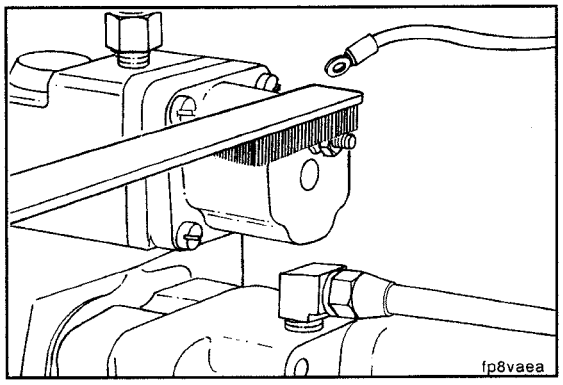
Torque Value: 3 N•m [25 in-lb]

Make sure the post is tight and secure in the coil.

NOTE: Only single post coils can be used on the fuel system. Two post coils will interfere with the cooling line.



Use a wire brush to clean any corrosion from the coil terminal.

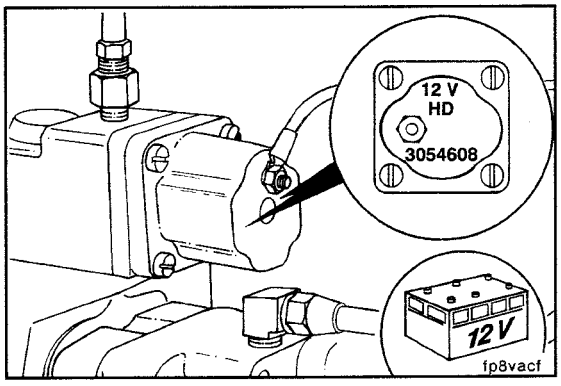


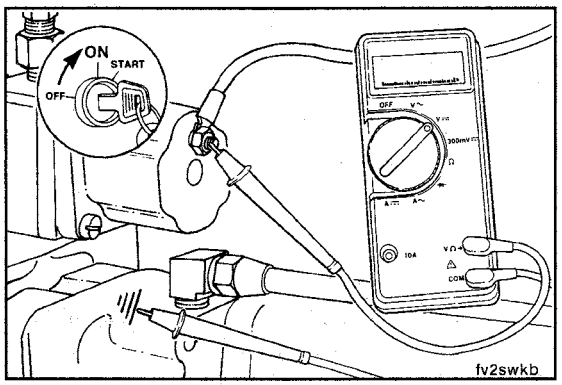
⚠ CAUTION ⚠

This must be the only wire connected to the shutoff valve.

Connect the wire. Make sure the shutoff valve coil is the correct voltage.

The coil voltage and part number are cast into the terminal connection end of the coil.



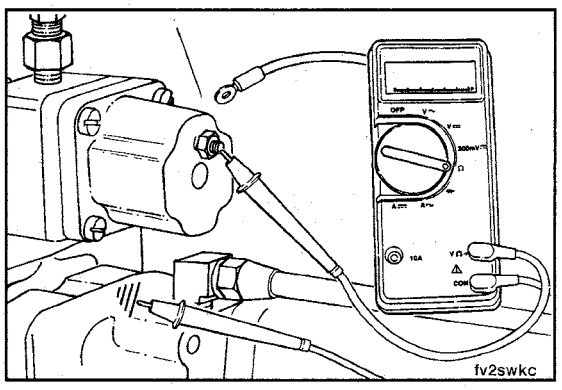


Turn the vehicle keyswitch to the ON position.

Check the VDC to the coil with a multimeter, Part No. 3377161, or equivalent.

The voltage **must** be the same as the battery voltage.

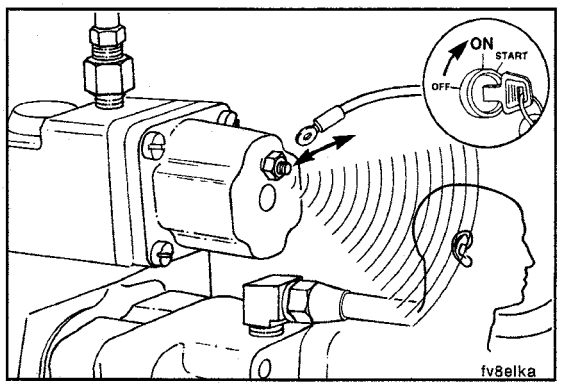
Turn the vehicle key switch to the OFF position.



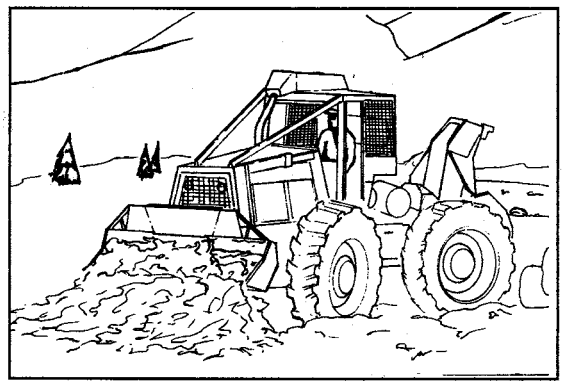
Make sure the coil wire is **not** connected before checking the coil resistance.

Check the coil resistance with a multimeter. The coil resistance **must** be 6 to 10 ohms for 12 VDC solenoids or 26 to 40 ohms for 24 VDC solenoids.

Replace the coil if the resistance does **not** meet the specifications.



Turn the vehicle keyswitch to the ON position. Listen for the valve to click when the wire is touched to the coil terminal. If the valve does **not** click, repair or replace the fuel shutoff valve. Refer to the M11 Shop Manual, Bulletin No. 3666075.



Stall Speed Test (005-054)

Stall Speed Check (005-054-046)

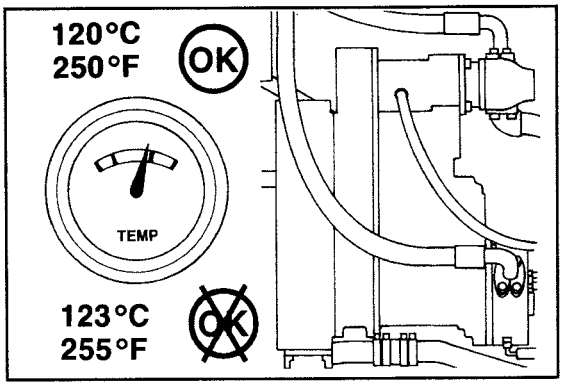
Converter Transmissions Stall Speed

The stall speed is the engine speed (rpm) obtained at full throttle when the converter output shaft is locked.

NOTE: It is possible the vehicle brakes will **not** hold an electronically controlled transmission.

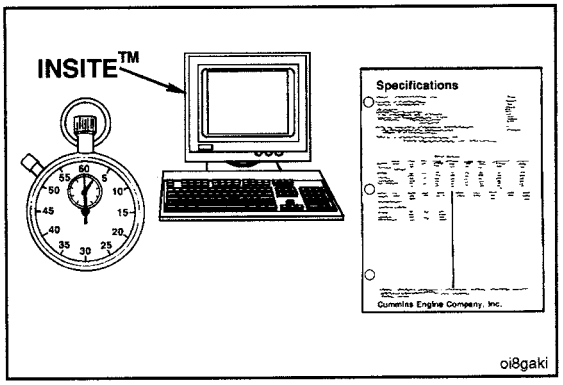
⚠ CAUTION ⚠

Do not exceed 120°C [250°F] converter oil temperature. Overheating can result and converter damage can occur. If the oil temperature exceeds 120°C [250°F], put the transmission in neutral and operate the engine until the oil temperature is below 120°C [250°F]. Check the converter oil level.

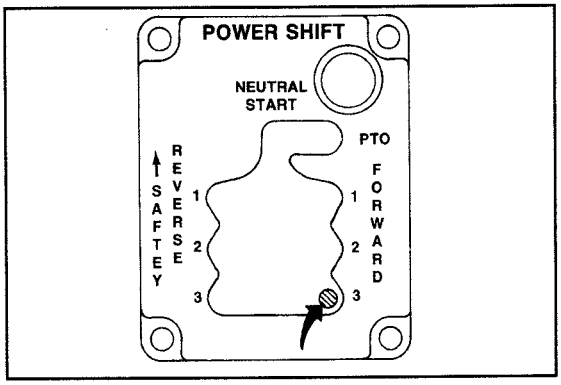


The following equipment is needed for this check:

- Stopwatch
- Cummins electronic service tool
- Equipment manufacturer's stall speed and time to stall specifications.

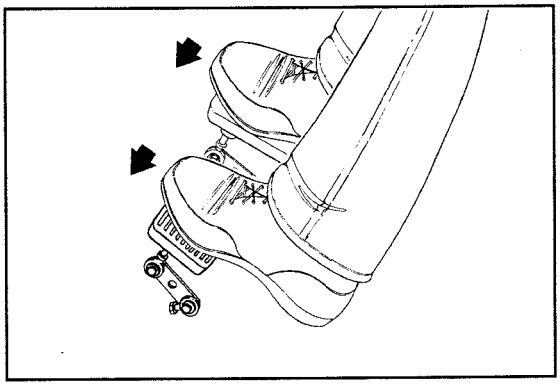


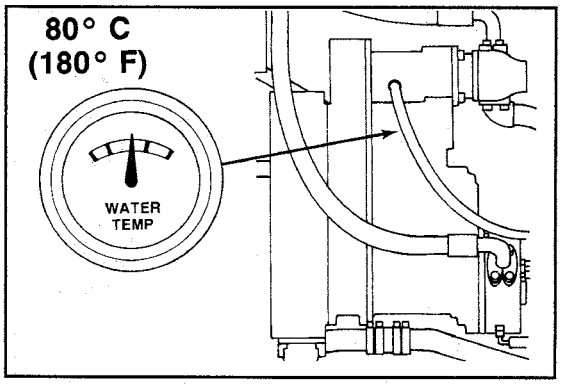
Place the gear selector in the highest gear or full forward.



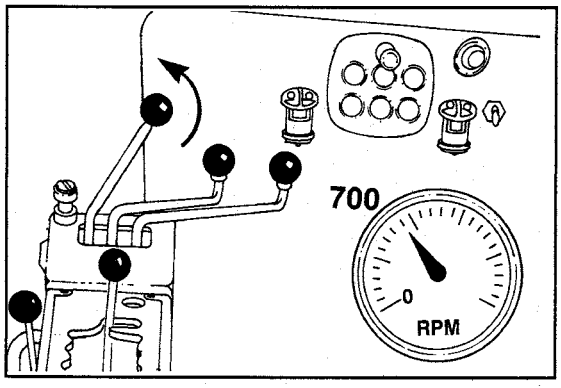
Make sure the vehicle has good brakes and air pressure in the brake system.

NOTE: The brakes **must** prevent the vehicle from moving when the engine is at full throttle. Engage the vehicle brakes to keep the vehicle from moving.

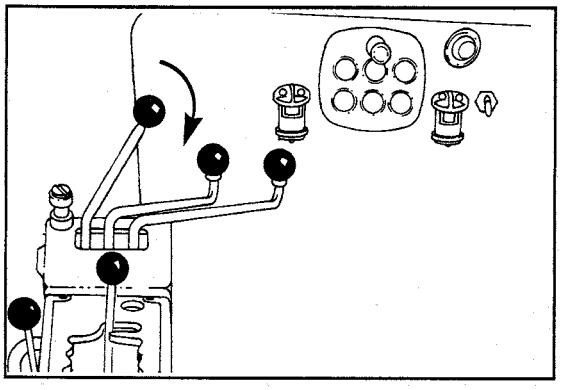




Operate the engine until the converter temperature is 80°C [180°F] or above.



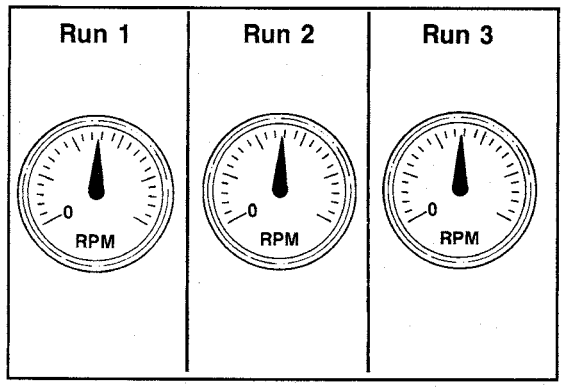
Bring the engine speed back to low idle.



△ CAUTION △

Do not exceed 120°C [250°F] converter oil temperature. Overheating and damage to the converter can occur.

Quickly move the throttle to the full OPEN position.

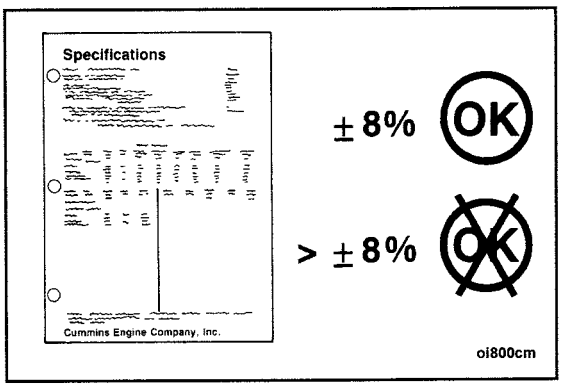


Check the engine speed (rpm) at the point of stall:

- **Always** hold the speed until it is stable
- Take several readings
- Make sure the readings are accurate.

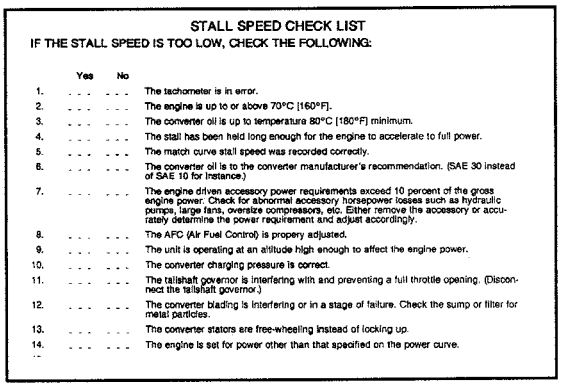
Check the speed (rpm) against the specifications for the equipment, converter, or automatic transmission.

NOTE: The stall speed for the engine and converter/ transmission can vary ±8 percent from the manufacturer's specifications.



If the stall speed is **not** within the specifications, refer to the Stall Speed Check List at the end of this section.

Check the equipment manufacturer's troubleshooting procedures for other reasons for stall speed problems.



STALL SPEED CHECK LIST

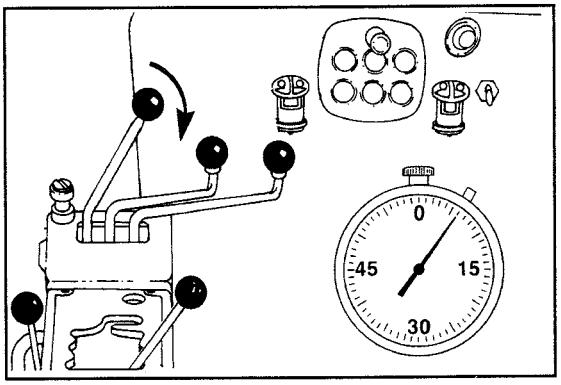
IF THE STALL SPEED IS TOO LOW, CHECK THE FOLLOWING:

	Yes	No	
1.	. . .	. . .	The tachometer is in error.
2.	. . .	. . .	The engine is up to or above 70°C [160°F].
3.	. . .	. . .	The converter oil is up to temperature 80°C [180°F] minimum.
4.	. . .	. . .	The stall has been held long enough for the engine to accelerate to full power.
5.	. . .	. . .	The match curve stall speed was recorded correctly.
6.	. . .	. . .	The converter oil is to the converter manufacturer's recommendation. (SAE 30 instead of SAE 10 for instance.)
7.	. . .	. . .	The engine driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversize compressors, etc. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.	. . .	. . .	The AFC (Air Fuel Control) is propery adjusted.
9.	. . .	. . .	The unit is operating at an altitude high enough to affect the engine power.
10.	. . .	. . .	The converter charging pressure is correct.
11.	. . .	. . .	The tailshaft governor is interfering with and prevensing a full throttle opening. (Disconnect the tailshaft governor.)
12.	. . .	. . .	The converter blading is interfering or in a stage of failure. Check the sump or filter for metal particles.
13.	. . .	. . .	The converter stators are free-wheeling instead of locking up.
14.	. . .	. . .	The engine is set for power other than that specified on the power curve.

Time Speed Check (005-054-047)

Perform the previous Stall Speed Check procedure through the "check the engine speed (rpm) at the point of stall" step; then:

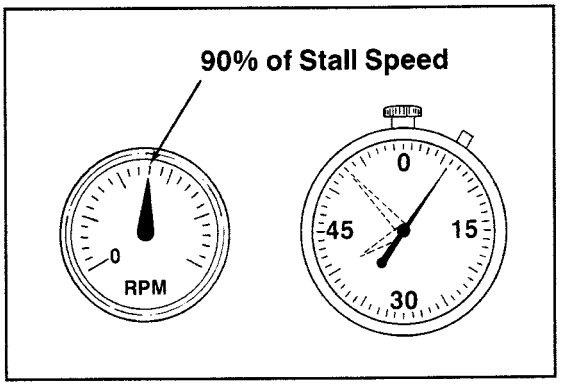
- Quickly move the throttle to the full OPEN position and start the stopwatch at the same time

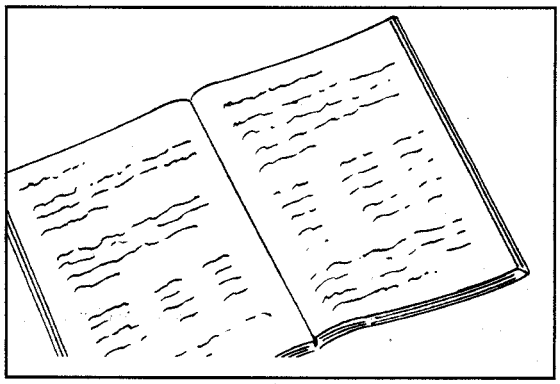


- When the engine speed is 90 percent of the stall speed rpm, stop the stopwatch

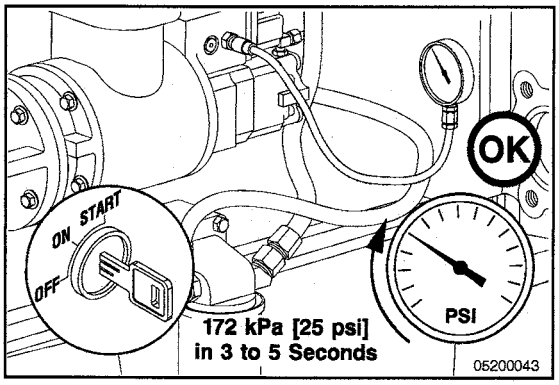
Example: Stall speed 2089 [2089 X 0.90 = 1880 rpm]

NOTE: The type of unit and the stall speed rpm can make the stall speed time a maximum of 10 seconds.





Check the equipment manufacturer's specifications for the time to stall or the acceleration time.



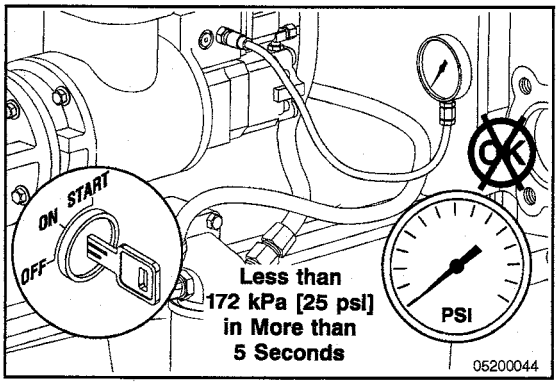
Fuel Pump Pressure Regulator (005-060)

Initial Check (005-060-001)

To check for a sticking pressure regulator, install a pressure gauge on the Compuchek® fitting in the side of the fuel shutoff valve.

Start cranking the engine.

The pressure gauge **must** start moving immediately and increase rapidly until the engine fires (approximately 172 kPa [25 psi]). This should take 3 to 5 seconds.



If the pressure gauge does **not** move or increases very slowly for more than 6 seconds, the regulator plunger is stuck open and will **not** let pressure build up quickly for a normal start. This can be caused by dirt, rust, or burrs on the plunger, or burrs on the plunger bore.

If the plunger is sticking, the gear pump **must** be replaced with a new or ReCon® unit. Refer to the Engine Shop Manual, Bulletin No. 3666075.

Stall Speed Check List

If the Stall Speed is Too Low, Check the Following:

	Yes	No	
1.			The vehicle tachometer is in error.
2.			The engine is up to or above 70°C [160°F].
3.			The converter oil is up to temperature 80°C [180°F].
4.			The stall has been held long enough for the engine to accelerate to full power.
5.			The match curve stall speed was recorded correctly.
6.			The converter oil is to the converter manufacturer's recommendation (SAE 30 instead of SAE 10, for instance).
7.			The engine-driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses, such as hydraulic pumps, large fans, oversize compressors, and so on. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.			The converter charging pressure is correct.
9.			The tailshaft governor is interfering with and preventing a full-throttle opening. Disconnect the tailshaft governor. Do **not** exceed the manufacturer's maximum output speed.
10.			The converter blading is interfering, or in a stage of failure. Check the sump or filter for particles.
11.			The converter stators are free-wheeling instead of locking up.
12.			The engine is set for power other than that specified on the power curve.
13.			The converter is wrong due to improper build or rebuild of unit.
14.			The converter is performing to the published absorption curve.
15.			The engine and converter match is correct. Check the engine and converter models for the proper match.
16.			The engine is matched to too large of a converter. If this condition is believed to exist, please report the engine-converter-accessory information to the factory.
17.			The engine power is down. Refer to the Engine Power Output Low troubleshooting and repair tree.

If the Stall Speed is too High, Check the Following:

	Yes	No	
1.			The accessory power requirements are less than 10 percent of the gross engine power.
2.			The converter oil is aerating or foaming. Check for low oil level, air leaks in suction line, lack of foam inhibitor in the oil, or suction screen or filter. It is accompanied by a noticeable loss of machine performance.
3.			The converter is being held at full stall. Check for slipping front disconnect clutch or a rotating output shaft. On the converter-transmission package, this can be impossible to check.
4.			The converter turbine element is beginning to fail and lose blades, or the converter was originally built with the wrong size element.
5.			The engine and converter match is correct, due to a revision in the engine rating or the converter performance.
6.			If the oil level is too high on the transmission-converter units with the oil sump in the transmission, it can cause severe aeration due to parts dipping in to the oil.
7.			The converter is performing to the published absorption curve.
8.			The converter charging pressure is correct.

The reasons for abnormal stall speeds listed above are some that have been encountered by Cummins representatives and probably do **not** include all possible causes. The correction of the problem is either covered in the vehicle service manual, the converter service manual, or is self-explanatory.

Section 6 - Injectors and Fuel Lines - Group 06

Section Contents

Page

Air in Fuel 6-9
Test 6-9
Gear Pump Drain Method 6-10
Sightglass Method 6-9

Cylinder Misfires or Smokes 6-12
Automated Cylinder Performance Test 6-12
ISM 6-12
Cylinder Cutout Test 6-12
ISM 6-12
Exhaust Manifold Temperature Test 6-13
Exhaust Manifold Tilt-back Method 6-13
General Information 6-12

ECM Cooling Plate, Fuel Cooled 6-14
Install 6-15
Remove 6-14

Fuel Drain Line Restriction 6-16
Measure 6-16

Fuel Filter (Spin-On Type) 6-17
Install 6-17
Remove 6-17

Fuel Inlet Restriction 6-19
Measure 6-19

Fuel Supply Lines 6-21
Inspect for Reuse 6-21
Remove 6-21

Injector 6-28
Install 6-31
ISM 6-31
Remove 6-28
ISM 6-28

Injectors and Fuel Lines - General Information 6-1
Theory of Operation 6-1
Hydromechanical Subsystem 6-1

Service Tools 6-7
Injectors and Fuel Lines 6-7

Static Injection Timing 6-22
Measure 6-24
Setup 6-22

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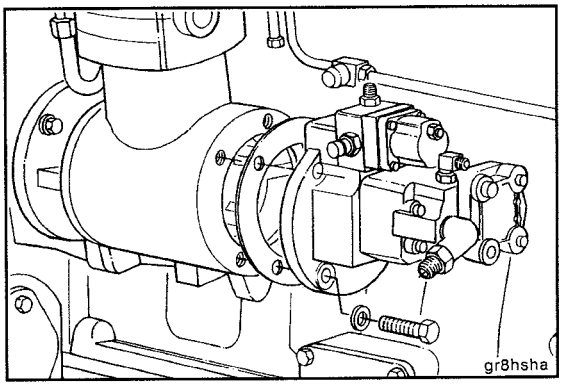
Injectors and Fuel Lines - General Information

Theory of Operation

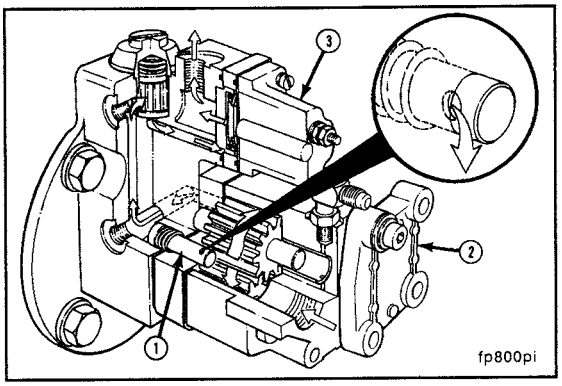
Hydromechanical Subsystem

The fuel pump is located in the same location as a CELECT™ Plus fuel pump.

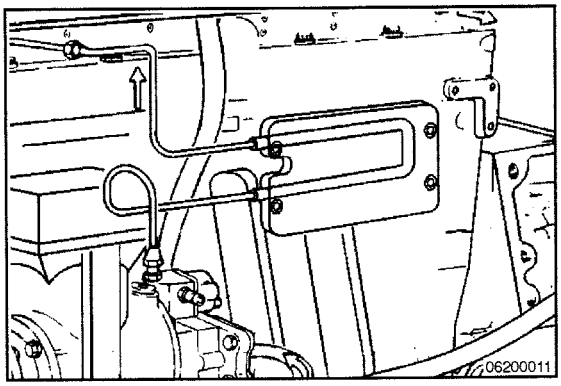


The fuel pump is a gear type of pump. The assembly includes a pressure regulator, pulsation damper, and solenoid valve.

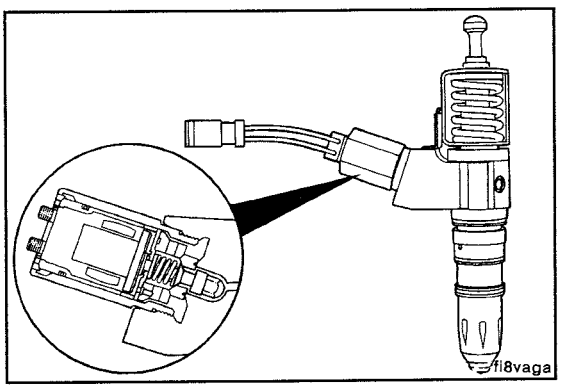
1. Pressure regulator
2. Pulsation damper
3. Solenoid valve.

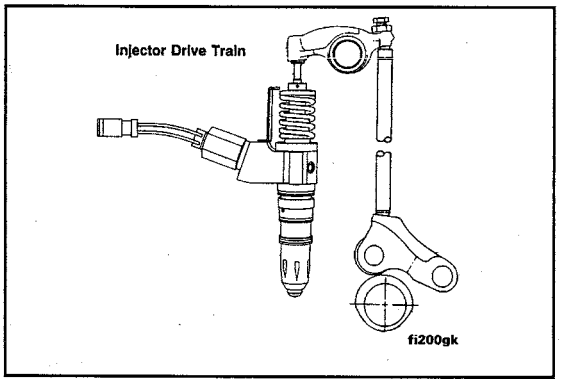


The ECM mounts on a cooling plate. During engine operation, fuel circulates through the cooling plate to absorb heat generated by the ECM.

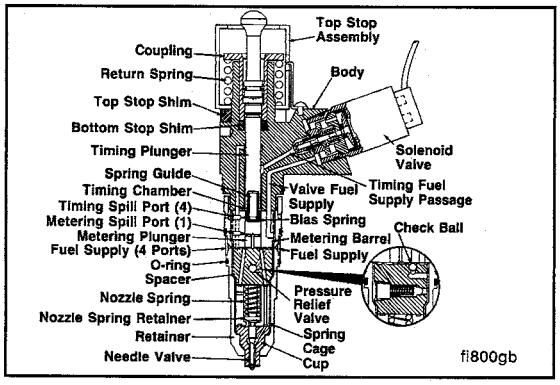


The injector assembly includes a solenoid valve, which controls the end of the fuel metering and the beginning of injection. The solenoid valve is normally open. An electronic signal from the ECM closes the valve as required.

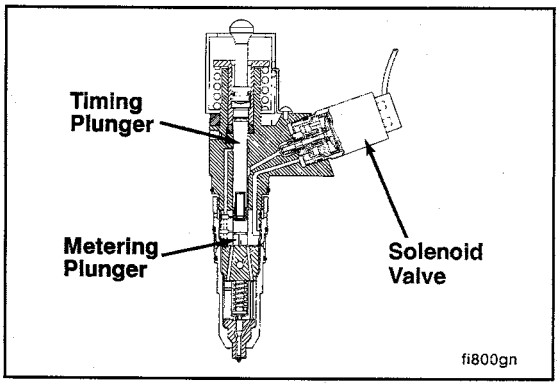




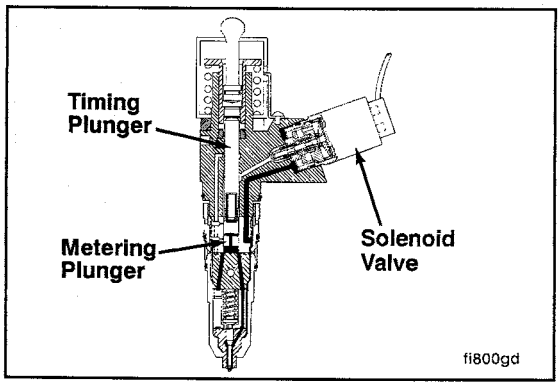
The fuel system uses the camshaft to create adequate pressure for injection.



Here is a cutaway view of the electronically controlled injector with the internal components identified.



At the start of metering, the metering plunger and the timing plunger are at the lower limits of their travel. The injector control valve is closed.

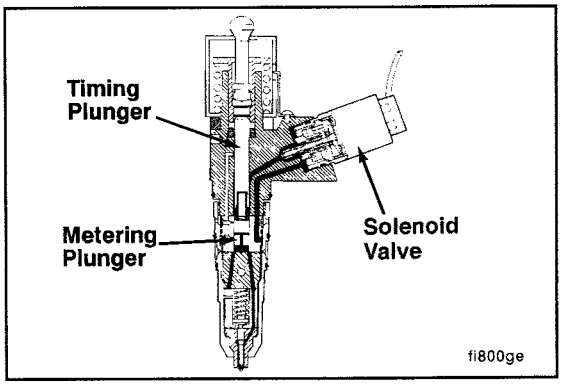


As the camshaft rotates, the timing plunger return spring forces the timing plunger upward.

Fuel flows past the metering check ball and into the metering chamber. This flow continues as long as the timing plunger is moving **upward**, and the injector control valve is **closed.**

Supply pressure, acting on the bottom of the metering piston, forces it to maintain contact with the timing plunger.

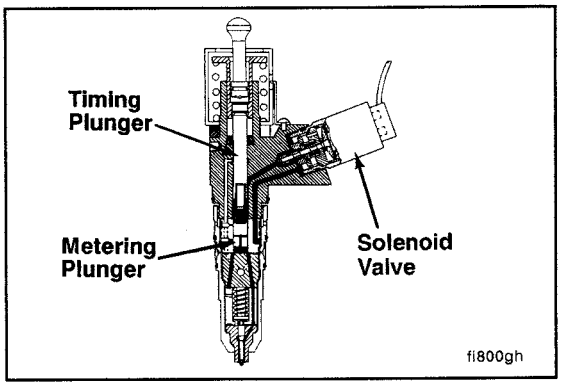
The ECM determines the end of the metering by signaling the injector control valve to **open**.



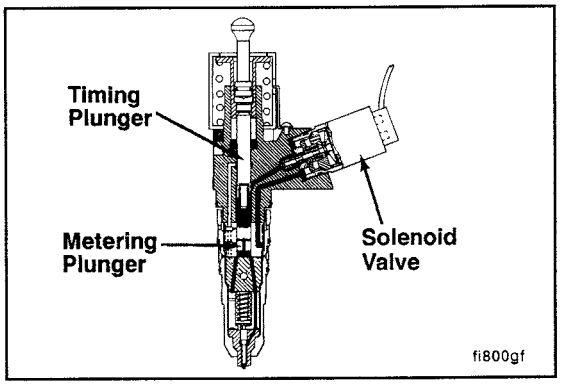
Fuel at supply pressure then flows into the **timing** chamber, thereby stopping metering piston travel.

During this time, the bias spring makes sure the metering plunger remains stationary, that it does **not** drift upward as the timing plunger moves upward. This same force against the metering plunger results in enough fuel pressure **below** the piston to keep the metering check ball seated.

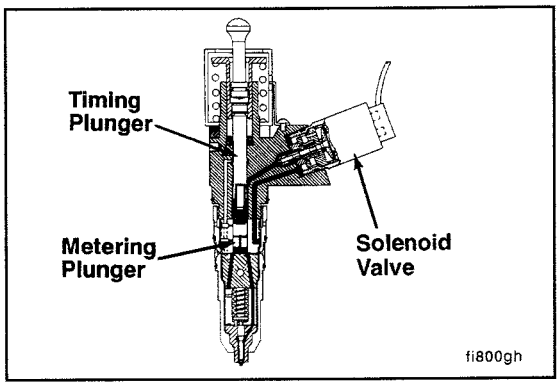
A precisely metered quantity of fuel is now trapped in the metering chamber. This determines the quantity of fuel that will be injected.

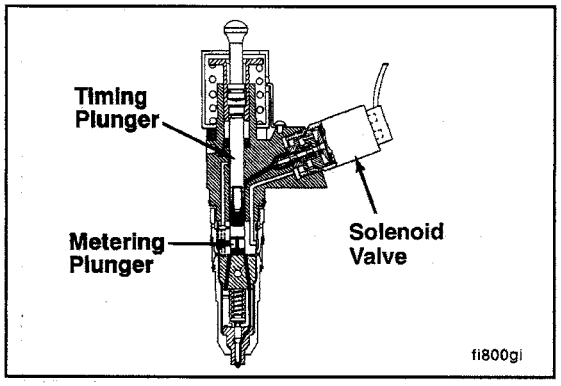


The timing plunger continues to move upward, and the timing **chamber** fills with fuel.

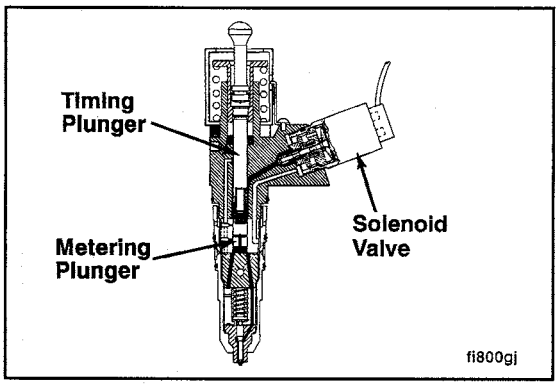


Now the timing plunger begins its **downward** travel. Initially, the injector control valve remains open, allowing fuel to flow from the timing chamber, through the injector control valve, and into the fuel supply passage.



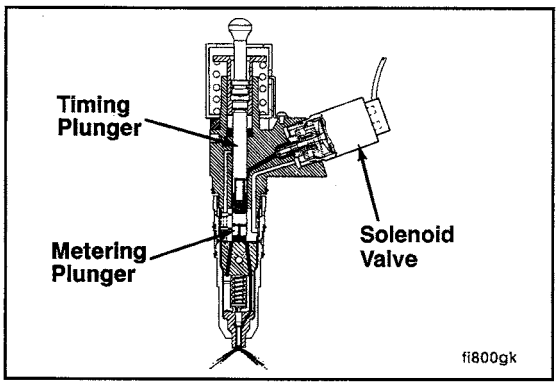


At the appropriate time, as determined by the ECM, the injector control valve closes, trapping fuel in the timing chamber. This trapped fuel creates a solid hydraulic link between the timing plunger and metering plunger.



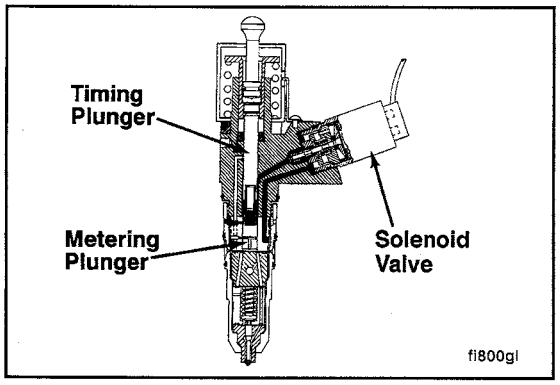
As a result, the metering plunger is forced to move downward with the timing plunger.

Because the fuel is trapped, the downward force on the timing plunger is transferred to the metering plunger, thereby increasing pressure in the metering chamber.



When this pressure reaches approximately 5000 psi, the needle valve begins to be forced upward.

Continued downward movement of the timing plunger and metering plunger results in steadily increasing fuel pressure. The result is that fuel is forced past the needle valve, through the spray holes, and into the combustion chamber.

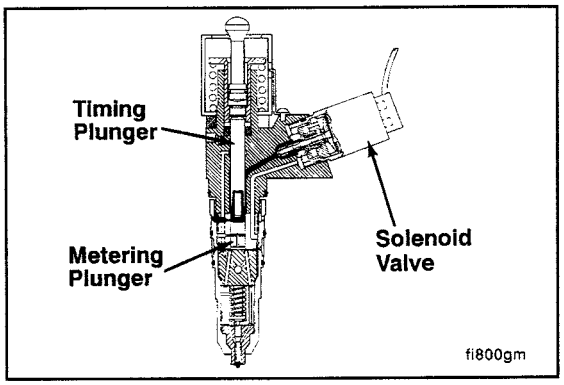


Injection continues until the spill passage of the metering plunger passes the metering spill port.

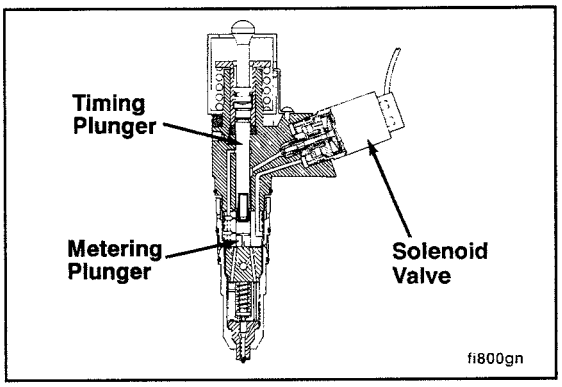
Metering chamber pressure drops rapidly, allowing the needle valve to close abruptly. This action results in a positive end of injection. The positive end of the injection prevents dribble and results in cleaner burning.

It is also at this point that the pressure relief valve "pops off," thereby reducing the effects of the high-pressure "spike" that occurs at the time of metering spill.

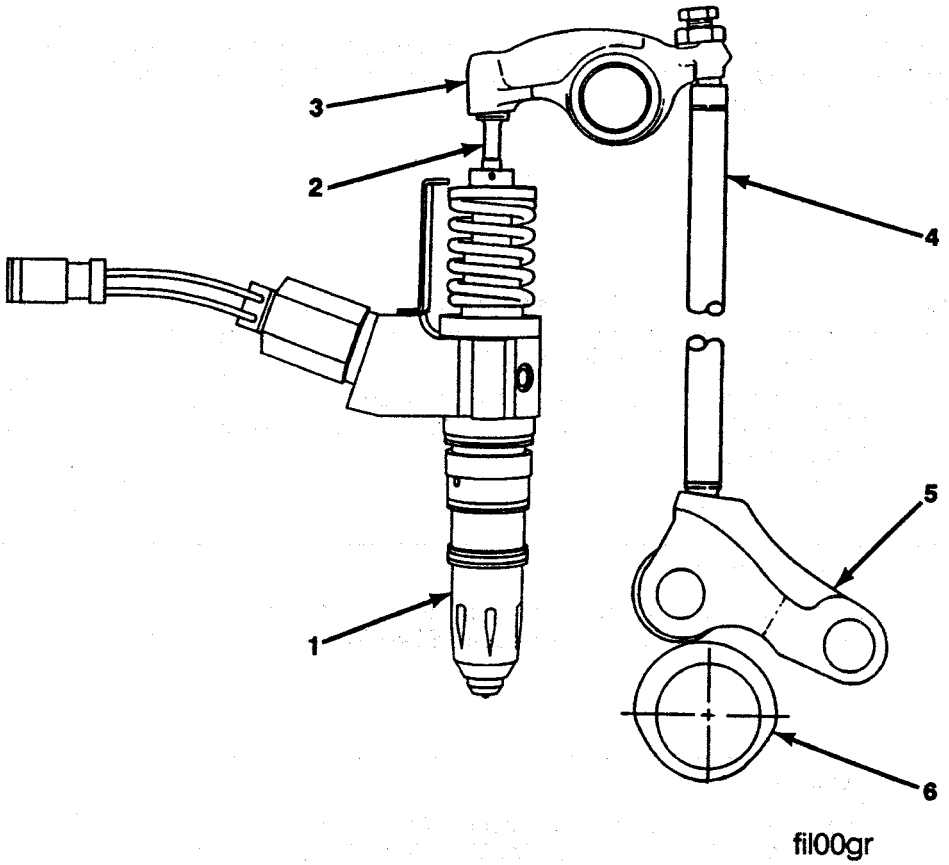
Immediately **after** the metering spill port is opened, the upper edge of the metering plunger passes the timing spill port.



This action allows the fuel in the timing chamber to be spilled back to the fuel drain as the timing plunger completes its downward movement.
This completes the injection cycle.



INJECTOR DRIVETRAIN

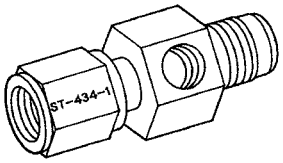
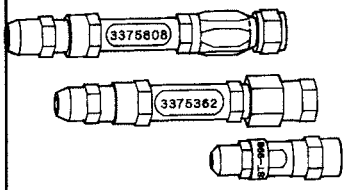
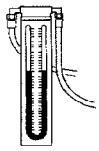
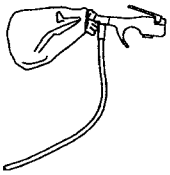
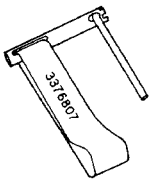


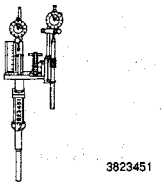
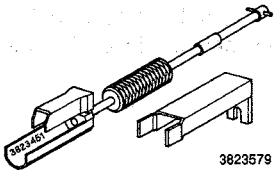
1. Injector
2. Injector Link
3. Rocker Lever
4. Push Rod
5. Cam Follower
6. Camshaft.

Service Tools

Injectors and Fuel Lines

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-434	**Vacuum Gauge (0 to 30 in. Hg)** Used to check fuel inlet restriction. Fuel restriction adapters, Part No. ST-434-1, 3375845, and 3376922, are required and **must** be ordered separately.	eg8togc
ST-434-1 ST-434-2	**Hose Adapter** Used with vacuum gauge, Part No. ST-434. Use Part No. ST-434-1 with No. 8 hose. Use Part No. ST-434-2 with No. 10 hose.	 st-434-1
ST-998 3375362 3375808	**Sight Glass** Used to check for air in the fuel suction line. Use Part No. 3375362 with No. 12 hose, and Part No. 3375808 with No. 16 hose.	
ST-1111-3	**Mercury-Filled Slack Tube Manometer** Used to measure fuel drain line restriction.	 st-1111-3
ST-1272-11 or 3823461	**Chip Removing Unit** Used to remove carbon from the top of the piston. Refer to capscrew salvage thread kit, Part No. 3376208. Chip unit, Part No. 3823461, is a vacuum tool.	 st-1272-11
3376807	**Filter Wrench** Used to remove or tighten spin on fuel filters.	 3376807

Tool No.	Tool Description	Tool Illustration
3823451	**Static Injection Timing Tool** Used to measure static timing.	 3823451
3823579	**CELECT™ Injector Puller and Driver Assembly** Used to remove and install CELECT™ injectors.	 3823579

Air in Fuel (006-003)

Test (006-003-012)

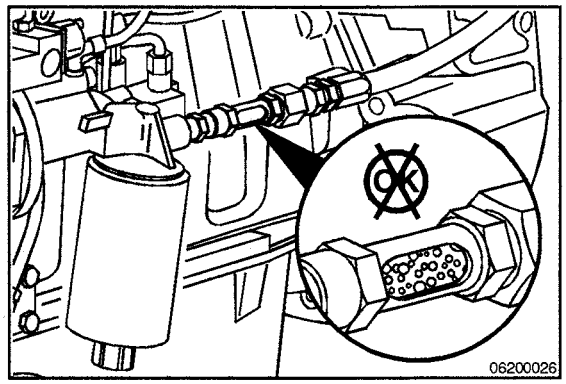
Sightglass Method

Remove the fuel suction line.

Install a sight glass, Part No. 3375362, in the line.

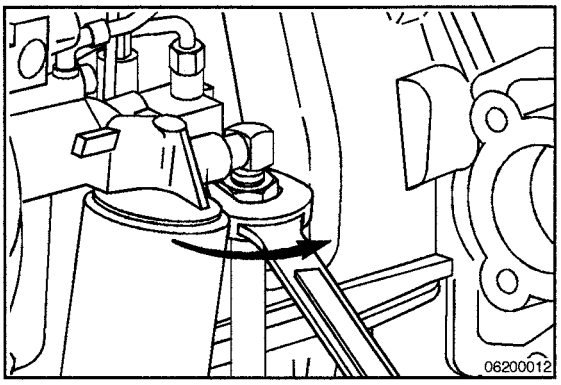
Operate the engine.

NOTE: A small air leak will have a milky appearance. A large air leak will look like bubbles in the fuel.

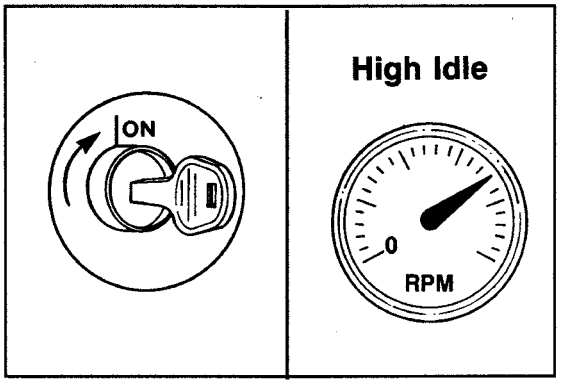


If an air leak is found, inspect the fuel lines, o-rings, and fittings for damage. Check for loose connections.

Replace the damaged lines or tighten the loose connections.

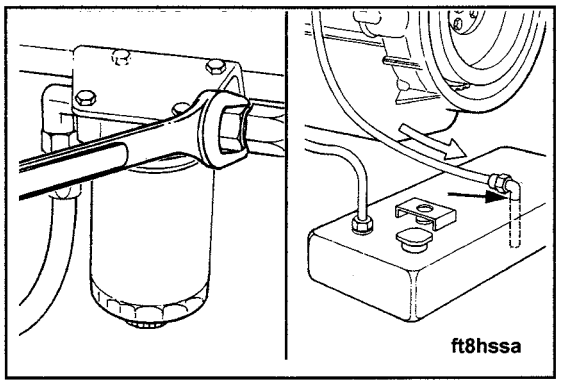


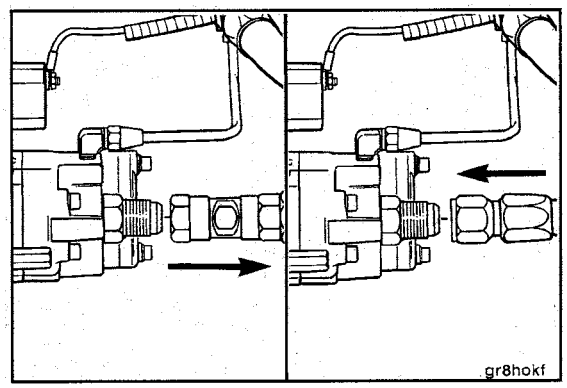
Operate the engine at high idle with no load, and check the sight glass.



Tighten the hose connections and the fuel filter.

Check the drop tube in the fuel tank for damage.

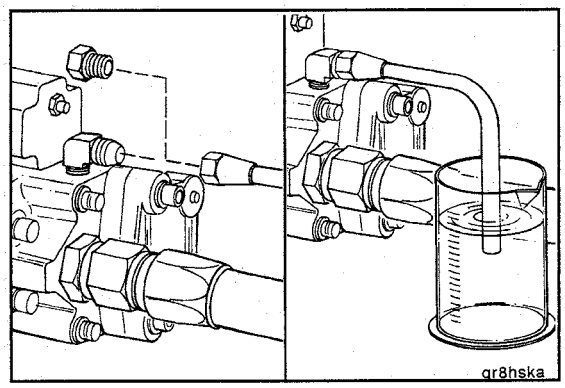




Replace any defective parts as required.

Remove the sight glass, and install the suction hose.

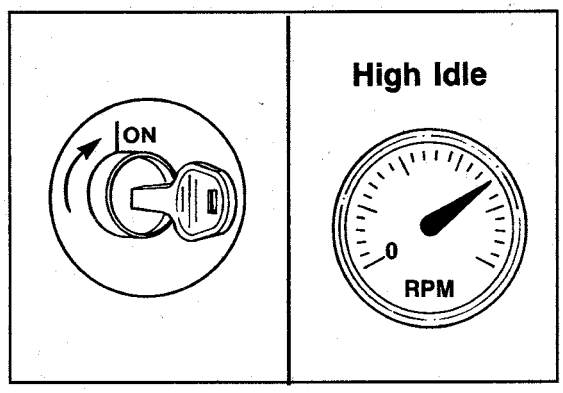
Test the engine again for other air leaks.



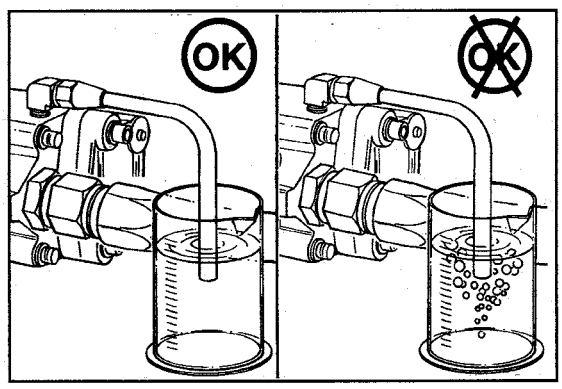
Gear Pump Drain Method

Remove the gear pump cooling drain line from the check valve, and install a plug in the line.

Install a hose on the check valve and place the other end of the hose in a container.



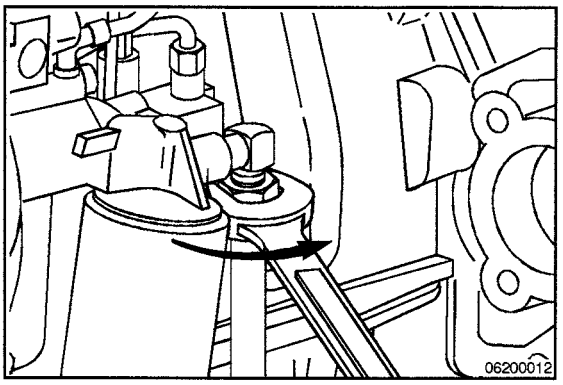
Operate the engine at high idle with **no** load.



If air is entering the fuel pump suction line, bubbles will be visible in the container of fuel.

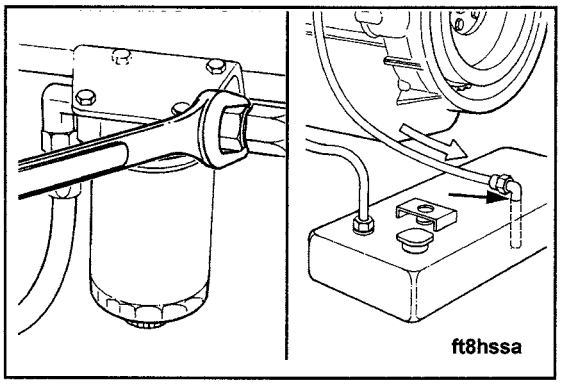
If bubbles are visible, tighten the fuel supply pump inlet fitting.

Tighten the cooling plate inlet and outlet fittings.

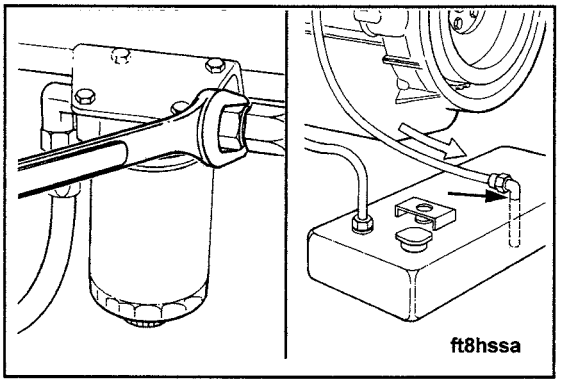


Tighten the hose connections and the fuel filter.

Check the drop tube in the fuel tank for damage.

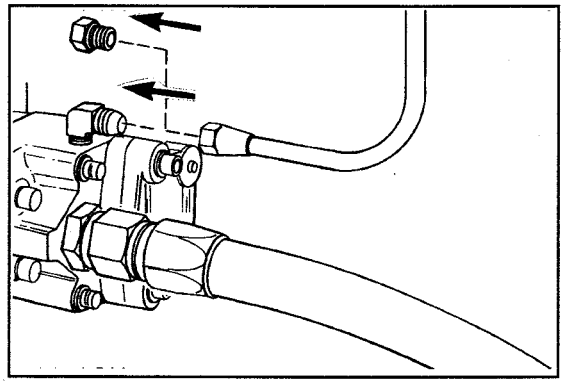


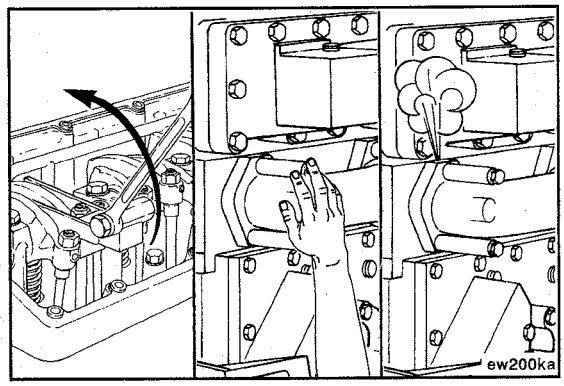
Correct the air leak and test again for other leaks.



Remove the hose from the check valve elbow and the plug from the cooling drain line.

Install the drain line on the check valve.





Cylinder Misfires or Smokes (006-005)

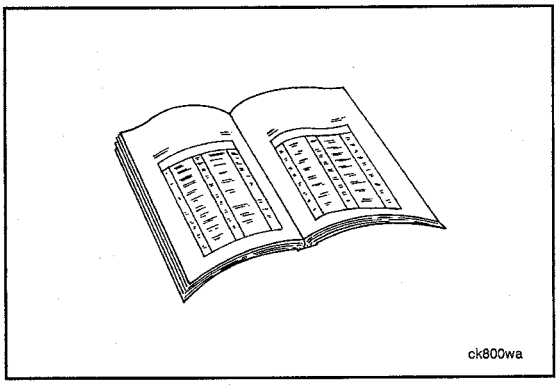
General Information

⚠ WARNING ⚠

Due to the stroke of the injectors on M series engines, do not use the mechanical method to perform a cylinder cutout test. When an injector on an engine is mechanically shorted (barred), the push rods can be thrown free, causing personal injury. Refer to the Automated Cylinder Performance Test to perform the test on M series engines.

The following methods can be used to find the cylinder(s) causing misfire/white smoke:

- Exhaust manifold temperature
- Tilting back exhaust manifold
- Automated cylinder performance test.



Automated Cylinder Performance Test (006-005-057)

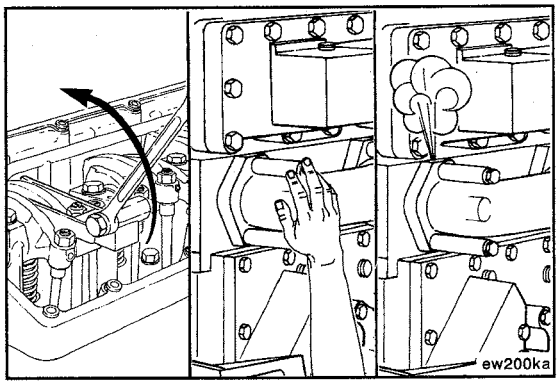
ISM

NOTE: Do **not** run the automated cylinder performance test on engines that are smoking at idle.

Perform the automated cylinder performance test at least twice.

Refer to the appropriate electronic service tool manual.

Minimum cylinder contribution is 71 percent.

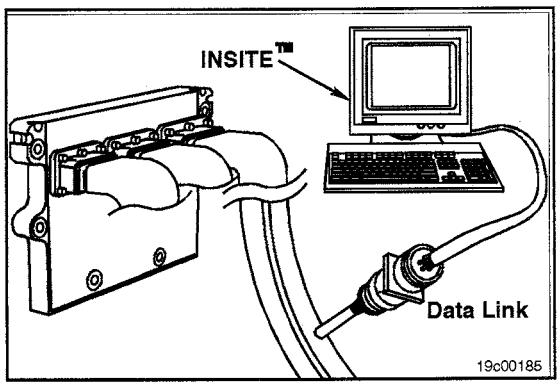


Cylinder Cutout Test (006-005-058)

ISM

The following methods can be used to find the cylinder(s) causing misfire/white smoke:

- Exhaust manifold temperature
- Tilting back exhaust manifold
- Automated cylinder performance test.



Cut out each cylinder while watching the exhaust smoke. Refer to the appropriate electronic service tool manual.

Replace the injector in the cylinder that causes a reduction in smoke when cut out.

Exhaust Manifold Temperature Test (006-005-059)

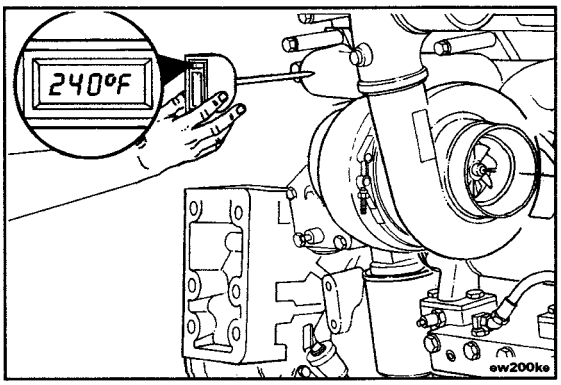
To locate a smoking cylinder, use a pyrometer or infrared temperature gun to measure the exhaust manifold surface temperature at each cylinder port.

The maximum exhaust manifold surface temperature at idle is 143°C [290°F].

A cylinder is smoking if:

- The exhaust manifold surface temperature at that exhaust port exceeds the above specification.
- The exhaust manifold surface temperature at that port is significantly higher than that for the other cylinder ports.

NOTE: If this test is inconclusive, tilt back the exhaust manifold to locate the smoking cylinder.

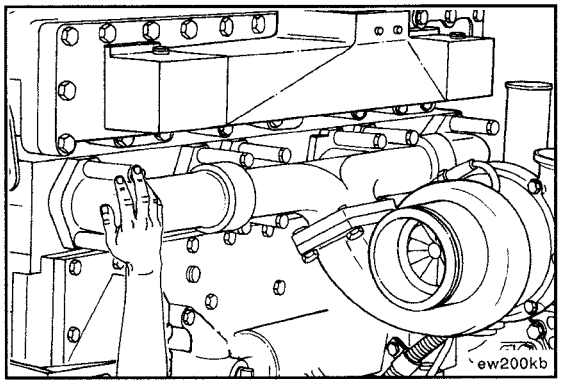


⚠ WARNING ⚠

Do not place hand on the exhaust manifold if the engine is hot or emiting thick black smoke.

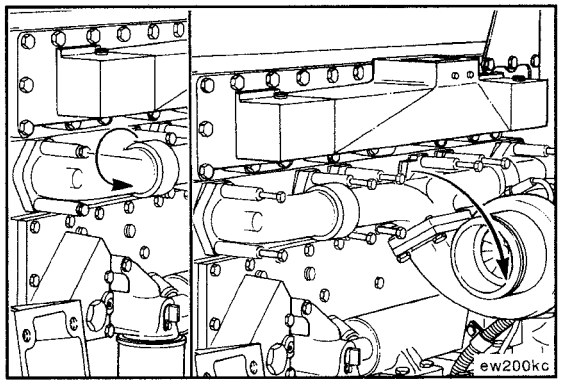
An alternative method is to place your hand on the exhaust manifold at each cylinder port. A smoking cylinder will feel hot.

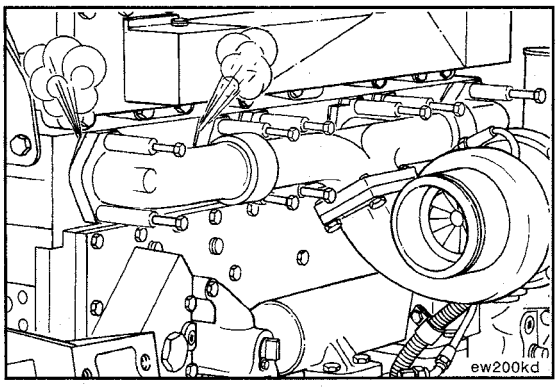
Replace the injector in the cylinder that is producing the smoke. Refer to Procedure 006-026.



Exhaust Manifold Tilt-back Method (006-005-060)

Loosen the exhaust manifold capscrews, and tilt the exhaust manifold back.

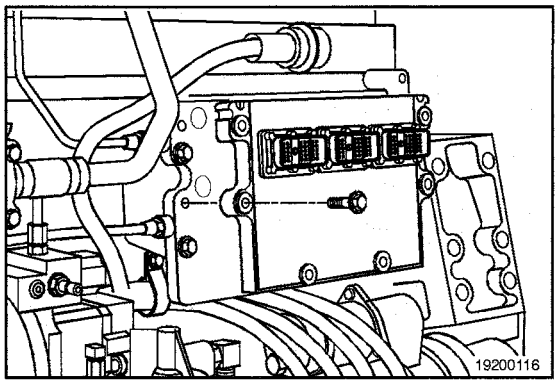




Idle the engine.

Observe the smoking cylinder.

Replace the injector in the cylinder that is producing the smoke. Refer to Procedure 006-026.

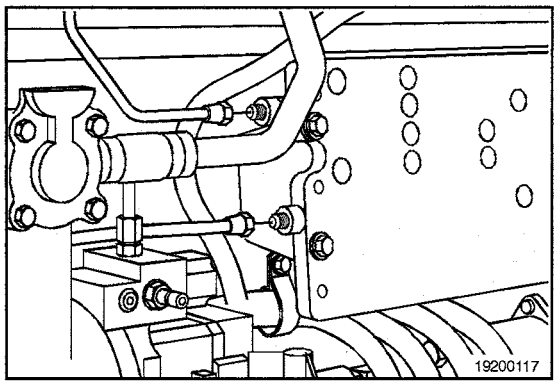


ECM Cooling Plate, Fuel Cooled (006-006)

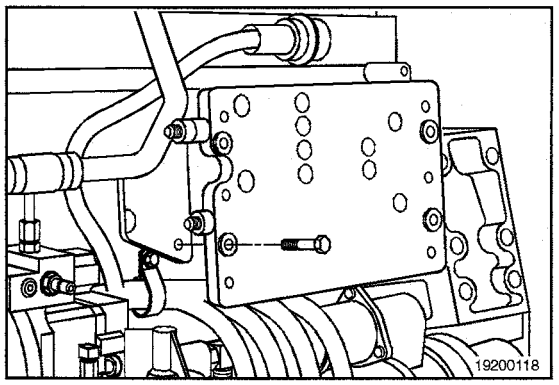
Remove (006-006-002)

Disconnect the engine wiring harness from the ECM.

Remove the six ECM mounting capscrews. These capscrews are metric. Remove the ECM from the cooling plate.



Remove the inlet and outlet fuel plumbing from the cooling plate.



Remove the four cooling plate mounting capscrews. Do **not** lose any of the heat-resistant grommets. The heat-resistant grommets are on both sides of the cooling plate. One of the mounting locations has heat-resistant star washer grommets on both sides of the cooling plate.

Remove the cooling plate.

Install (006-006-026)

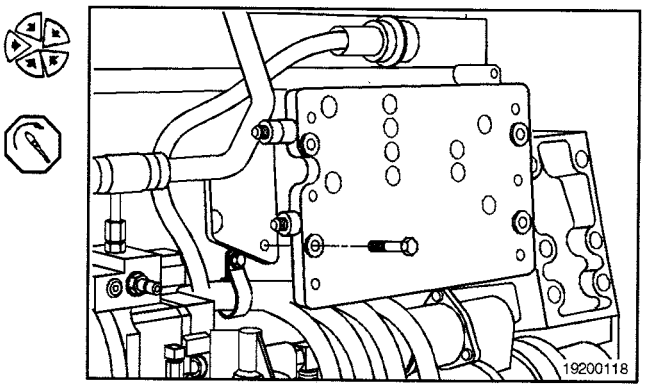
Install a new cooling plate.

Install the heat-resistant grommets on both sides of the cooling plate.

Install the two heat-resistant star washer grommets at the same mounting location.

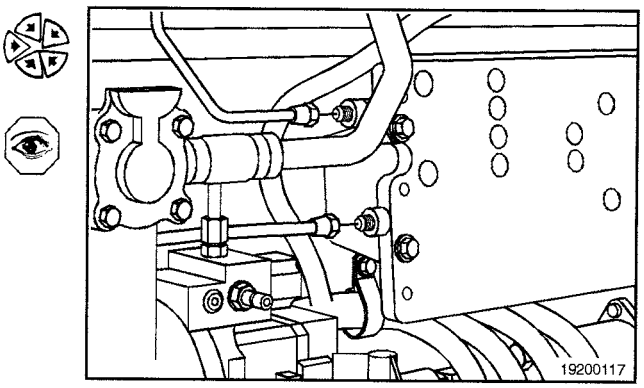
Tighten the four capscrews.

Torque Value: 40 N•m [30 ft-lb]



Connect and tighten the inlet and outlet plumbing to the cooling plate.

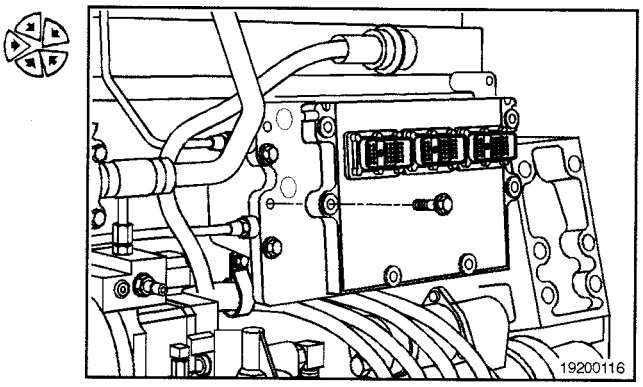
Inspect for paint or grease on the cooling plate.



⚠ CAUTION ⚠

Do not paint the cooling plate. Make sure there is no grease or dirt between the ECM and the cooling plate.

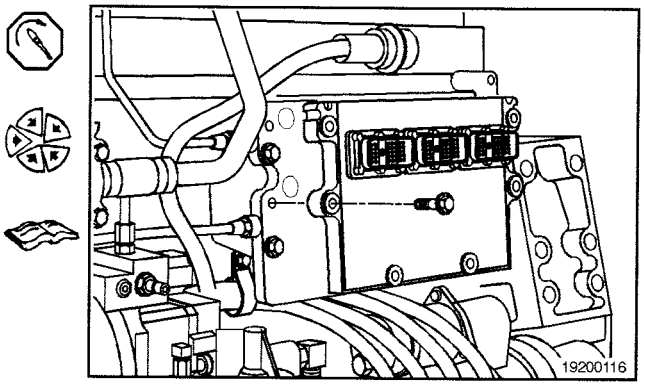
Install the ECM on the cooling plate. Install the six capscrews. Install the star washer under one of the capscrews.

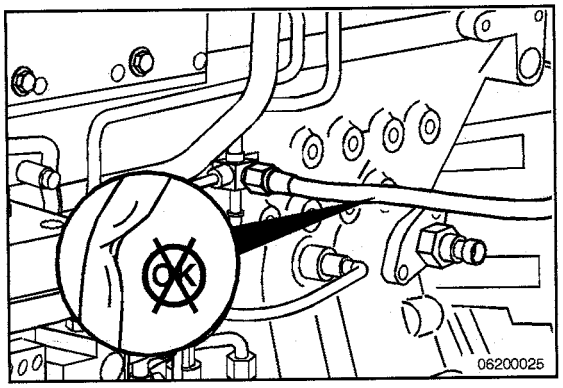


Tighten the four capscrews.

Torque Value: 7 N•m [65 in-lb]

Connect the engine harness and OEM harness connectors to the ECM. Refer to Procedure 019-031 in the ISM Fuel System Troubleshooting and Repair Manual, Bulletin No. 3666266.



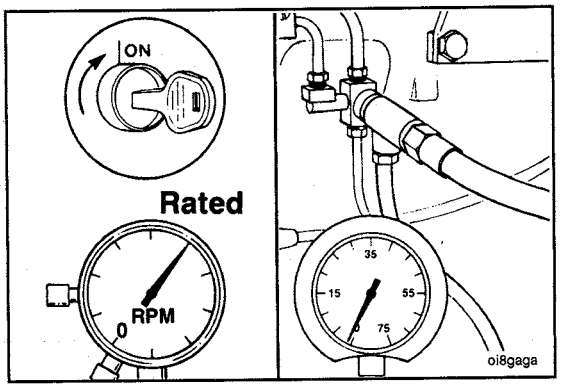


Fuel Drain Line Restriction (006-012)

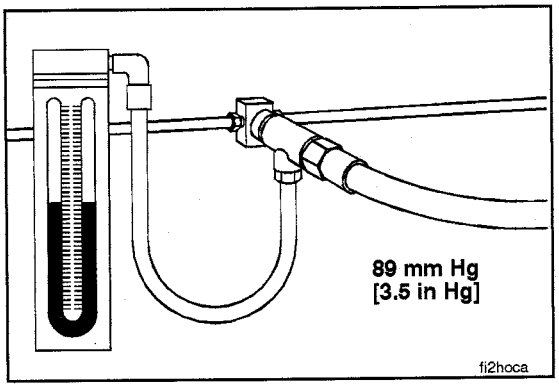
Measure (006-012-010)

Inspect the drain lines, and make sure the lines do **not** have any loops and are **not** kinked.

Remove the fuel drain line, and install the mercury manometer, Part No. ST-1111-3

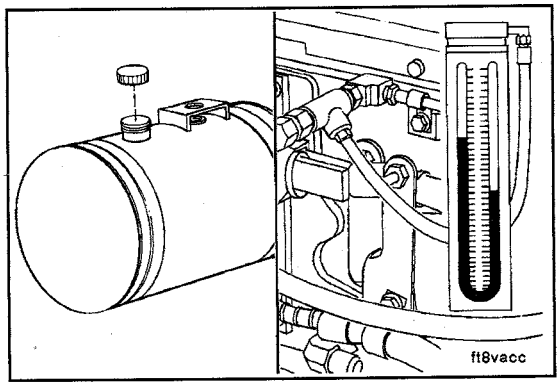


Operate the engine at rated speed and no load.



Observe the reading on the manometer. Hold the manometer at the same level as the connection.

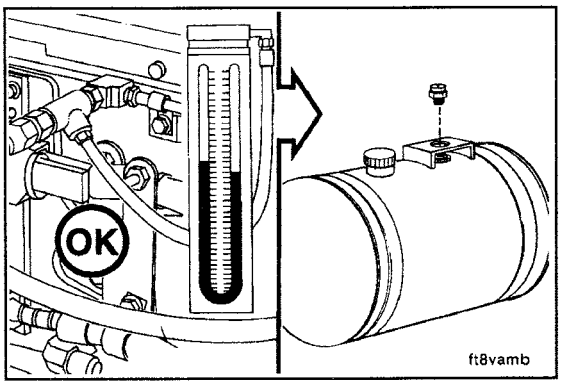
Fuel Drain Line Restriction		
mm Hg		in Hg
89	MAX	3.5



If the restriction is above the maximum specifications, remove the fuel tank fill cap and check again.

If the restriction is below the specifications when the cap is removed, replace the tank vents.

If the restriction is still above the specifications, inspect the drain lines for restrictions.

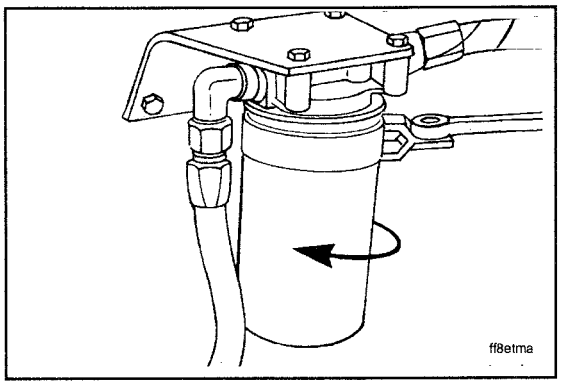


Fuel Filter (Spin-On Type) (006-015)

Remove (006-015-002)

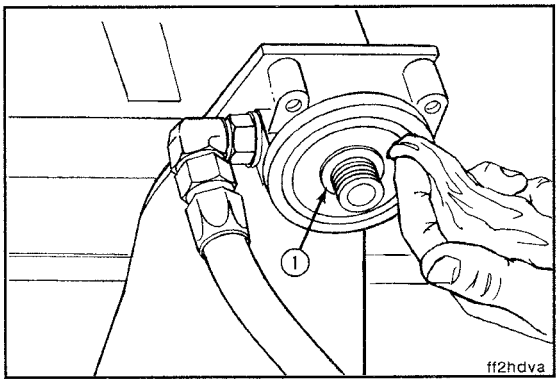
Clean the area around the fuel filter and fuel filter head.

Remove the fuel filter with filter wrench, Part No. 3376807.



Remove the thread adapter sealing ring (1).

Use a clean, lint-free towel to clean the gasket surface on the fuel filter head.



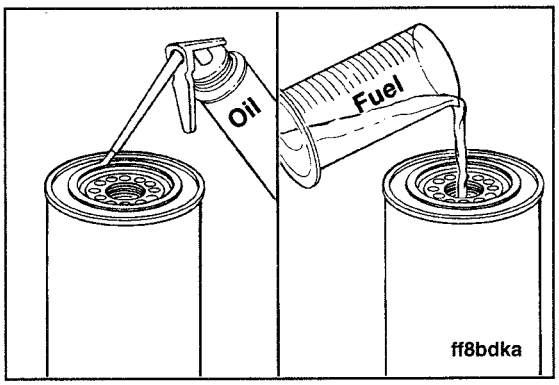
Install (006-015-026)

NOTE: Cummins Engine Company, Inc., requires a fuel-water separator be installed in the fuel supply system.

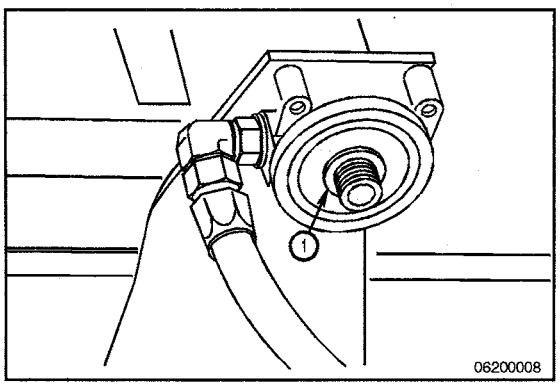
Use the correct filter(s) for your engine.

Fuel filter specifications, Cummins Engine Company, Inc., Standard No. 14,223:

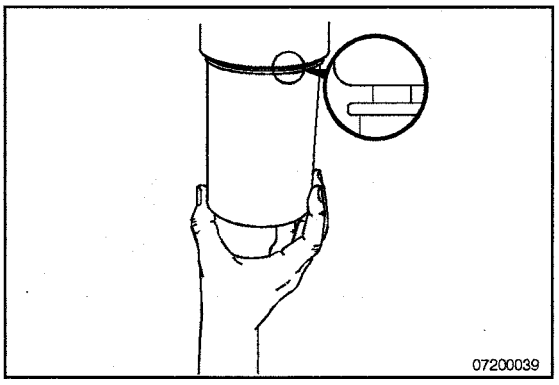
Efficiency:	98.7% at 10 microns 96% at 8 microns 86% at 5 microns
Water Removed:	Free = 95% Emulsified = 95%



NOTE: A 10-micron fuel filtration is required with Centinel™, if equipped.

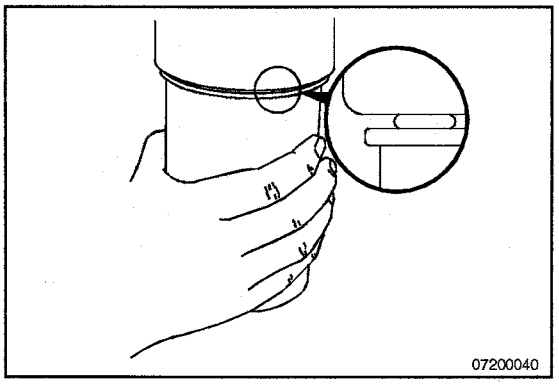


Install the new thread adapter sealing ring (1) supplied with the new filter.



Install the filter on the filter head.

Turn the filter until the gasket contacts the filter head surface.



⚠ CAUTION ⚠

Mechanical overtightening of the filter can distort the threads and damage the fuel filter seal.

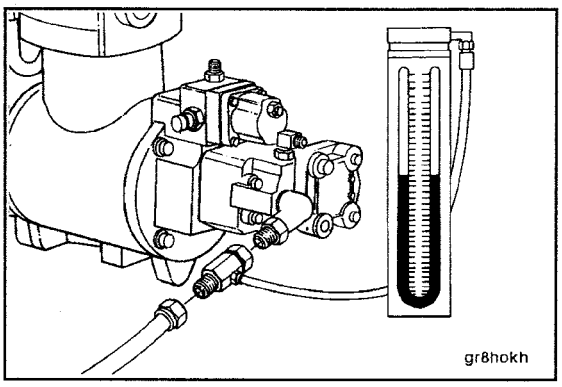
Tighten the filter an additional 1/2 to 3/4 of a turn after the gasket contacts the filter head surface, or as specified by the filter manufacturer.

Fuel Inlet Restriction (006-020)

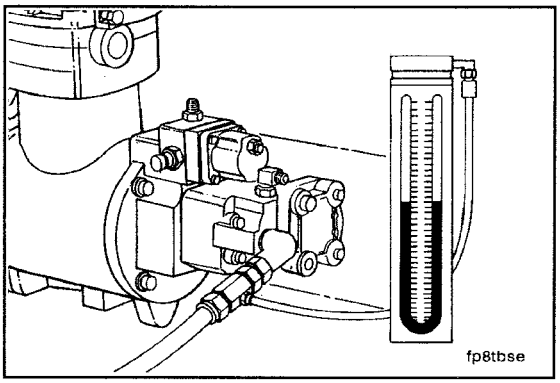
Measure (006-020-010)

Remove the fuel supply hose to the gear pump, and install the manometer, Part No. ST-1111-3. Use the appropriate hose adapter for the specific engine as described in the Service Tools list.

NOTE: If the gear pump inlet fitting has a Compuchek® fitting, the manometer can be installed there.



Hold the manometer at the same level as the gear pump connection.



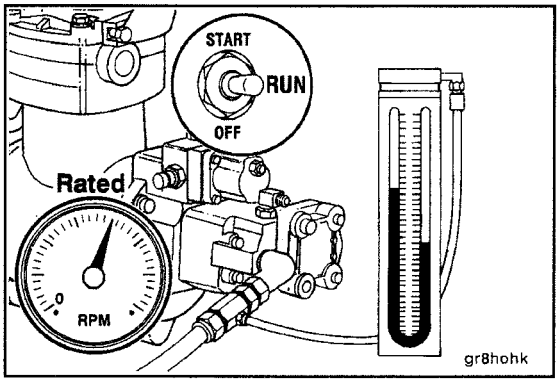
Operate the engine at rated speed and **no** load.

Observe the reading on the manometer.

Fuel Inlet Restriction			
	mm Hg		in Hg
Clean Filter	152	MAX	6
Dirty Fiter	254	MAX	10

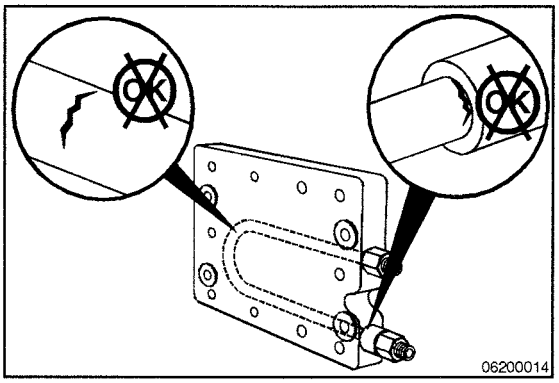
Correct the restriction, or replace the fuel filter.

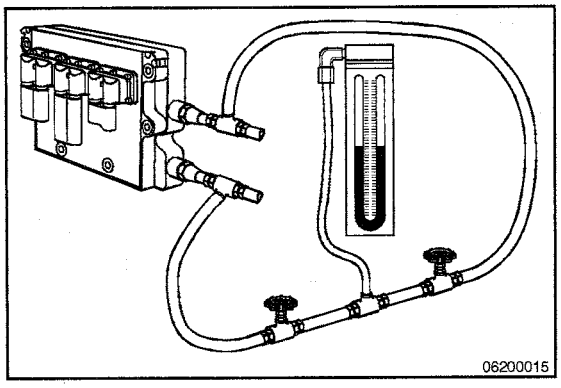
NOTE: The cooling plate on M Series engines has about 25.4-mm Hg [1-in Hg] restriction.



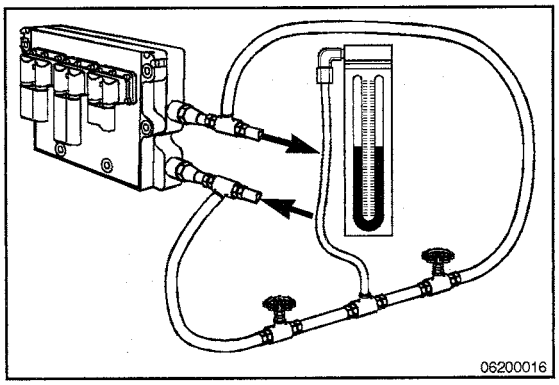
Cooling Plate Inspection

Inspect the cooling plate for restriction, porosity, and leakage. To inspect for porosity and leakage, examine the cooling plate for fuel leaks. If any leaks are found, replace the cooling plate. Refer to Procedure 006-006.

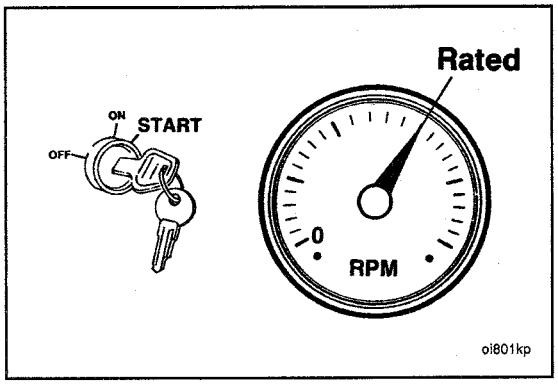




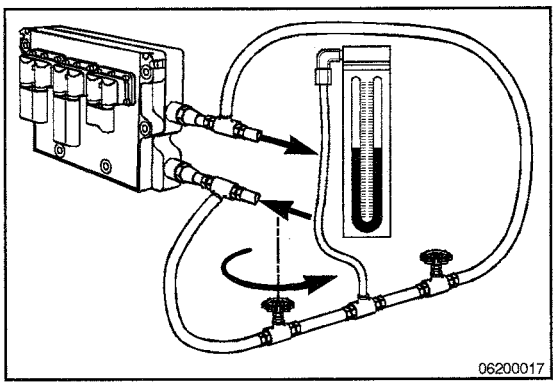
Install the mercury manometer, Part No. ST-1111-3, line to a tee fitting. Connect one on and off valve at either side of the tee. Attach the hose and appropriate fittings.



Remove the fuel line from the rear of the cooling plate (fuel in). Install one side of the manometer hose into the fuel line. Connect the line to the cooling plate. Connect the other side of the manometer hose into the line from the front of the cooling plate (fuel out). Make sure both valves are closed.



Start the engine, and operate it at rated rpm and no load.

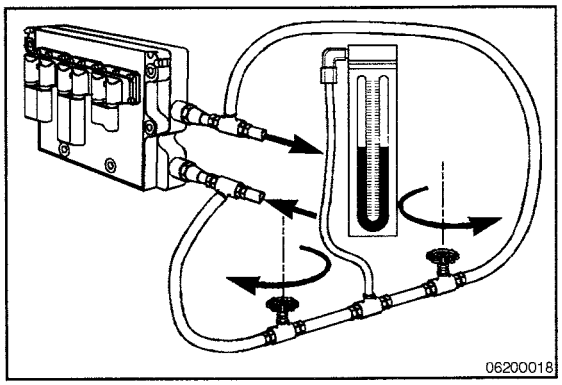


Open the valve on the inlet side of the manometer, and read the vacuum on the manometer. Record the vacuum reading.

Close the valve on the inlet side of the manometer. Open the valve on the outlet side of the manometer. Record the vacuum reading on the manometer.

Cooling Plate Restriction		
mm Hg		in Hg
25	MAX	1

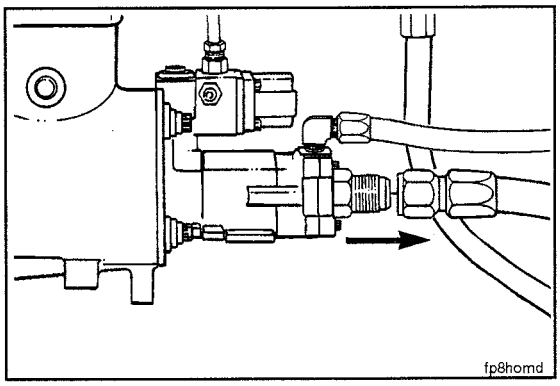
If the restriction is greater than the value given, clean or replace the cooling plate.



Fuel Supply Lines (006-024)

Remove (006-024-002)

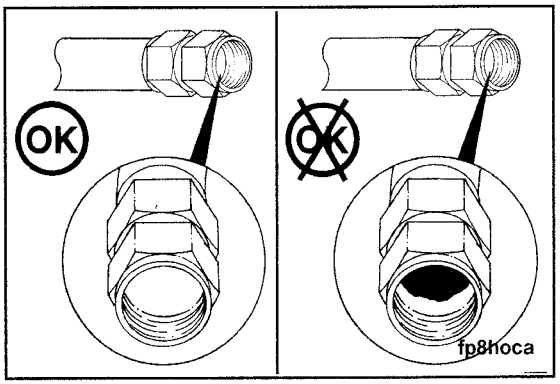
Remove the fuel line or fuel hose.



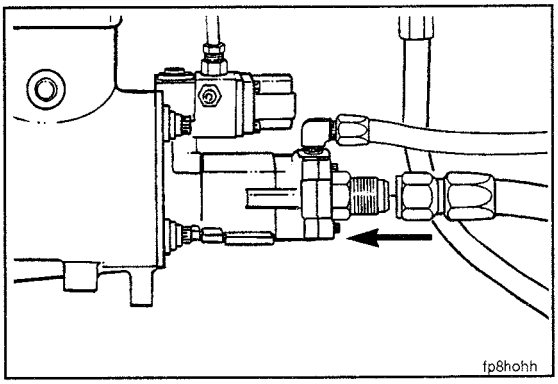
Inspect for Reuse (006-024-007)

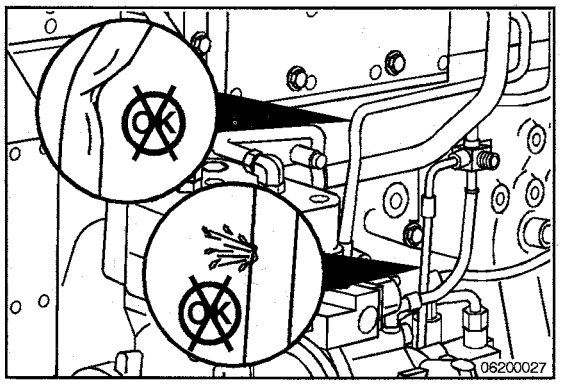
Inspect the inside of the fuel hose.

- The inner lining of the hose can separate from the center hose section.
- A separation or flap can cause a restriction in the fuel flow.



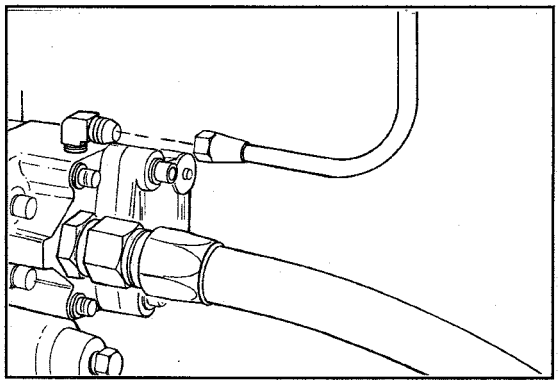
Replace the fuel hose if damage is found.



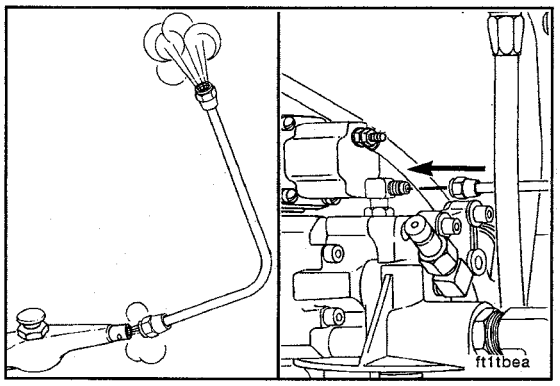


Check for cracks that can cause a pressure loss.

Check the metal fuel lines for sharp bends that can cause a pressure restriction.



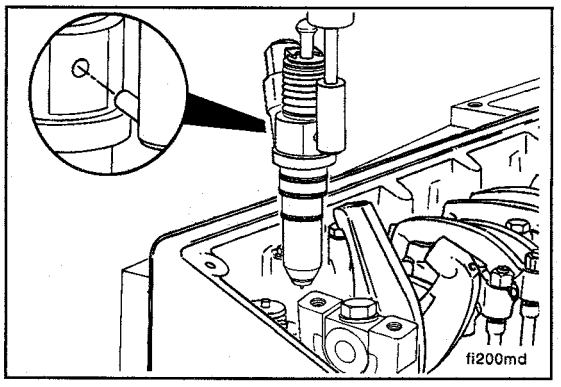
If a line(s) is damaged, replace the line(s).



Use compressed air to flush the lines and remove any loose dirt particles.

Install the fuel lines.

Install any brackets that were in place on the fuel plumbing.



Static Injection Timing (006-025)

Setup (006-025-011)

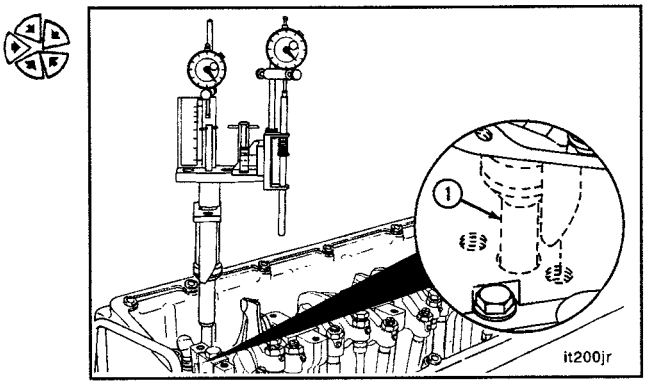
Remove the rocker lever cover. Refer to Procedure 003-011.

Remove the injector from cylinder No. 1. Refer to Procedure 006-026.

NOTE: It is **not** necessary to remove all injectors; however, engine rotation will be easier with all injectors removed.

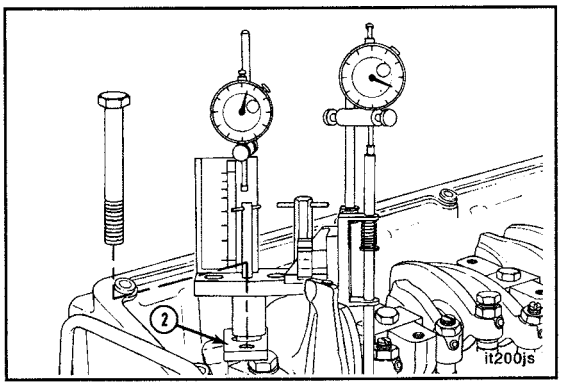
The timing tool, Part No. 3824942, can be installed without removing the rocker housing.

Install the piston plunger rod (1) in the injector bore of No. 1 cylinder.



Align the swivel bracket (2) with the injector hold-down capscrew hole.

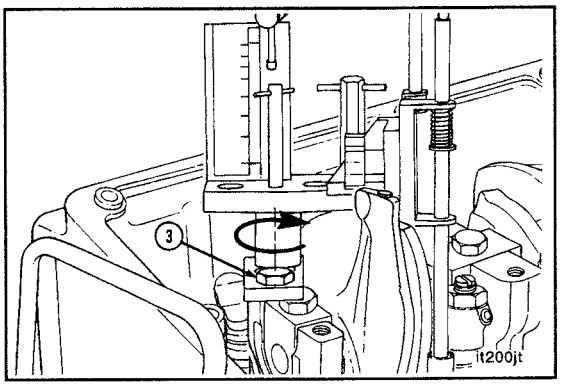
Install capscrew, Part No. 3823600, through the swivel bracket. The capscrew is included with the timing tool kit.



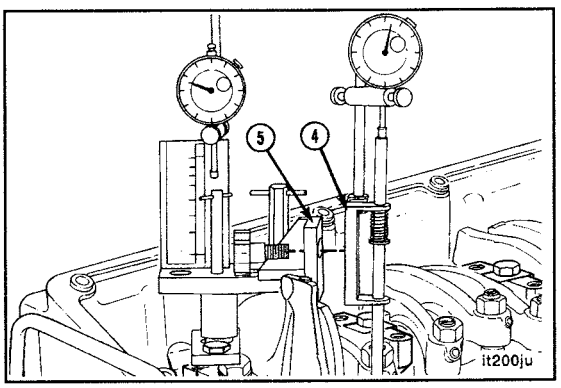
⚠ CAUTION ⚠

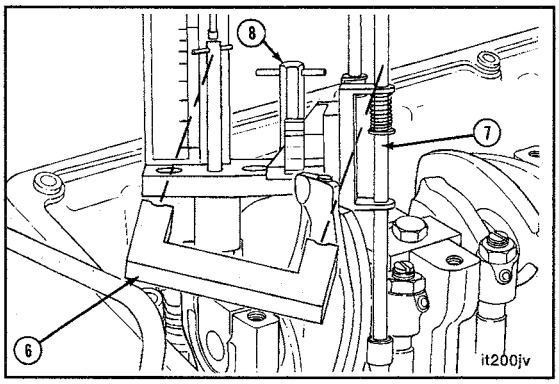
Do not tighten the capscrew too tightly. The capscrew can be damaged.

Tighten the capscrew (3) enough to hold the timing fixture rigidly.



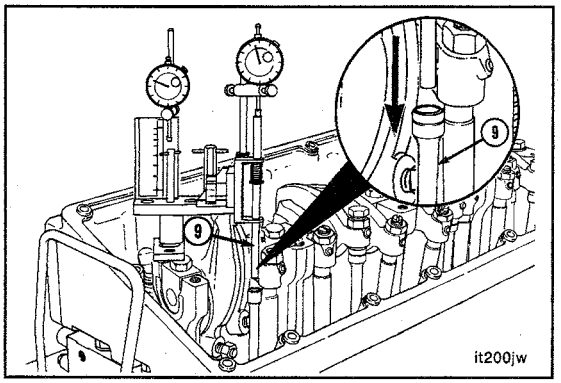
Position the timing tool push tube plunger bracket (4) on the backside of the center bracket (5).





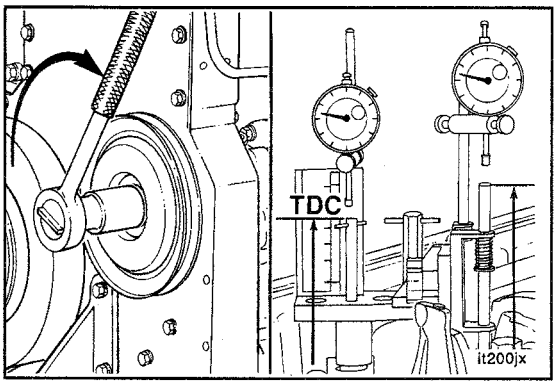
Use the alignment tool (6), Part No. 3376180, to align the push rod plunger rod (7).

Be sure to tighten the clamp handle (8) after the plunger rod is aligned, and remove the alignment tool.



Install the injector push rod (9) between the injector camshaft follower and the plunger rod.

The push rod (9) **must** be vertically aligned with the plunger rod. If it is **not**, incorrect timing values will result. Be careful **not** to drop the push rod into the engine.



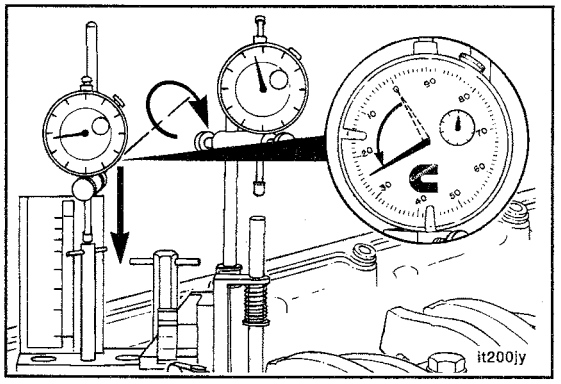
Measure (006-025-010)

△ CAUTION △

Use the accessory driveshaft to rotate the crankshaft. If another method is used, the injection timing will not be correct, or the engine can be damaged.

Determine the piston top dead center (TDC) on the compression stroke by rotating the accessory driveshaft **clockwise**.

The piston is on the compression stroke when both plungers move in an upward direction at the same time. Top dead center is indicated by the maximum **clockwise** indicator position of the piston travel indicator pointer.

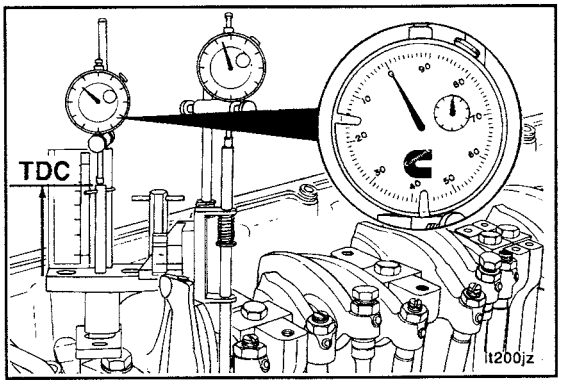


△ CAUTION △

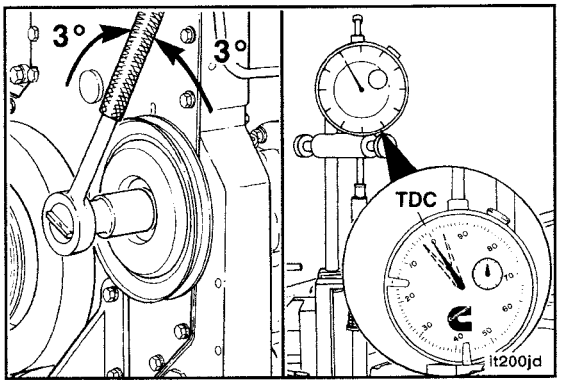
Both indicators must have a travel range of at least 6.35-mm [0.250-in], or the indicators will be damaged.

Position the gauge contact tip in the center of the plunger rod, and lower the gauge to within 0.63-mm [0.025-in] of the fully compressed position.

Set the dial indicator over the piston plunger rod to zero "0" when the piston plunger rod has reached maximum upward movement (TDC).

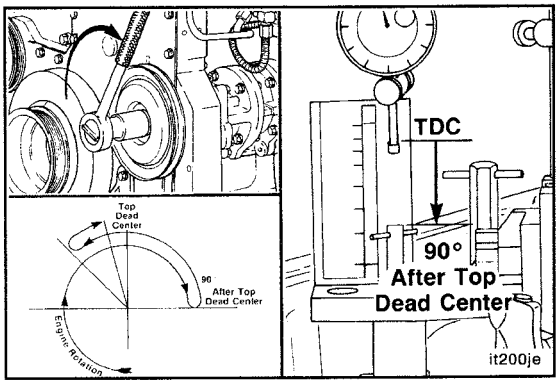


Rotate the accessory driveshaft back and forth, before and after the zero "0" indicator reading, for approximately 3 degrees to be sure the piston is at top dead center.



Rotate the accessory driveshaft **clockwise** to 90-degrees after top dead center (ATDC).

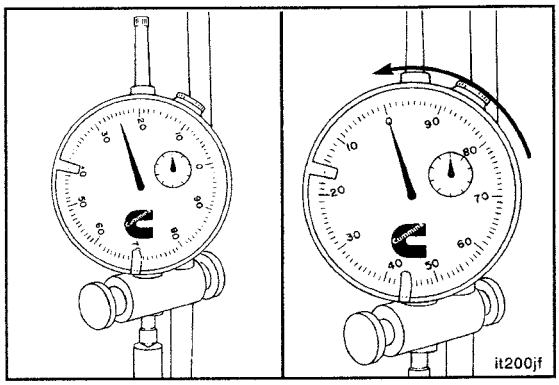
The piston plunger will be at the "L10 90 degree" mark on the timing fixture.

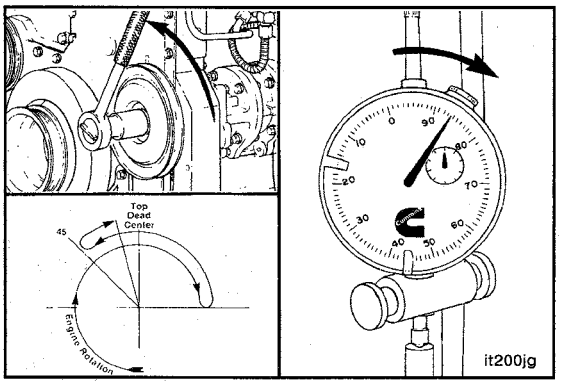


Position the push rod dial indicator contact tip in the center of the plunger rod, and lower the gauge to with in 0.63 mm [0.025 in] of the fully compressed position.

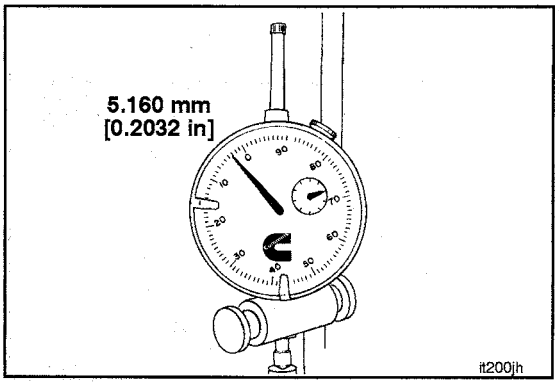
Set the push rod dial indicator to zero "0."

Rotate the accessory driveshaft **counterclockwise** to top dead center.



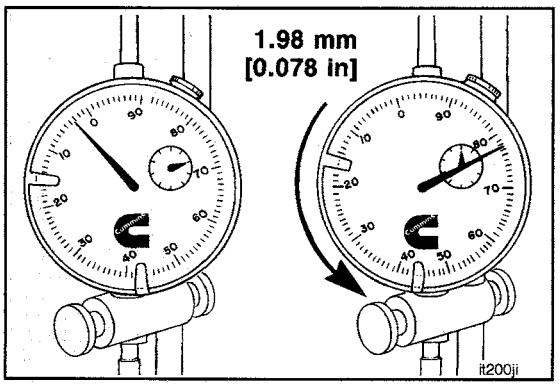


Continue to rotate the accessory driveshaft **counterclockwise** until the crankshaft is at 45-degrees before top dead center (BTDC). This step is necessary to remove gear backlash in the engine.

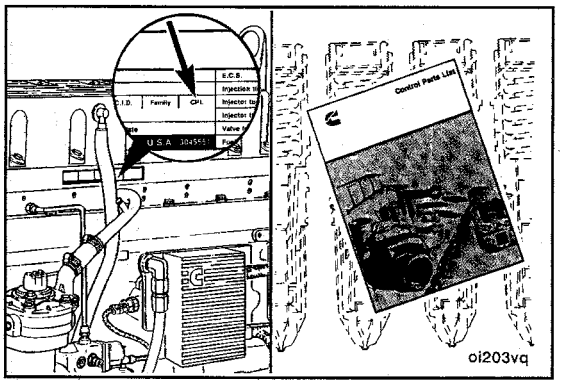


Rotate the accessory driveshaft **clockwise** slowly until the piston travel gauge is at 5.160-mm [0.2032-in] before top dead center.

If the crankshaft is rotated beyond the 5.160-mm [0.2032-in] BTDC position, the crankshaft **must** be rotated **counterclockwise** back to the 45-degrees before top dead center mark.



Read the push rod travel gauge **counterclockwise** from zero "0." This travel represents the injection timing value. In the example shown, the value is 1.98-mm [0.078-in].

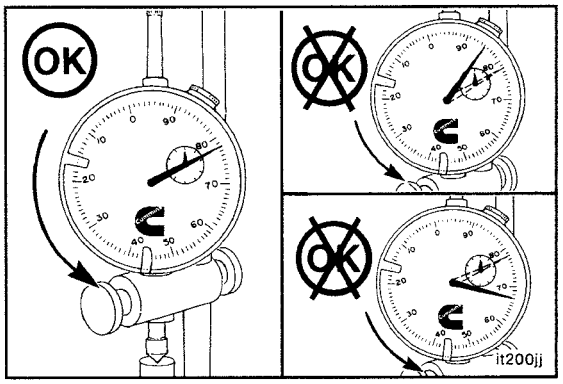


To verify the correct injection timing for a particular engine, check the Control Parts List (CPL) number on the engine dataplate, then refer to the CPL Manual, Bulletin No. 3379133. Timing codes are listed as two alphabetical characters.

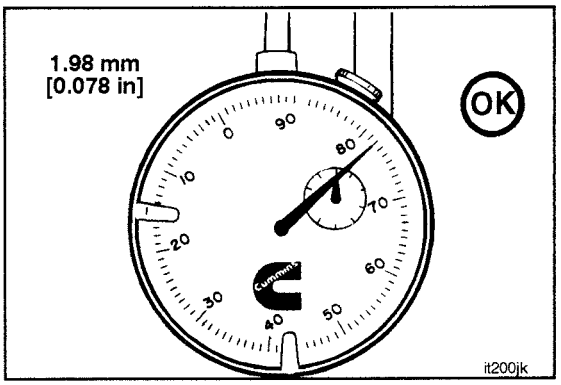
If the indicator reading is lower than the specification, the timing is advanced.

If the indicator reading is higher than the specification, the timing is retarded.

NOTE: The push rod **must** be vertically aligned with the plunger, or incorrect timing values will result. Repeat the procedure if in doubt.



Injection timing can be changed by removing the camshaft gear and installing an offset key. Refer to Procedure 001-012.



The accompanying table lists offset keys by part number and degree of offset.

Never advance injection timing beyond the specification limits. The engine's durability will be diminished.

Camshaft Keys

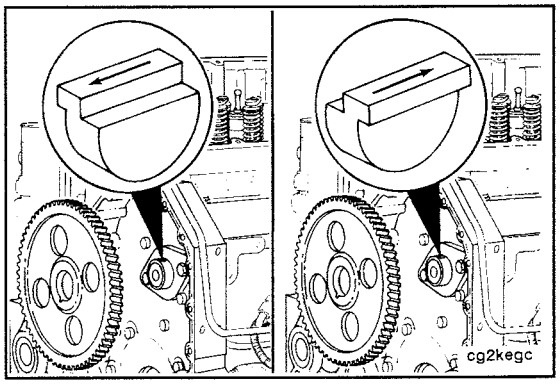
	Degree of Offset	Change in Push Rod Travel	
Key Part No.	(To the Camshaft)	mm	In.
3009953	0.00	0.000	0.0000
3030893	0.25	0.051	0.0020
3009948	0.50	0.102	0.0040
3030894	0.75	0.152	0.0060
3009949	1.00	0.203	0.0080
3030895	1.25	0.254	0.0100
3009950	1.50	0.305	0.0120
3030896	1.75	0.356	0.0140
3009951	2.00	0.406	0.0160
3030897	2.25	0.457	0.0180
3030898	2.50	0.508	0.0200

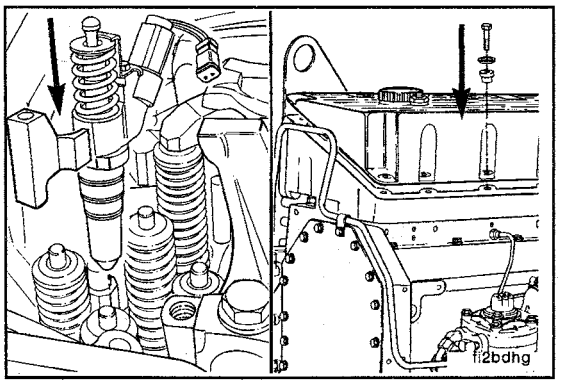
It200nb

If the arrow on the key is pointing toward the engine, the timing is retarded.

If the arrow is pointing away from the engine, the timing is advanced.

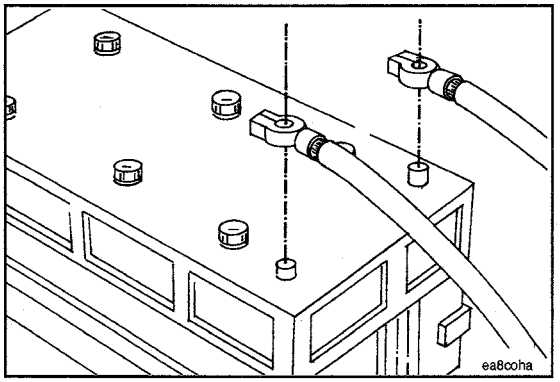
After installing a new timing key, **always** recheck the timing to be sure the timing is within the specifications.





Install the injector(s). Refer to Procedure 006-026.

Install the rocker lever cover. Refer to Procedure 003-011.



Injector (006-026)

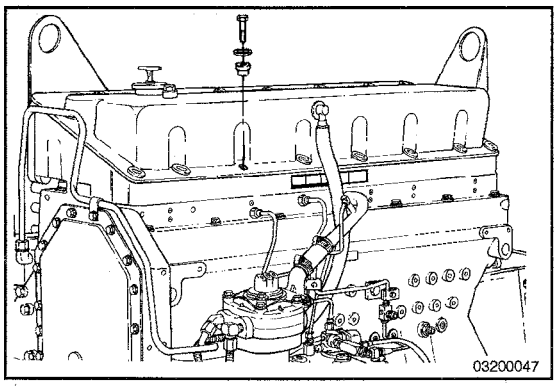
Remove (006-026-002)

ISM

⚠ WARNING ⚠

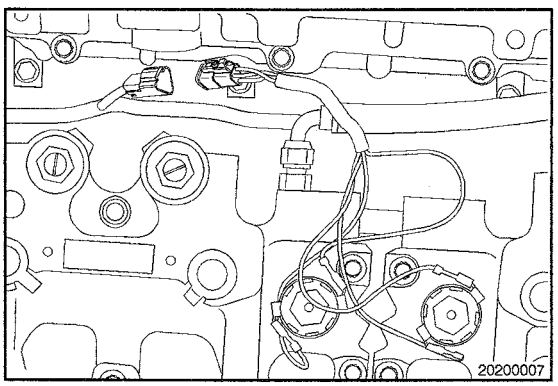
Batteries can emit explosive gases. To avoid personal injury, always ventilate the compartment before servicing the batteries. To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the battery cables before removing or installing the injectors.



Remove the air piping from the charge air cooler to the intake manifold. Remove the hose from the crankcase breather.

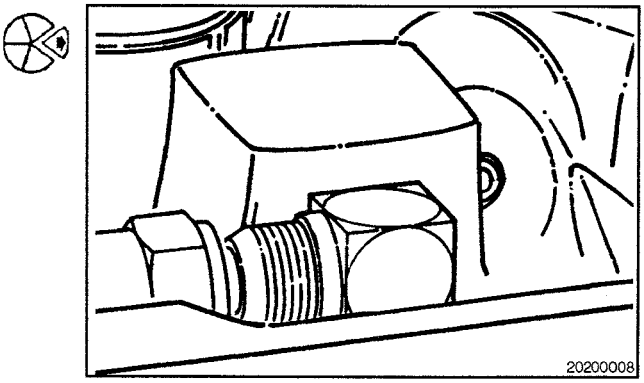
Remove the rocker lever cover. Refer to Procedure 003-011.



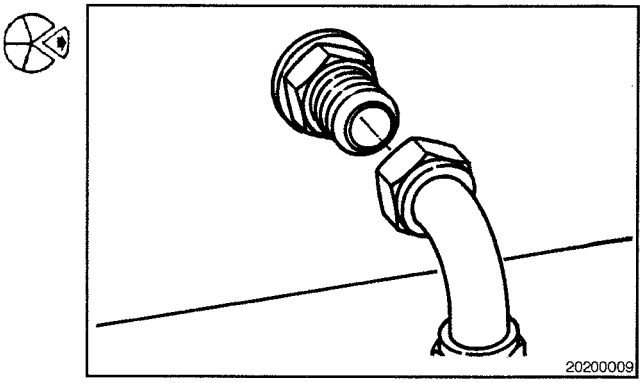
If the engine is equipped with engine brakes, the brakes **must** be removed in order to remove the injectors.

Disconnect the two electrical connections from the terminals on the inside and outside of the engine brake spacer housing.

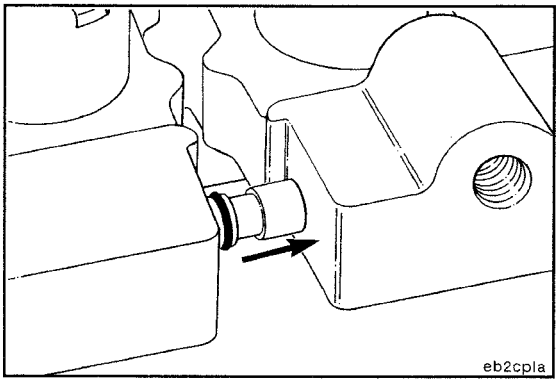
Disconnect the internal oil supply hose connection.



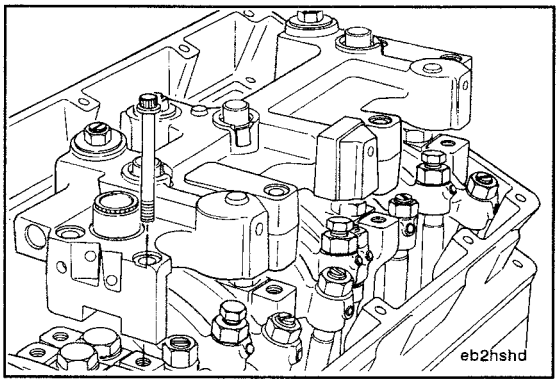
Remove the external oil supply hose.

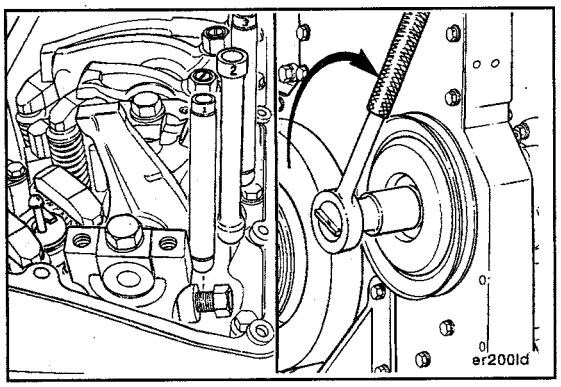


Use your fingers or a screwdriver to press the engine brake housing oil connector into the front brake housing to allow clearance for the housing removal.



Remove the 16 engine brake mounting capscrews and both engine brake housings.



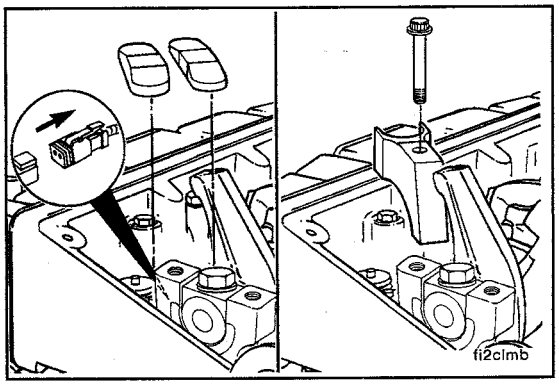


Loosen the injector and valve adjusting screws, and remove the push rods and push tubes on the cylinder requiring injector replacement.

Some push rods are under compression due to the valves being open. Rotate the crankshaft **clockwise** with the accessory drive pulley to relieve the spring tension.

Mark the position of the push rods and push tubes as they are removed. Due to wear patterns on the cam follower sockets and adjusting screws, the push rods and push tubes **must** be installed in the same position as from which they are removed.

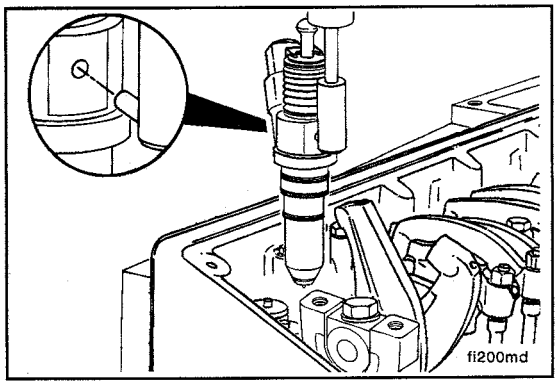
Hold the push rod with one hand to prevent it from falling into the engine. Loosen each adjusting screw, and remove the push rod.



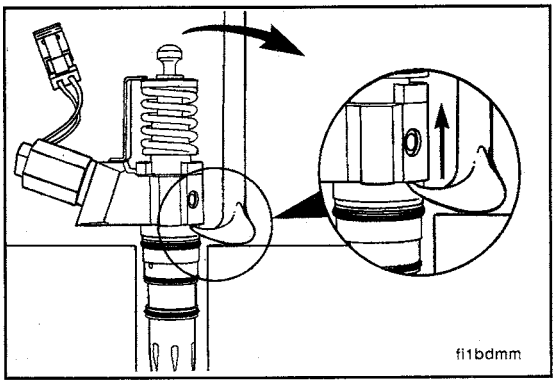
Remove the crossheads. Mark the position and orientation of the crossheads as they are removed. Due to wear patterns, they **must** be installed in the same position from which they were removed.

Disconnect the injector wires. Number the injector electrical connections as they are removed. They **must** be connected to the same cylinder when they are installed.

Remove the clamp capscrew and injector hold-down clamp.



Remove the injectors using injector tool, Part No. 3823579. Insert the pin of the tool into the hole provided in the body of the injector.



If injector puller, Part No. 3823579, is **not** available, carefully use a pry bar. Pry upward on the injector against the cylinder head.

Install (006-026-026)

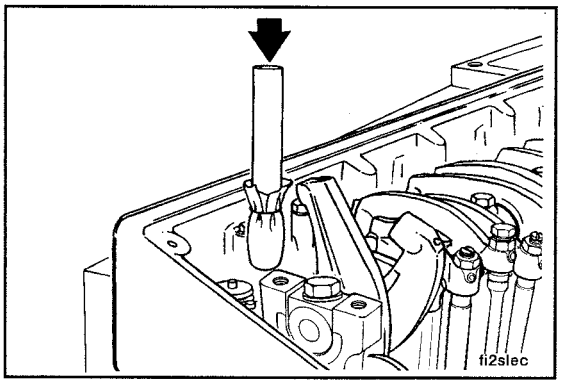
ISM

⚠ CAUTION ⚠

Do not use anything metal to scrape the copper injector sleeves.

Use a clean wooden stick with a clean cloth wrapped around the end to remove all the carbon from the copper injector sleeves in the cylinder head.

Use chip removing unit, Part No. 3823461 or ST-1272-11, to remove the carbon from the top of the piston.

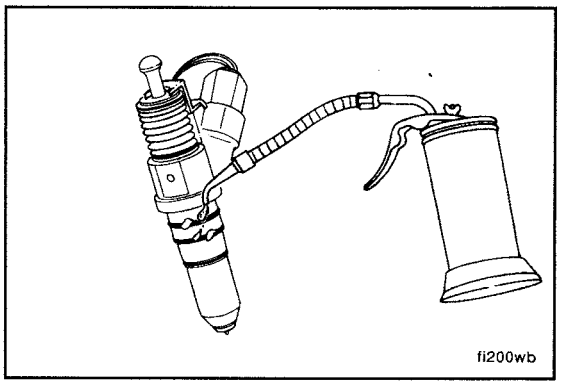


NOTE: It is important that three new o-rings be installed and oriented correctly on the injector when installing the injectors.

Install three new o-rings on each injector. Do **not** twist the o-rings.

Part No.	Location	Color Code
3070136	Top	Red
3070137	Middle	White
3070138	Bottom	Blue

Lubricate the o-rings with clean 15W-40 lubricating oil just before installation.

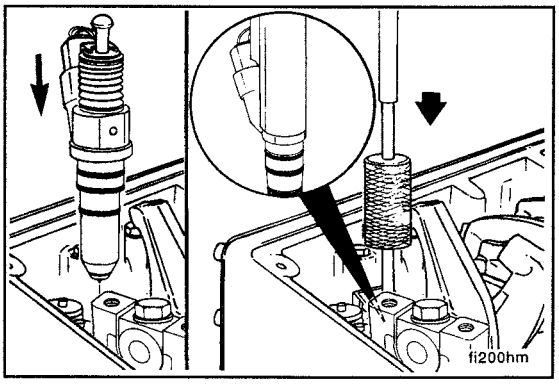


Place the injector in the cylinder head injector bore with the injector solenoid valve toward the intake port. Align the injector equally between the valve springs.

⚠ CAUTION ⚠

Do not drive the injector in by striking the solenoid valve area. This can damage the solenoid or cause the injector to be out of alignment in the bore, which will result in o-ring damage.

Use injector tool, Part No. 3823579, to seat the injector in the bore.



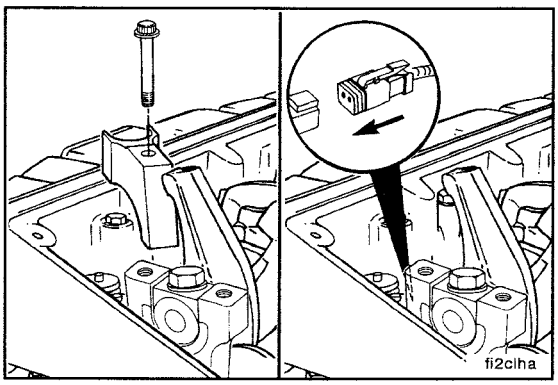
⚠ CAUTION ⚠

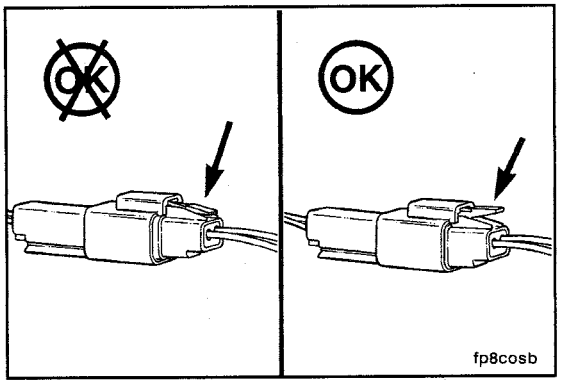
The injector must be fully seated before installing the hold-down clamp. The hold-down clamp can not pull the injector into the bore. Engine damage can occur if the injector is not fully seated.

Install the injector hold-down clamp capscrew.

Torque Value: 75 N•m [55 ft-lb]

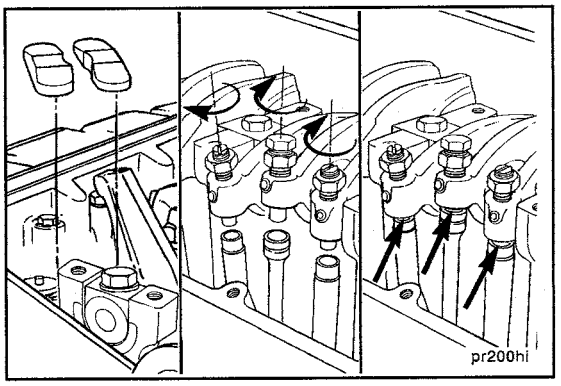
Connect the injector wires. Make sure the wires are connected to the same cylinder they were removed from.





Check the wire connector to make sure the connector is properly locked in position.

If the wire connector will **not** properly lock into position, refer to the Troubleshooting and Repair Manual, CELECT™ Plus Fuel System, ISM Engines, Bulletin No. 3666266.

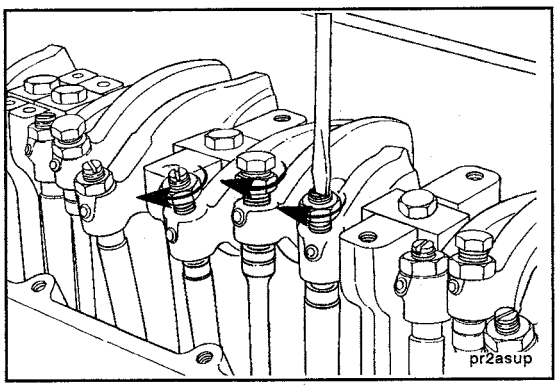


Install the crossheads on the intake and exhaust valves.

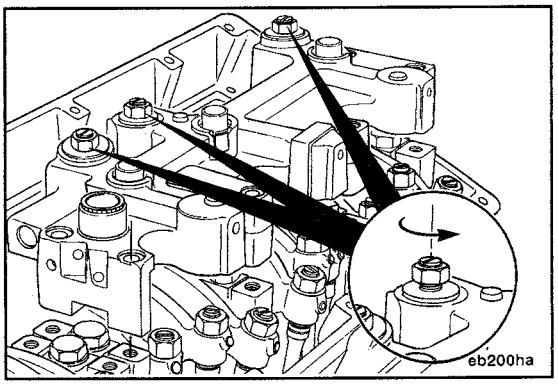
NOTE: The crossheads **must** be installed in the same position from which they were removed.

Rotate the rocker levers down, and install the push rods and push tubes.

NOTE: It is necessary to bar the engine over and install the push rods and push tubes as camshaft position allows.



Adjust the valves and injectors. Refer to Procedure 003-004.



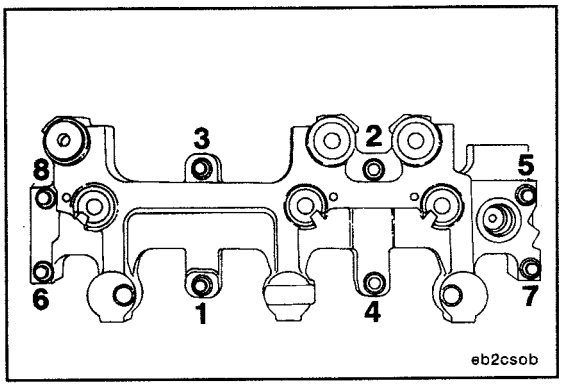
Loosen the locknuts on the engine brake slave piston. Make sure the slave pistons are fully retracted.

Install the engine brake housing on the rear rocker lever supports.

Use clean 15W-40 oil to coat the bottom side of the capscrew heads and threads.

Install the capscrews in the rocker lever supports. Tighten the capscrews in the sequence shown.

Torque Value: 81 N•m [60 ft-lb]

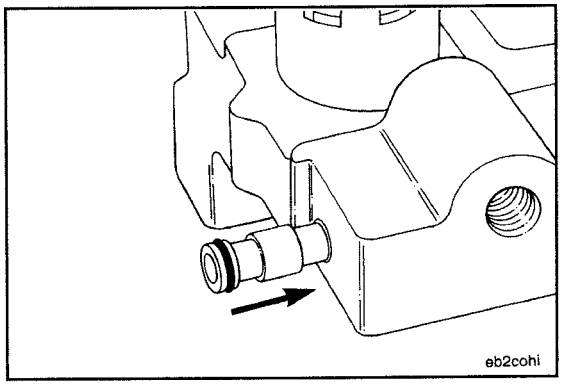


Install new o-rings on the brake oil connector.

Use clean 15W-40 oil to lubricate the o-rings on the oil connector.

Press the connector all the way into the front housing by hand.

NOTE: When installing the front housing, be sure the oil connector and o-ring are in position to be pushed into the rear housing.

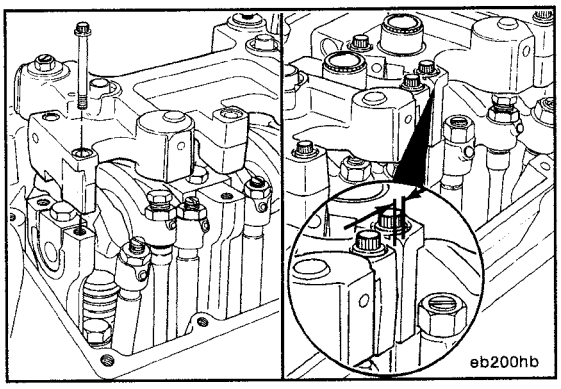


Install the front engine brake housing on the front rocker lever supports.

Center the oil connector between the front and rear housings before tightening the capscrews.

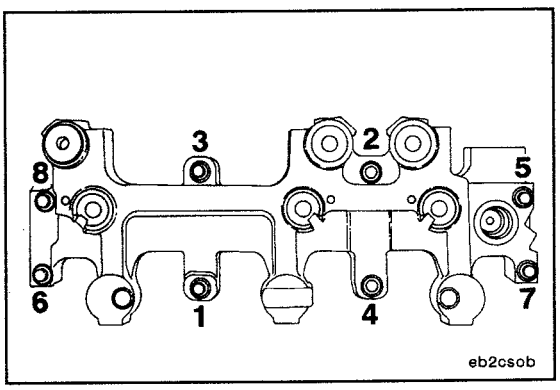
Use clean 15W-40 oil to coat the bottom side of the capscrew heads and threads.

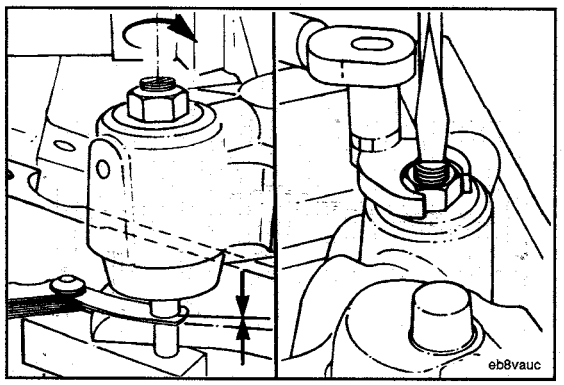
Install the capscrews in the rocker lever supports.



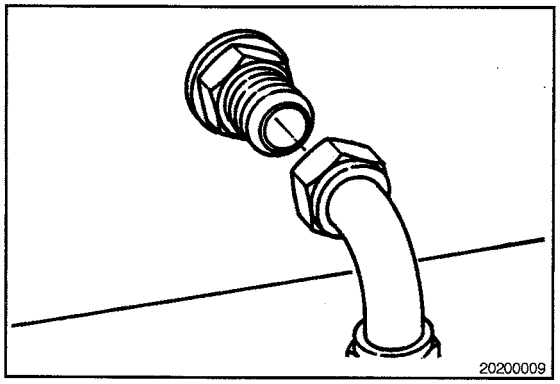
Tighten the capscrews in the sequence shown.

Torque Value: 81 N•m [60 ft-lb]

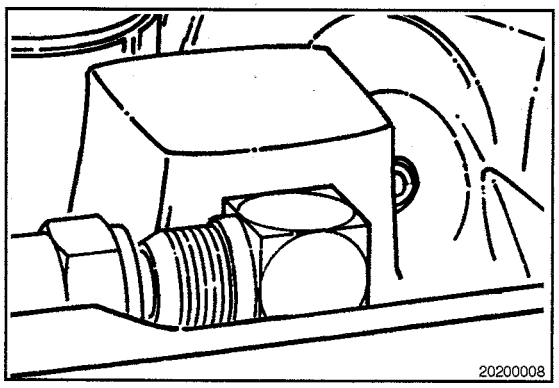




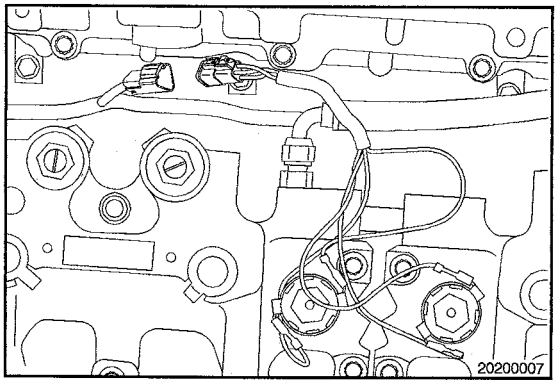
Adjust the engine brakes. Refer to Procedure 003-004.



Install and tighten the external oil supply hose fitting to the front brake housing.



Install the internal oil supply hose.



Install the engine brake terminal electrical leads on the outside of the spacer.

Connect the two solenoid electrical wires to the terminals on the inside of the spacer.

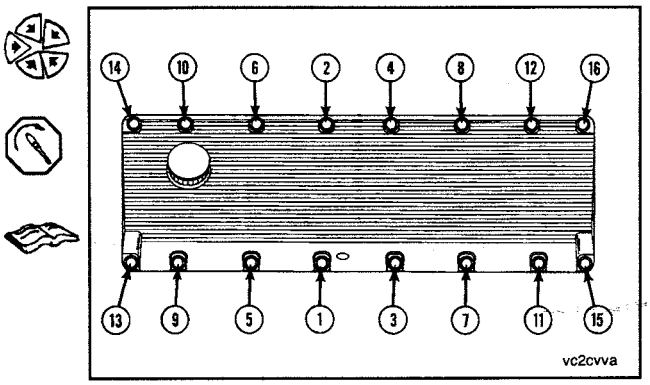
Install the rocker housing cover.

Install the 16 isolaters and capscrews. Tighten the capscrews in the sequence shown.

Torque Value: 15 N•m [130 in-lb]

Install the crankcase breather tube. Install the air piping from the charge air cooler to the intake manifold. Refer to the manufacturer's specifications for the correct hose clamp torque value.

Connect the battery cables.



NOTES

Section 7 - Lubricating Oil System - Group 07

Section Contents

Page

Centinel System (ISM Engines) 7-51
General Information 7-51
Install 7-52
Prime 7-53
Remove 7-52

Flow Diagram, Lubricating Oil System 7-4
Flow Diagram 7-4

Lubricating Oil and Filters 7-9
Inspect 7-9

Lubricating Oil Contamination 7-46
Fluorescent Dye Tracer 7-46
Fuel Pressure Test 7-48

Lubricating Oil Cooler 7-9
Clean 7-10
Install 7-12
Pressure Test 7-11
Remove 7-9

Lubricating Oil Dipstick 7-13
Calibrate 7-13

Lubricating Oil Dipstick Housing 7-14
Clean 7-15
Inspect for Reuse 7-15
Install 7-15
Remove 7-14

Lubricating Oil Filter (Canister-Type) 7-15
Leak Test 7-15

Lubricating Oil Filter Head 7-18
Clean 7-19
Disassemble 7-18
Inspect for Reuse 7-19
Install 7-20
Remove 7-18

Lubricating Oil Filter (Spin-On) 7-16
General Information 7-16
Install 7-17
Remove 7-16

Lubricating Oil High Pressure Relief Valve 7-21
Initial Check 7-21
Inspect for Reuse 7-22
Install 7-22
Remove 7-21

Lubricating Oil Leaks 7-23
Maintenance Check 7-23

Lubricating Oil Pan 7-25
Clean 7-26
Drain 7-25
Fill 7-29
Inspect for Reuse 7-27
Install 7-27
Front Sump Pan 7-27
Rear Sump Pan 7-29
Remove 7-25
Front Sump Pan 7-25
Rear Sump Pan 7-26

Lubricating Oil Pressure Gauge 7-31
Test 7-31

Page

Lubricating Oil Pressure Regulator (Main Rifle) 7-31
Inspect for Reuse 7-32
Install 7-33
Remove 7-31

Lubricating Oil Pump 7-34
Inspect for Reuse 7-35
Install 7-36
Remove 7-34

Lubricating Oil System 7-38
Prime 7-38

Lubricating Oil System - General Information 7-1
General Information 7-1

Lubricating Oil Temperature Gauge 7-39
Test 7-39

Lubricating Oil Thermostat 7-39
Inspect for Reuse 7-40
Install 7-40
Remove 7-39

Lubricating Oil Transfer Tube 7-41
Clean 7-41
Inspect for Reuse 7-42
Install 7-42
Remove 7-41

Lubricating Oil Viscosity Sensor 7-44
Inspect for Reuse 7-45
Install 7-45
Remove 7-44

Service Tools 7-7
Lubricating Oil System 7-7

Specifications 7-6
Lubricating Oil System 7-6

Lubricating Oil System - General Information

General Information

The use of quality engine lubricating oils, combined with appropriate oil drain and filter change intervals, is a critical factor in maintaining engine performance and durability.

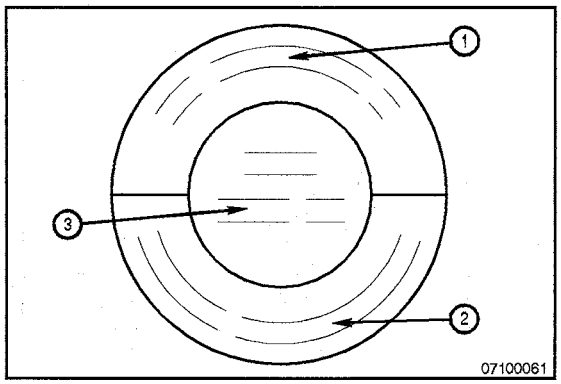
Cummins Engine Company, Inc. recommends the use of a high quality 15W-40 multiviscosity heavy-duty engine oil that meets the requirements of Cummins Engineering Specification CES 20071 or CES 20076 (such as Valvoline Premium Blue or Premium Blue 2000). American Petroleum Institute (API) specification CH-4 can be used as an alternative to CES 20071. Oils that meet API specification CG-4 can be used, but at a reduced drain interval according to the Oil Drain Intervals by Severity of Service mi [km] chart listed in the ISM Auto/Transit Bus Operation and Maintenance Manual, Bulletin 3666319. The oil grades CC, CD, CE, or CF has been obsoleted by API and should **not** be used.

Shortened drain intervals may be required with monograde oils as determined by close monitoring of the oil condition with scheduled oil sampling. Use of single-grade oils may affect engine oil control.

Synthetic engine oils, API category III, are recommended for use in Cummins engines operating in ambient temperature conditions consistently below -25°C[-13°F]. Above this temperature it is recommended the petroleum based multigrade lubricants be used. Synthetic 0W-30 oils that meet API category III can be used in operations where the ambient temperature never exceeds 0°C[32°F]. 0W-30 oils do **not** offer the same level of protection against fuel dilution as do higher multigrade oils. Higher cylinder wear may be experienced when using 0W-30 oils in high-load situations.

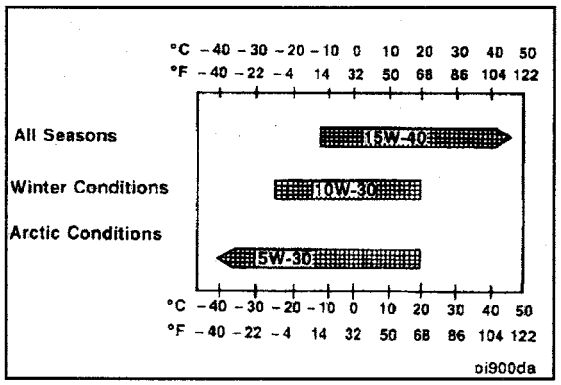
For further details and an explanation of engine lubricating oils for Cummins engines, refer to Cummins Engine Oil Recommendations, Bulletin No. 3810340.

Additional information regarding lubricating oil availability throughout the world is available in the Engine Manufacturing Association (EMA) Lubricating Oils Data Book for Heavy Duty Automotive and Industrial Engines. The data book can be ordered from: Engine Manufacturers Association, One Illinois Center, 111 East Wacker Drive, Chicago, IL, U.S.A. 60601; (312) 644-6610.



The API service symbols are shown in the accompanying illustration.

1. The upper half of the symbols displays the appropriate oil categories.
2. The lower half contains words to describe oil energy-conserving features.
3. The center section identifies the SAE oil viscosity grade.



Oil viscosity should be chosen according to the typical climate conditions experienced by the user. Use of 15W-40 is recommended for the best engine durability at higher ambient temperature. For cold temperature conditions, 10W-30 or 5W-30 viscosity can be used for easier starting, improved oil flow, and improved fuel economy.

New Engine Break-in Oil

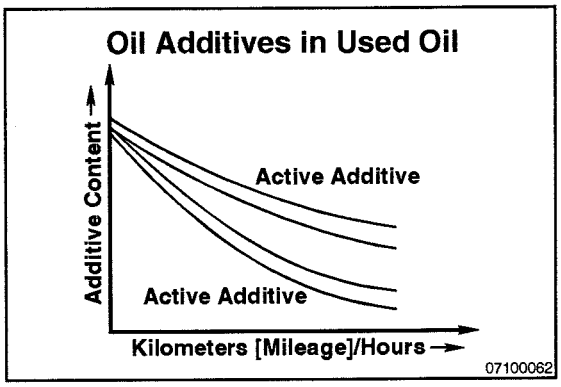
Special "break-in" engine lubricating oils are **not** recommended for new or rebuilt Cummins engines. In general, use the same oil during break-in as that used in normal operation. Synthetic or partially synthetic engine lubricating oils, however, can **not** be used during break-in of a new or rebuilt engine. To make sure the piston rings seat properly, use a high quality petroleum-based engine lubricating oil during the first engine oil drain period.

Oil Drain Interval

As the engine oil becomes contaminated, essential oil additives are depleted. Lubricating oils protect the engine as long as these additives are functioning properly. Progressive contamination of the oil between oil and filter change intervals is normal. The amount of contamination will vary depending on the operation of the engine, kilometers or miles on the oil, fuel consumed, and new oil added.

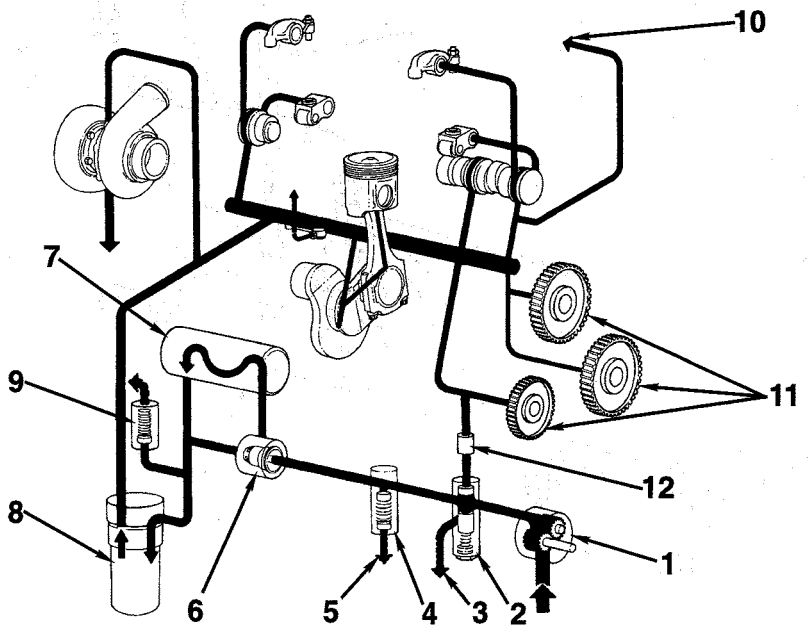
Extending oil and filter change intervals beyond the recommendations will decrease engine life due to factors such as corrosion, deposits, and wear.

Refer to the oil drain chart in this section to determine which oil drain interval to use for your application.



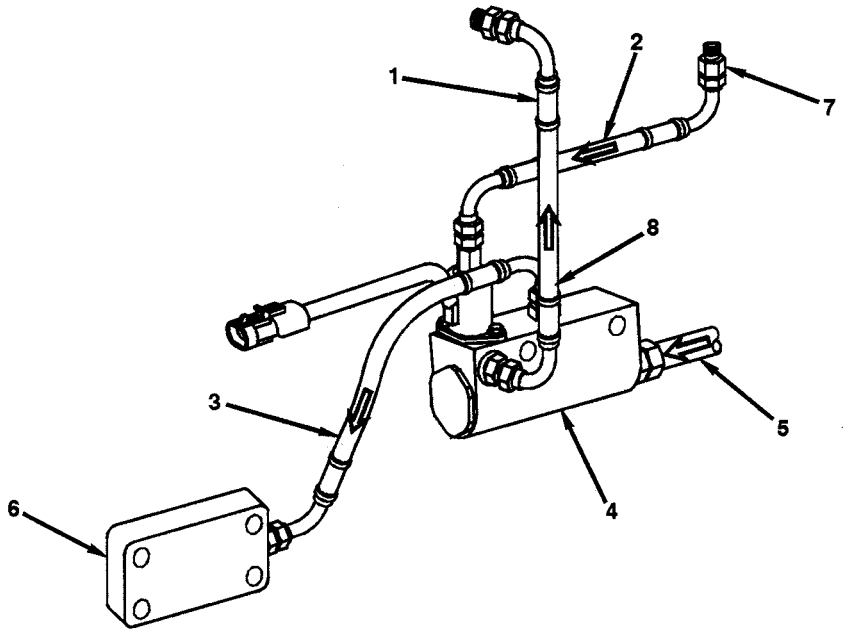
Flow Diagram, Lubricating Oil System

Flow Diagram



1. Oil Pump
2. Pressure Regulator Valve
3. Oil Return to Pan
4. High Pressure Relief Valve
5. Oil Return to Pan
6. Oil Thermostat
7. Oil Cooler
8. Combination Oil Filter
9. Filter Bypass Valve
10. Accessory Drive/Air Compressor
11. Idler Gears
12. Viscosity Sensor.

Centinel™ (optional)



07200066

1. Oil Drain Hose to Fuel
2. Oil Rifle Hose
3. Oil Replenishment Hose
4. Control Valve
5. OEM Fresh Oil Supply (from makeup tank)
6. New Oil into Pan (cover)
7. Rifle check valve
8. Outlet check valve.

Specifications

Lubricating Oil System

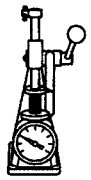
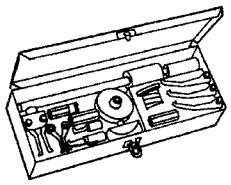
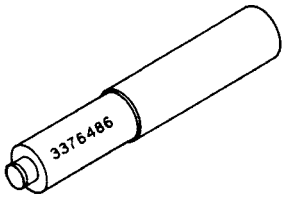
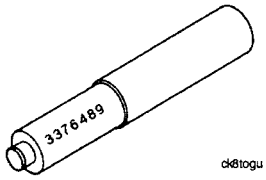
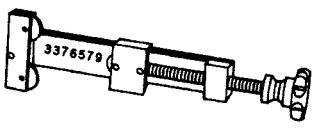
Oil Pressure:
- Low Idle (minimum allowable) ..... 70 kPa [10 psi]
- At 1200 rpm or Torque Peak (minimum allowable) ..... 207 kPa [30 psi]

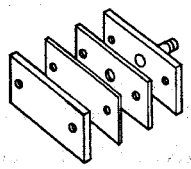
Oil Capacity of Standard Engine:
- Combination Filter:
  - LF9000 ..... 3.0 liters [0.8 gal]
  - LF9001 ..... 2.6 liters [0.7 gal]
- Oil Pan (high-low) ..... 34 to 26.5 liters [9 to 7 gal]
  - Transit Bus Oil Pan (high-low) ..... 34 to 30.3 liters [9 to 8 gal]

Service Tools

Lubricating Oil System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3397929	**Oil Filter Wrench** Used to remove and install the lubricating oil filters.	
3375182	**Spring Compression Tester** Measures spring force at a given spring height.	 kn8togs
3375784	**Light-Duty Puller Kit** Used to remove the high oil pressure regulator retainer plug.	 ck8togl
3376486	**Regulator Valve Seat Driver** Used to install the high oil pressure seat in the cylinder block.	
3376489	**Retainer Plug Driver** Used to install the high oil pressure regulator retainer plug in the cylinder block.	 ck8togu
3376579	**Tube Cutter** Used to open the oil filter for filter element inspection.	 lf8togd

Tool No.	Tool Description	Tool Illustration
3376861	**Lubricating Oil Cooler Pressure Test Kit** Used to pressure-test the lubricating oil cooler element. The test kit consists of two gaskets, Part No. 3376866, plates, Part No. 3376890, and Part No. 3376889.	 lc2tqga

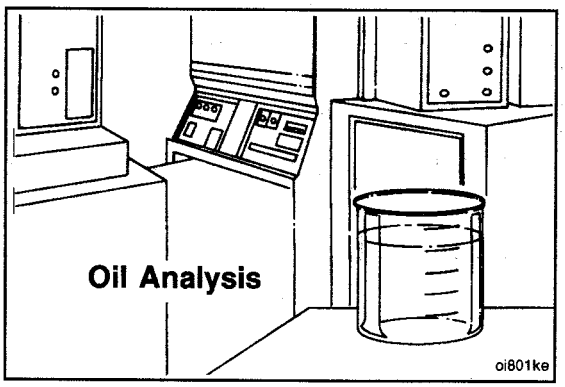
Lubricating Oil and Filters (007-002)

Inspect (007-002-062)

Analysis

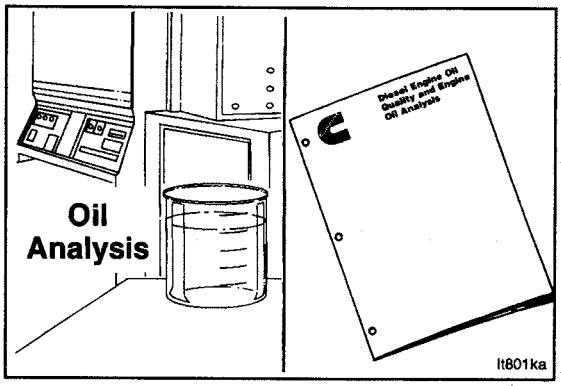
A used oil analysis can help diagnose internal damage and determine the cause, such as:

- Intake air filter malfunction
- Coolant leaks
- Oil diluted with fuel
- Metal particles causing wear.



For additional oil analysis information, refer to Diesel Engine Oil Quality and Engine Oil Analysis, Bulletin No. 3810232.

NOTE: Do **not** disassemble an engine for repair based **only** on the results of an oil analysis. Inspect the oil filters, also. If the oil filter shows evidence of internal damage, find the source of the problem and repair the damage. Refer to the appropriate section(s) based on the following oil filter inspection.

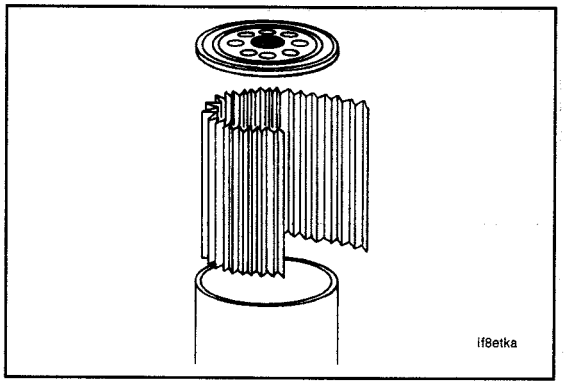


Oil Filter

Use tube cutter, Part No. 3376579, to open the combination oil filter.

Inspect the filter element for evidence of moisture or metal particles.

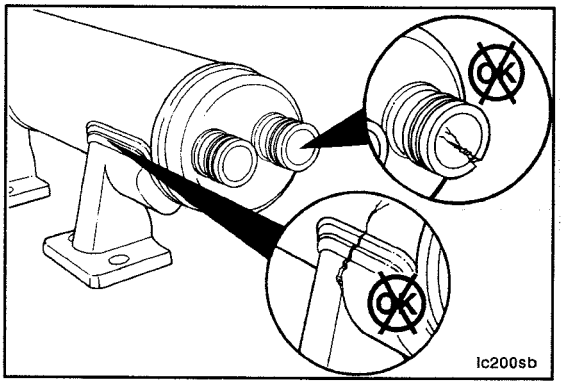
Metal	Possible Source
Copper	Bearings and Bushings
Chromium	Piston Rings
Iron	Cylinder Liners, Overhead Components
Lead	Bearing Overlay Material
Aluminum	Piston Wear or Scuffing

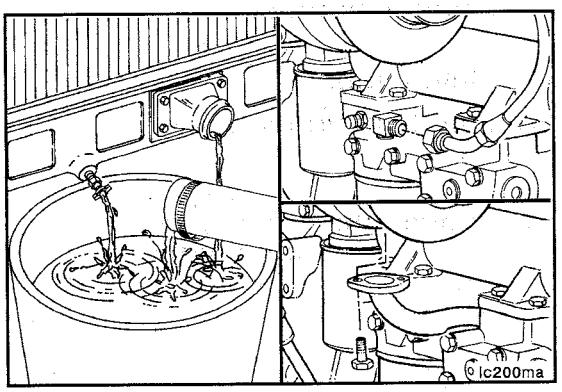


Lubricating Oil Cooler (007-003)

Remove (007-003-002)

NOTE: Do **not** attempt to repair a defective oil cooler. A defective oil cooler **must** be replaced.



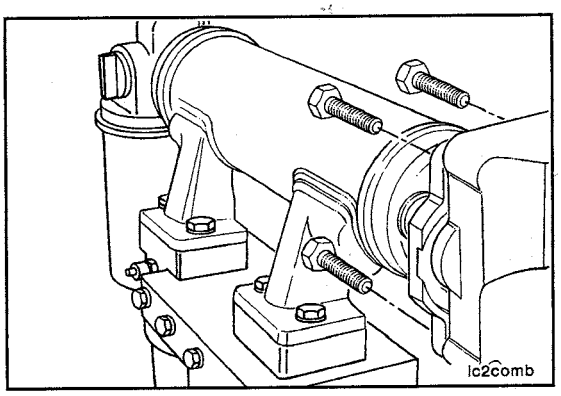


Some applications can require turbocharger removal. Refer to Procedure 010-033.

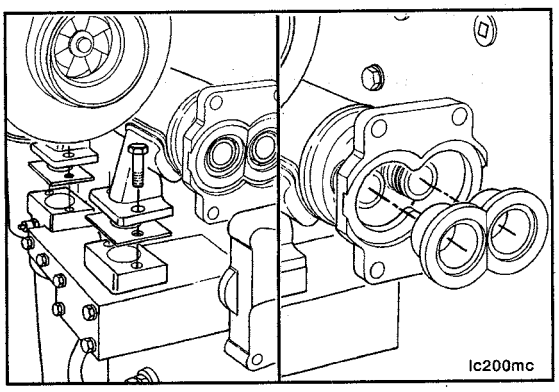
Drain the cooling system. Refer to Procedure 008-018.

Remove the turbocharger oil supply line from the lubricating oil filter head.

Remove the turbocharger drain line from the turbocharger. Remove the support bracket capscrew.

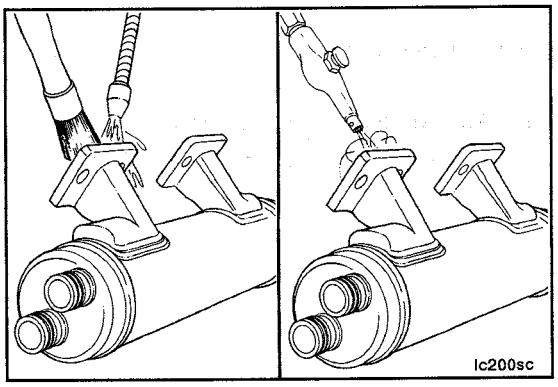


Remove the four oil cooler thermostat housing flange capscrews.



Remove the four oil cooler mounting capscrews, oil cooler, and gaskets.

Remove the oil cooler water inlet and outlet tubes and the mounting flange.



Clean (007-003-006)

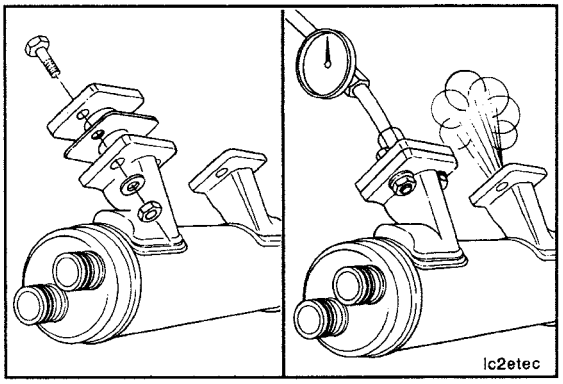
NOTE: Do **not** allow dirt to enter the oil passages when cleaning the oil cooler.

Use solvent to clean the oil cooler. Dry with compressed air.

Use lubricating oil cooler pressure test kit, Part No. 3376861, to seal the oil passages.

Install pressure test plate, Part No. 3376889, on one of the two oil passage openings.

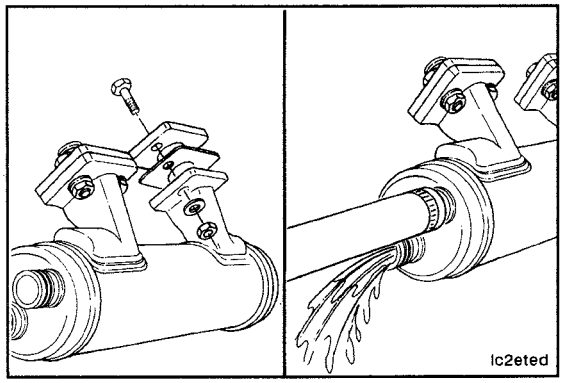
Attach an air pressure line to the test plate, and blow the oil from inside the oil passages.



Install the other pressure test plate to seal the oil passage openings.

NOTE: Both oil passage openings **must** be sealed before cleaning the water core of the oil cooler.

Use a water system cleaner, attached to the water outlet side of the housing, to clean the water core.

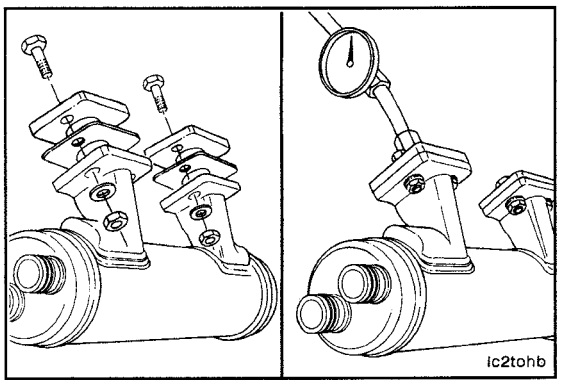


Pressure Test (007-003-013)

Install the two test plates and gaskets from lubricating oil cooler pressure test kit, Part No. 3376861, to the oil passage openings of the oil cooler housing.

Install a regulated air pressure line to test plate, Part No. 3376889, and apply air pressure.

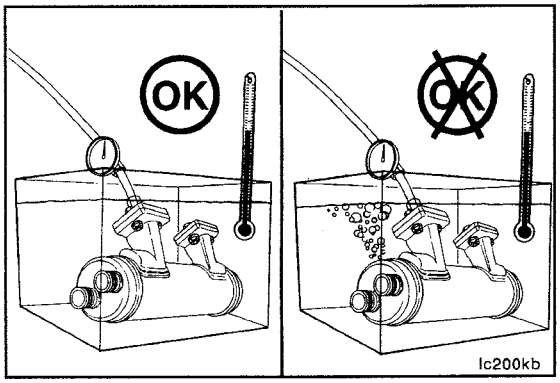
Air Pressure: 414 kPa [60 psi]

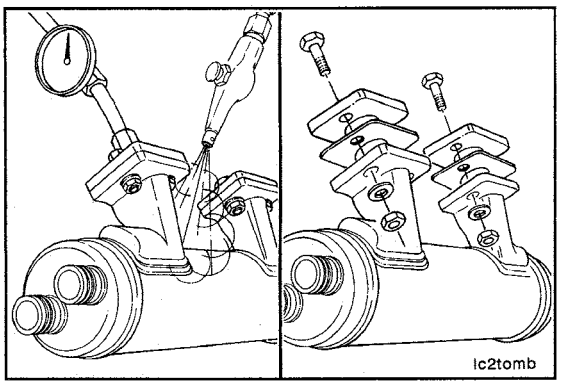


Install the oil cooler in a tank of heated water and inspect for leaks.

Temperature: 82 °C [180 °F]

If leaks are found, the oil cooler **must** be replaced.

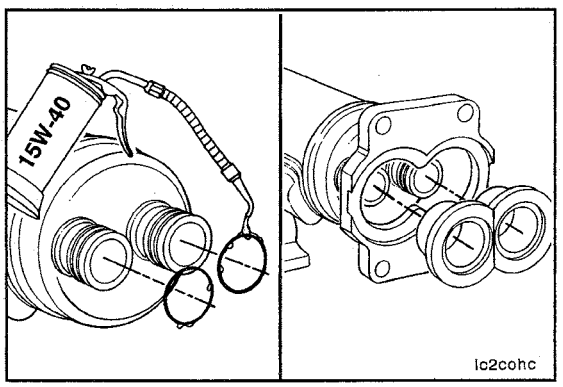




Remove the oil cooler from the water tank.

Dry the oil cooler with compressed air.

Remove the pressure test equipment.

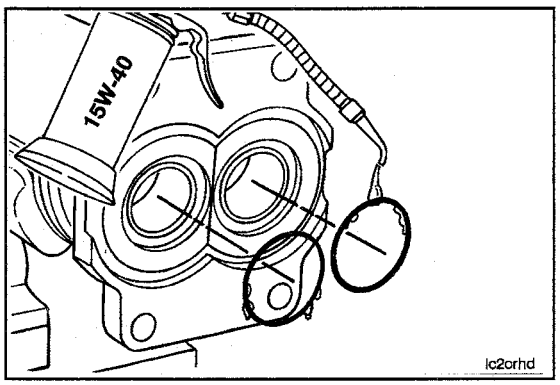


Install (007-003-026)

Install two new o-rings on the oil cooler water inlet and outlet transfer tubes.

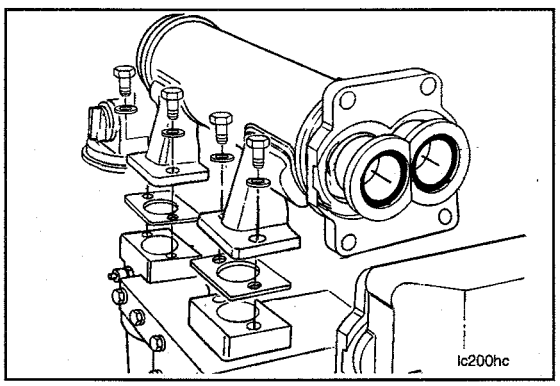
Lubricate the o-rings with clean 15W-40 engine oil.

While holding the mounting flange in place, install both transfer tubes into the oil cooler as far as possible. The straight sides of the transfer tube flanges **must** face each other when installed.



Install two new o-rings on the ends of the oil cooler water transfer tubes.

Lubricate the o-rings with clean 15W-40 engine oil.



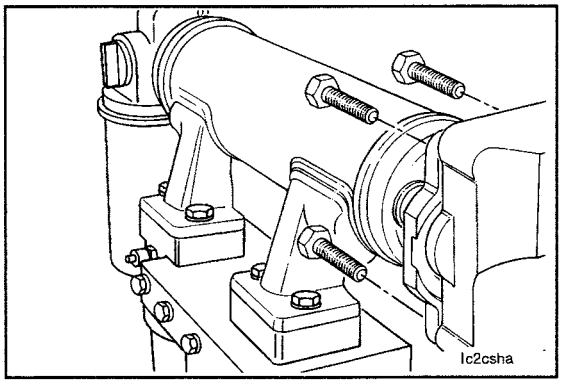
Install two new gaskets on the lubricating oil filter head.

Install the oil cooler on the engine, and tighten the mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]

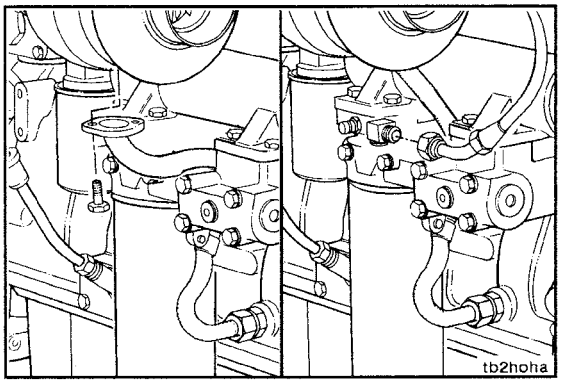
Install the four oil cooler thermostat mounting flange capscrews. Tighten the capscrews alternately and evenly.

Torque Value: 47 N•m [35 ft-lb]



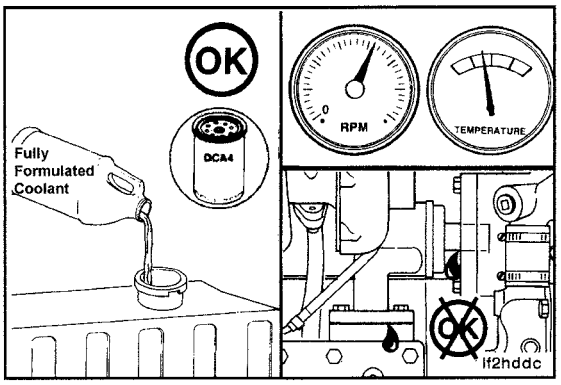
Install the turbocharger drain line and support bracket.

Install the turbocharger oil supply line to the lubricating oil filter head.



Fill the cooling system. Refer to Procedure 008-018.

Operate the engine to normal operating temperature and check for oil and coolant leaks.



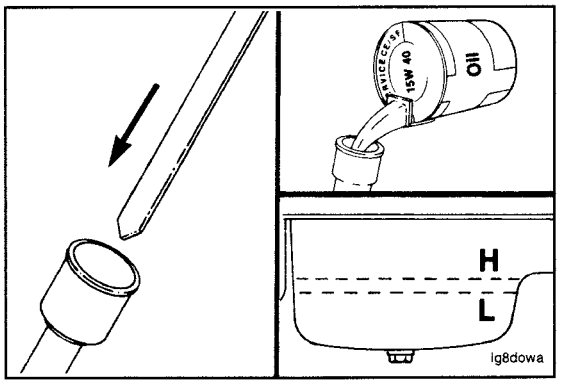
Lubricating Oil Dipstick (007-009)

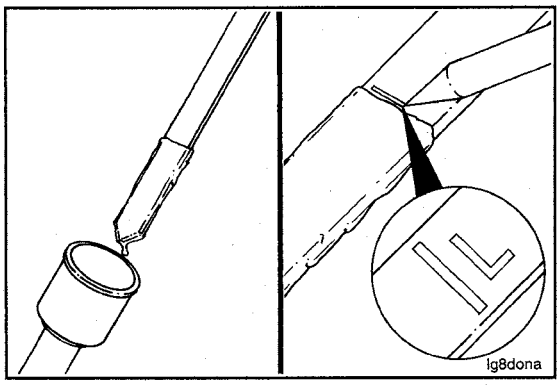
Calibrate (007-009-030)

NOTE: This procedure **must** begin with the oil pan drained.

Install the dipstick in the dipstick tube housing.

Use the correct volume of clean 15W-40 oil to fill the oil pan to the specified "low" oil level. Refer to Lubricating Oil System - Specifications in this section for the correct engine oil capacity for your application.



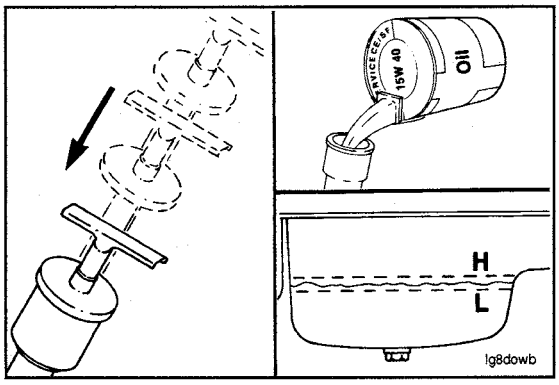


⚠ CAUTION ⚠

Use care when marking the dipstick, or the dipstick will break if the scribe mark is too deep.

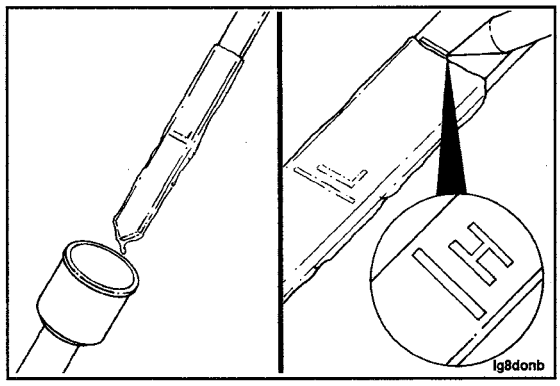
Remove the dipstick and scribe a mark across the stick at the oil level. Label the mark with an "L" to indicate the "low" oil level.

If a new blank dipstick is being used, cut the dipstick off approximately 38 mm [1.5 in] below the "low" oil level mark.

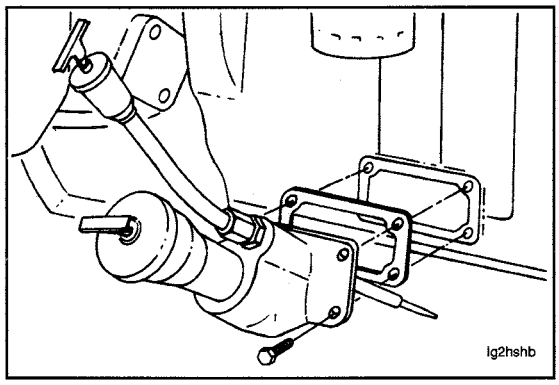


Wipe off the dipstick, and install it in the dipstick tube housing.

Use the correct volume of oil to fill the oil pan to the specified "high" oil level. Refer to Lubricating Oil System Specifications in this section for engine oil capacity.



Remove the dipstick, and scribe a mark across the stick at the oil level. Label the mark with an "H" to indicate the "high" oil level.



Lubricating Oil Dipstick Housing (007-010)

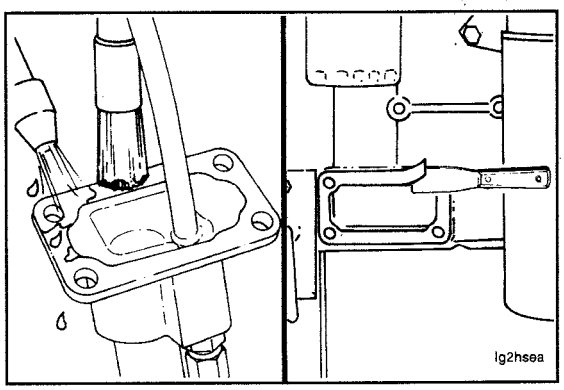
Remove (007-010-002)

Remove the four capscrews and the housing.

Clean (007-010-006)

Clean the housing gasket surface.

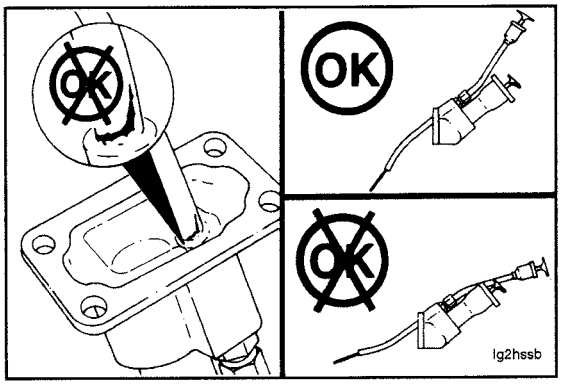
Clean the cylinder block gasket surface.



Inspect for Reuse (007-010-007)

Inspect the dipstick guide tube.

If the guide tube is cracked, missing, or **not** angled downward into the oil pan, replace the dipstick tube housing.



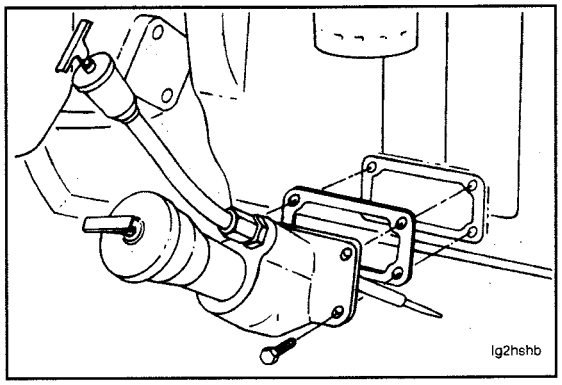
Install (007-010-026)

Install a new gasket and the dipstick tube housing.

Install the four capscrews.

Torque Value: 47 N•m [35 ft-lb]

Check the dipstick calibration. Refer to Procedure 007-009.

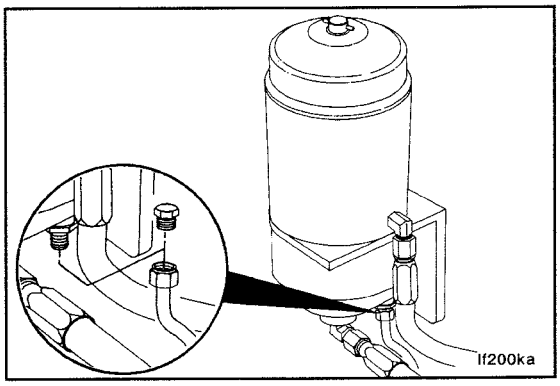


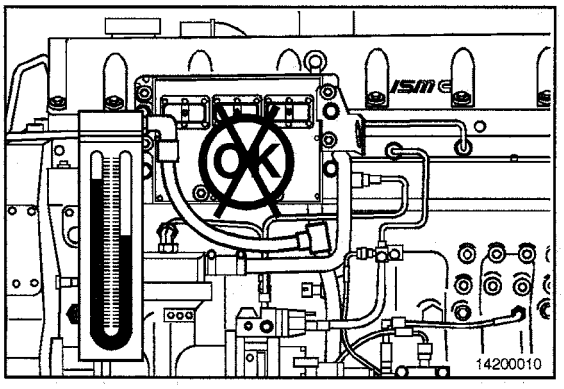
Lubricating Oil Filter (Canister-Type) (007-012)

Leak Test (007-012-014)

This procedure outlines the steps to isolate a centrifugal bypass filter when checking possible causes of high engine crankcase blowby.

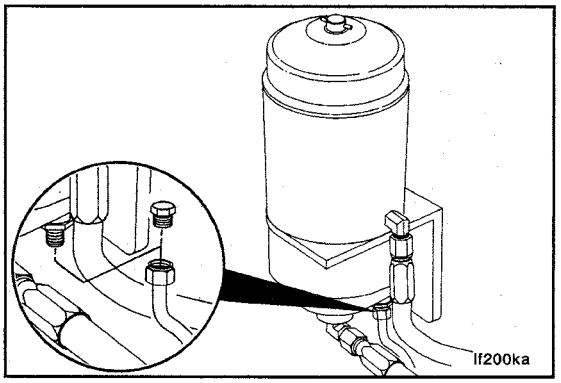
Disconnect the air supply line from the centrifugal bypass filter assembly. Cap the end of the air supply line to prevent system air loss during test.





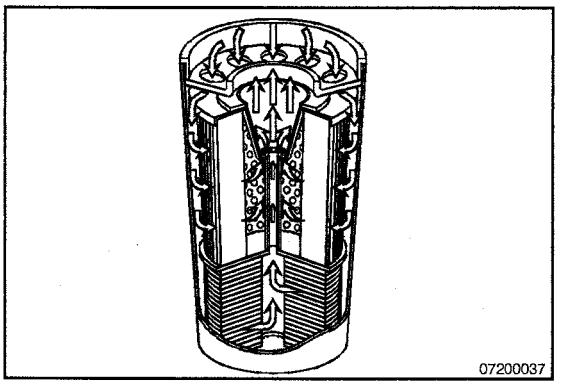
Operate the engine and check the engine blowby. Refer to Section 14.

If the blowby falls within the correct specifications, repair the centrifugal filter. Refer to the manufacturer's guidelines for the correct procedure.



Remove the cap from the air supply line.

Connect the air supply line to the centrifugal bypass filter assembly.

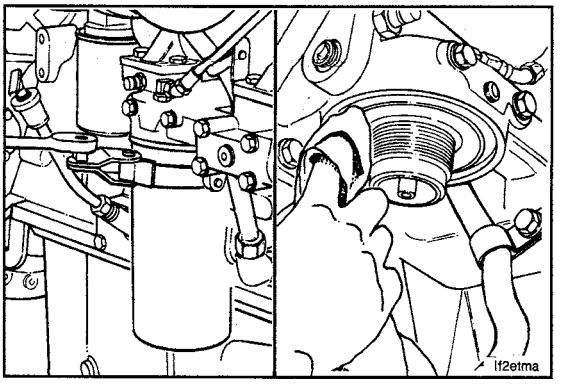


Lubricating Oil Filter (Spin-On) (007-013)

General Information

A combination oil filter is present on the engine. The upper portion of the combination filter contains the full-flow filter element while the lower portion contains the bypass filter element.

Oil circulates through the full flow and bypass portions of the filter, into the filter head, and is directed to the engine's main oil rifle.



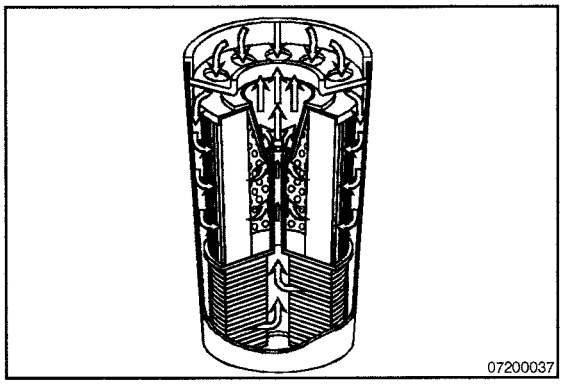
Remove (007-013-002)

Clean the area around the lubricating oil filter head.

Use oil filter wrench, Part No. 3375049, to remove the filter.

Clean the gasket surface of the filter head. The o-ring can stick on the filter head. Make sure it is removed.

Install (007-013-026)



⚠ CAUTION ⚠

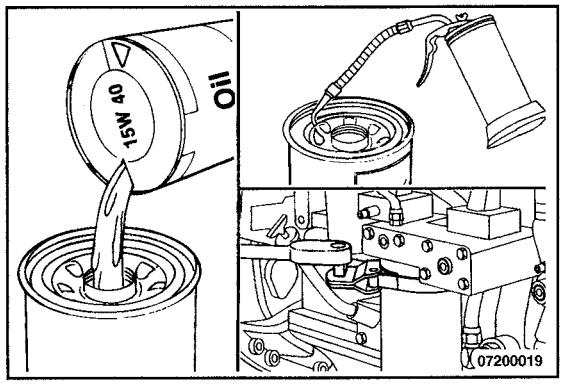
Do not replace LF9001 lubricating filter with extended length LF9000 lubricating filter without verifying adequate clearance with suspension and/or chassis at extremes of travel. The engine can be damaged.

Use the correct oil filter for your engine. Cummins Engine Company, Inc. requires a lubricating oil filter(s) be used that meets the specifications given in Cummins SAM 10,765.

Combination lubricating Filter

Cummins Part No. 3406810 or Fleetguard® Part No. LF9000.

Cummins Part No. 3406809 or Fleetguard® Part No. LF9001.



⚠ CAUTION ⚠

The lack of lubrication during the delay until the filter is pumped full of oil at start-up is harmful to the engine.

Fill the filter with clean oil. Choose the correct oil for your operating climate as outlined in Section V of the ISM Operation and Maintenance manual, ISM Series Engines Automotive/Transit Buses, bulletin 3666319. The LF9001 filter capacity is 2.6 liters [0.7 gal]. The LF9000 filter capacity is 3.0 liters [0.8 gal]. Apply a light film of oil to the gasket sealing surface before installing the new filter.

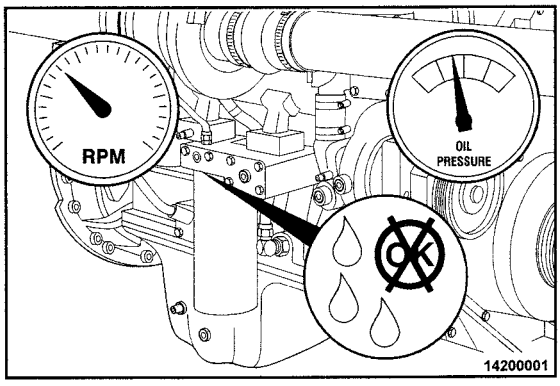
⚠ CAUTION ⚠

Mechanical overtightening of the filter can distort the threads or damage the filter element seal.

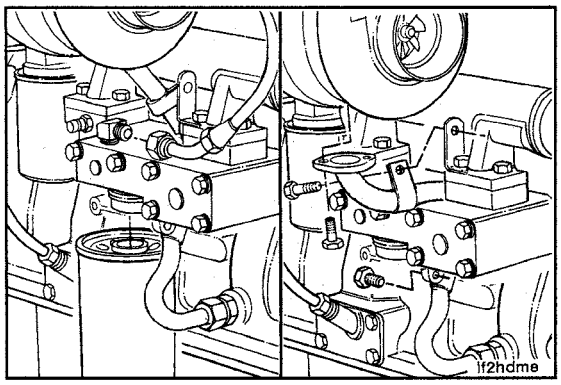
Install the filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

Use oil filter wrench, Part No. 3375049, to tighten the filter to the specifications supplied with the filter.

Operate the engine at idle speed for 3 minutes to inspect for leaks at the filter(s).



NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.



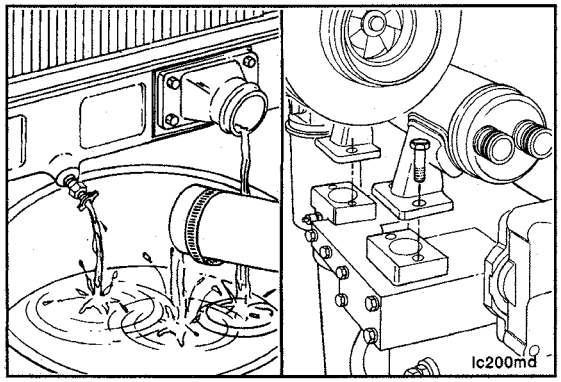
Lubricating Oil Filter Head (007-015)

Remove (007-015-002)

Remove the oil filter. Refer to Procedure 007-013.

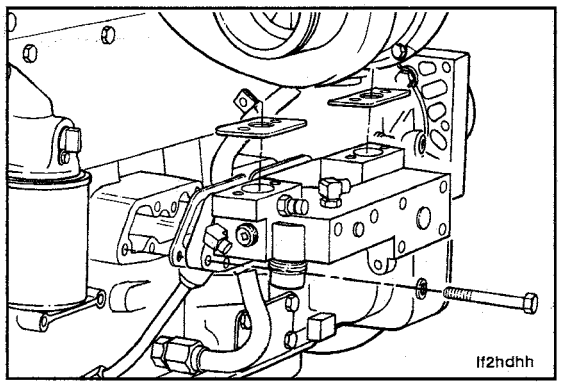
Remove the turbocharger oil supply line from the oil filter head.

Remove the turbocharger oil drain line from the turbocharger. Remove the two support brackets from the filter head.



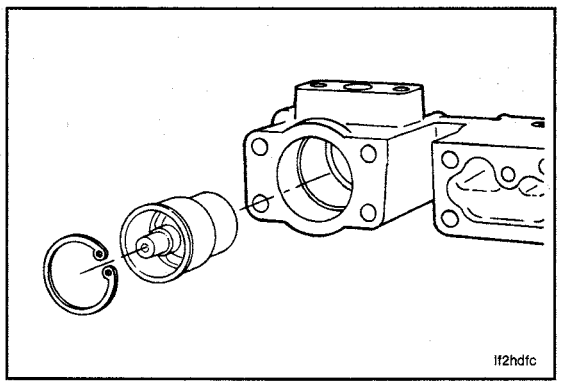
Drain the cooling system. Refer to Procedure 008-018.

Remove the lubricating oil cooler. Refer to Procedure 007-003.



Remove the nine filter head capscrews and the filter head.

Remove the gaskets.



Disassemble (007-015-003)

Use snap ring pliers to remove the snap ring in the thermostat bore.

Remove the lubricating oil thermostat.

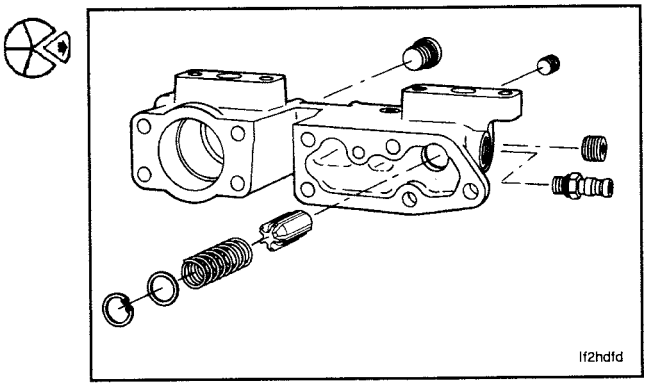
⚠ WARNING ⚠

To avoid personal injury, use care while removing the bypass valve. The valve spring is under compression. Wear face and eye protection.

Remove the snap ring from the bypass valve bore.

Remove the washer, spring, and bypass valve.

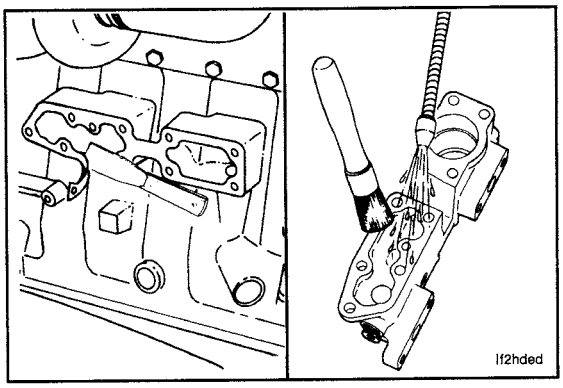
Remove the remaining plugs and fittings from the filter head.



Clean (007-015-006)

Clean the filter head and cylinder block gasket surfaces.

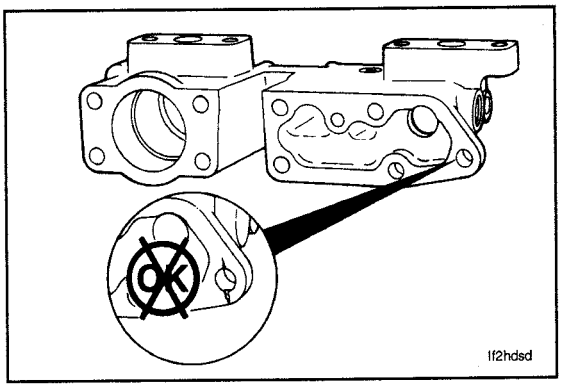
Use solvent to clean the filter head. Dry with compressed air.



Inspect for Reuse (007-015-007)

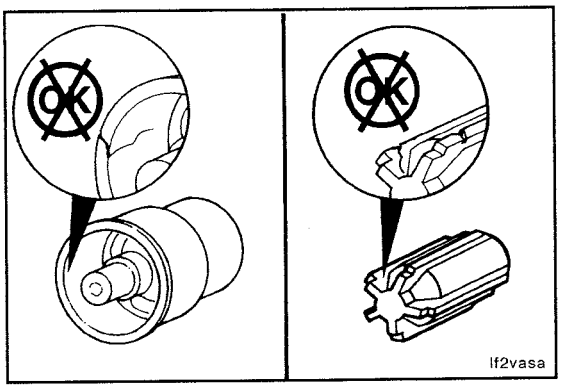
Inspect for cracks or other damage.

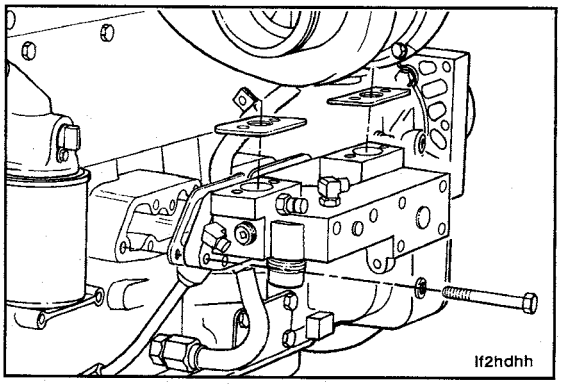
Inspect the lubricating oil thermostat. Refer to Procedure 007-039.



Inspect the thermostat and bypass valve for cracks or other damage.

If the bypass valve or thermostat are damaged, they **must** be replaced.



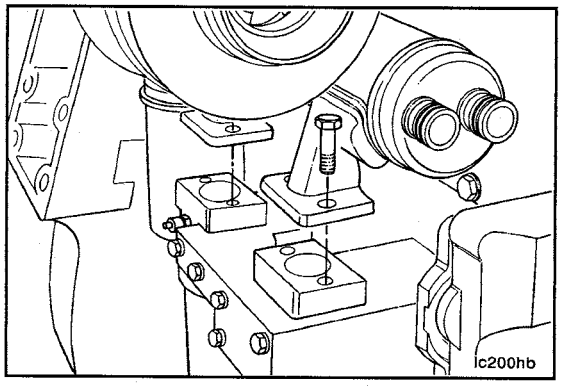


Install (007-015-026)

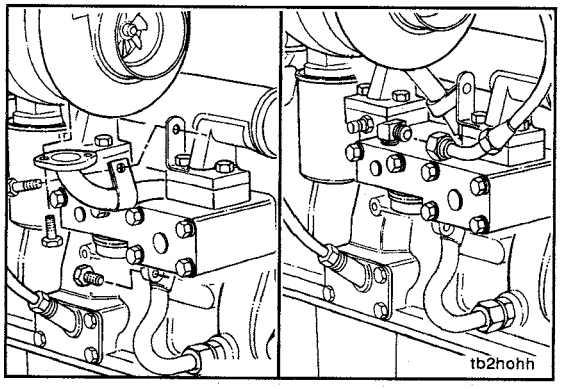
Use a new gasket and install the filter head to the cylinder block.

Install the nine capscrews and tighten.

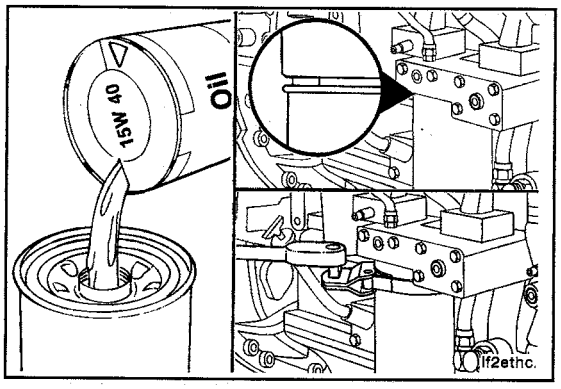
Torque Value: 47 N•m [35 ft-lb]



Install the lubricating oil cooler. Refer to Procedure 007-003.



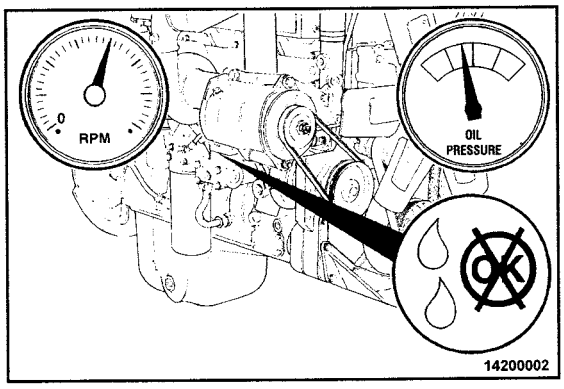
Install the turbocharger oil supply and drain lines and support brackets.



Install the lubricating oil filter. Refer to Procedure 007-013.

Operate the engine at idle speed for 3 minutes to inspect for leaks at the filter head.

NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

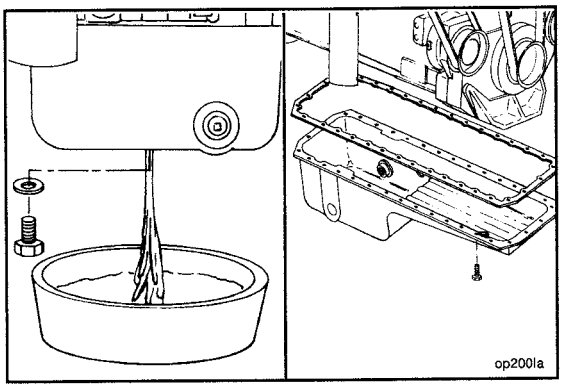


Lubricating Oil High Pressure Relief Valve (007-021)

Initial Check (007-021-001)

Drain the lubricating oil. Refer to Procedure 007-025.

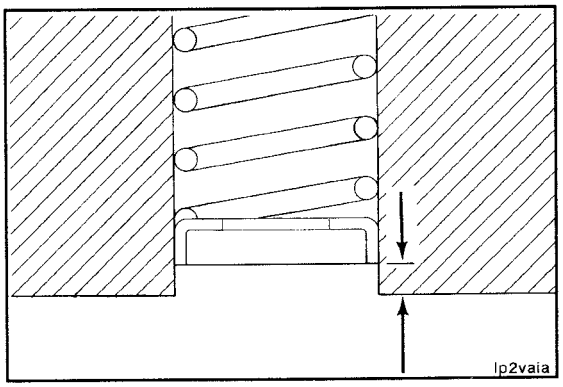
Remove the oil pan. Refer to Procedure 007-025.



Measure the installed depth of the relief valve retainer cup plug.

Relief Valve Retainer Installed Depth		
mm		in
8.03	MIN	0.316
8.53	MAX	0.336

NOTE: If the plug depth is **not** within the specifications given, remove the high-pressure regulator assembly and inspect the parts.



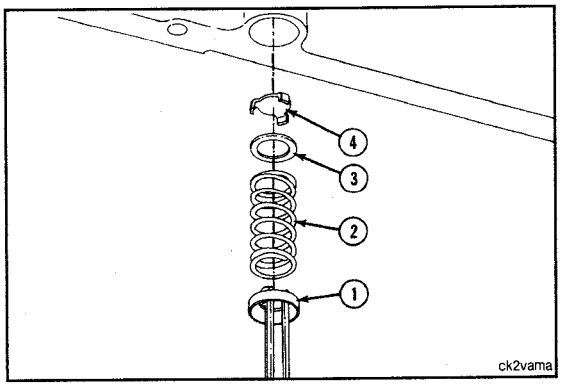
Remove (007-021-002)

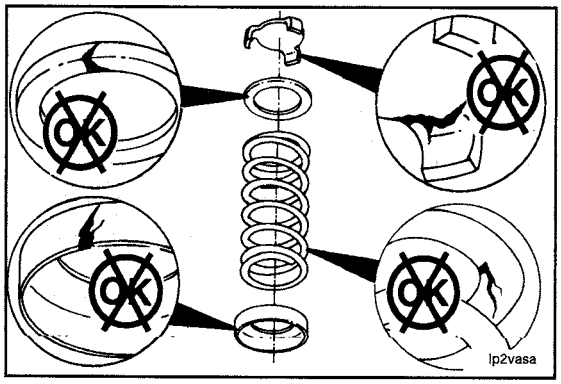
⚠ WARNING ⚠

Use caution while removing the retainer plug (1). The pressure relief valve spring (2) is under compression. Personal injury can result. Wear face and eye protection.

Use light-duty puller kit, Part No. 3375784, or equivalent to remove the retainer plug (1).

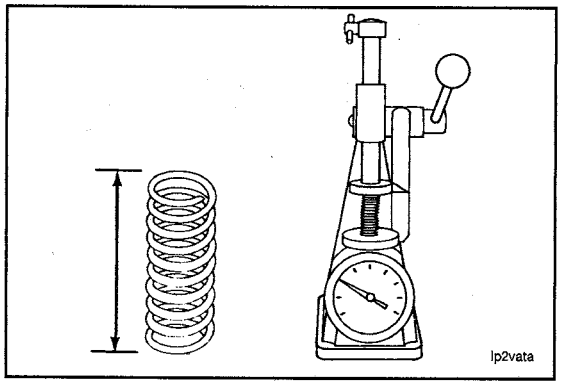
Remove the pressure relief valve spring (2), washer (3), and valve disc (4).





Inspect for Reuse (007-021-007)

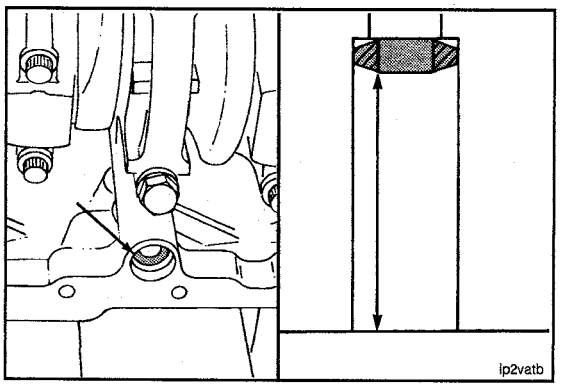
Inspect the parts for damage.



Use a spring compression tester, Part No. 3375182, to measure the relief valve spring tension.

Compress the spring to 29.1-mm [1.15-in] height. The force required to compress the spring **must** be:

Force Required to Compress Spring to 29.1 mm [1.15 in]		
N		lbf
263	MIN	59
322	MAX	72

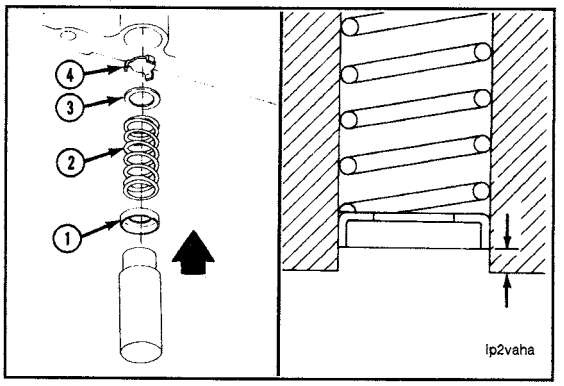


Measure the relief valve seat depth in the cylinder block.

Relief Valve Seat Depth		
mm		in
62.62	MIN	2.465
63.62	MAX	2.505

If the relief valve seat is **not** at the specified depth or is loose or **not** level in the cylinder block, the seat **must** be removed and inspected. Use puller kit, Part No. 3375784, to remove the seat.

If the seating surfaces are free of indentations, the seat can be reused. If the surfaces have indentations, the seat **must** be replaced. Use relief valve seat driver, Part No. 3376486, to install the seat.



Install (007-021-026)

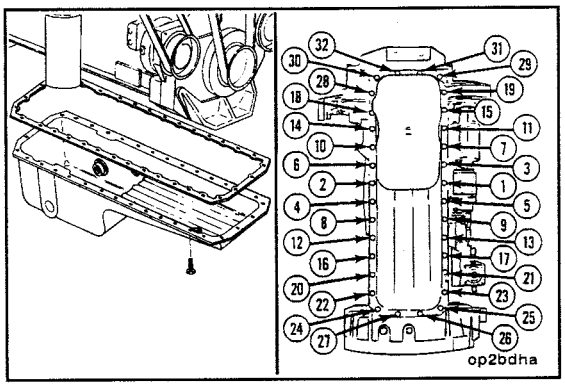
Install the valve disc (4), washer (3) and spring (2).

Use flat washers equal to 5 mm [0.197 in] with plug driver, Part No. 3376489, to install the new retainer cup plug (1).

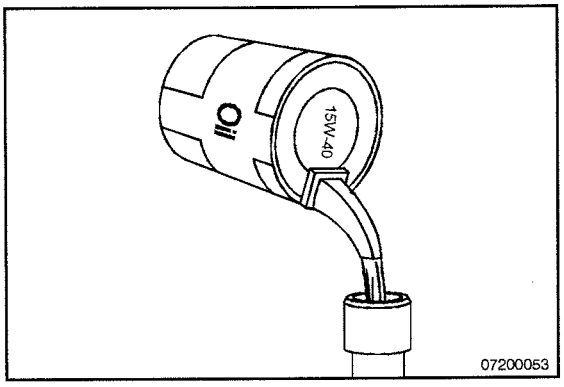
Measure the retainer plug depth in the cylinder block.

Relief Valve Retainer Installed Depth		
mm		in
8.03	MIN	0.316
8.53	MAX	0.336

Install the oil pan. Refer to Procedure 007-025.

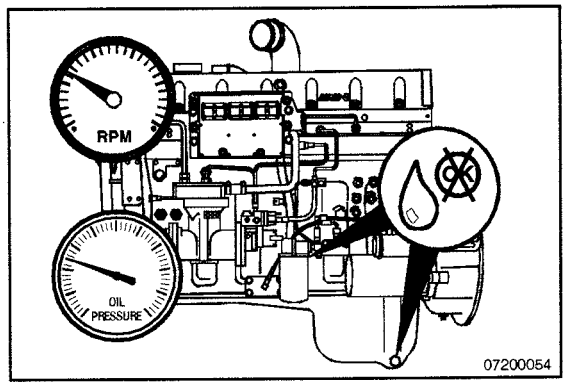


Fill the engine with clean 15W-40 oil. Refer to Procedure 007-025.



NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

Operate the engine at idle speed for 3 minutes to inspect for leaks.



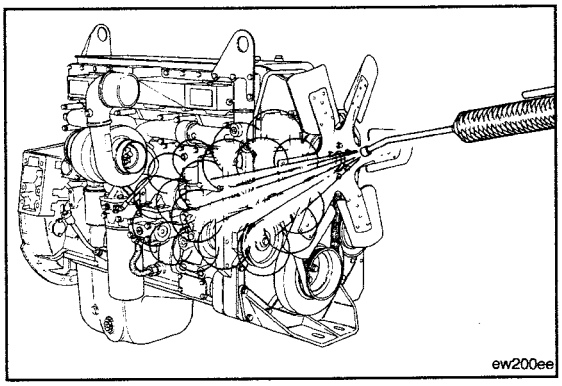
Lubricating Oil Leaks (007-024)

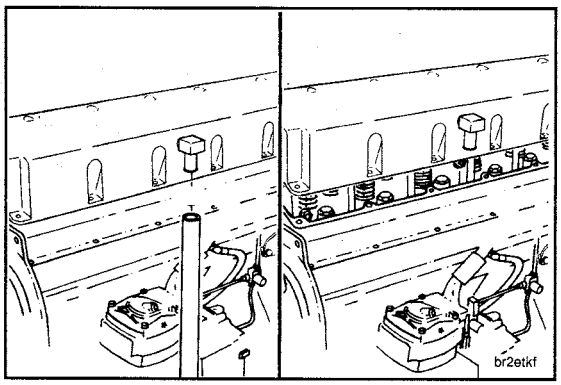
Maintenance Check (007-024-008)

⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam can cause serious personal injury.

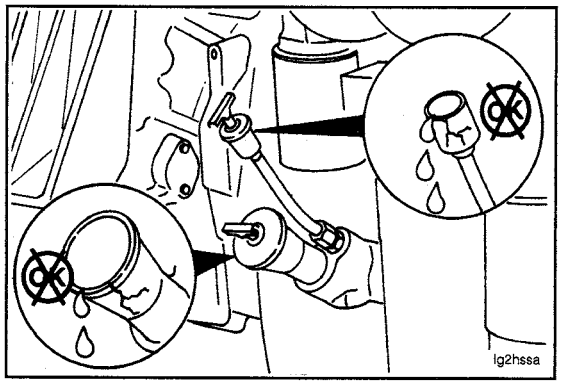
Use a steam cleaner or high-pressure washer to clean the engine. Dry with compressed air.



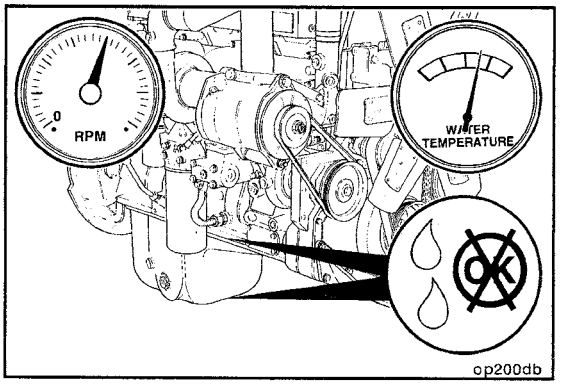


Inspect the internal crankcase breather, hose, and tube for restriction. Refer to Procedure 003-002.

NOTE: The rocker lever housing cover **must** be removed to inspect the internal engine crankcase breather.



Check for a loose, damaged or missing oil dipstick tube, dipstick, or oil filler cap.



Operate the engine to normal operating temperature, and inspect the exterior of the engine for leaking gaskets, seals, o-rings, pipe plugs, or fittings.

NOTE: Before replacing any gaskets, check the capscrews to be sure they are tightened to the correct torque values. Refer to Section V for the specific component capscrew torque specifications.

Lubricating Oil Pan (007-025)

Drain (007-025-005)

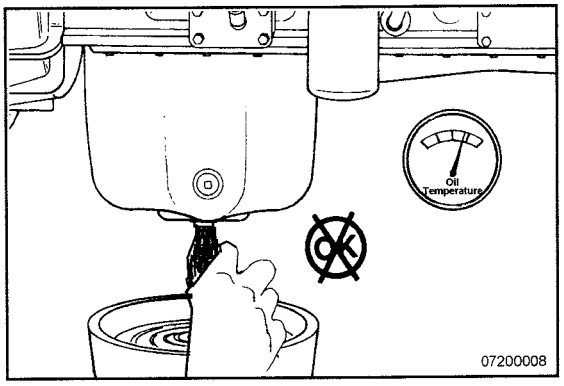
⚠ WARNING ⚠

Some state and federal agencies in the United States of America have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

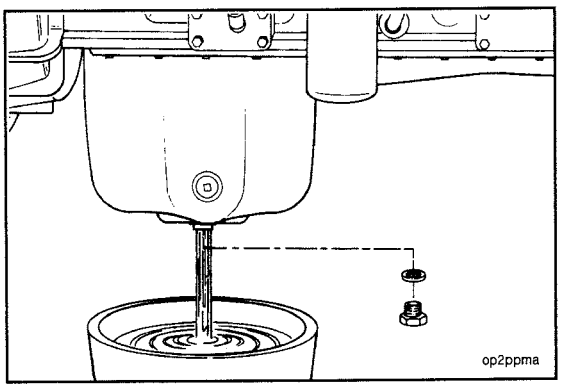
⚠ WARNING ⚠

Avoid direct contact of hot oil with your skin. Hot oil can cause personal injury.

Change the lubricating oil and filter at the specified oil drain interval. Refer to the oil drain intervals by serverity of service Km [mi] chart listed in Section 2 of the Operation and Maintenance Manual, ISM Series Engines, Automotive/ Transit Buses, bulletin No. 3666319, to find the correct oil drain interval for your application.



Operate the engine until the water temperature reaches 60°C [140°F]. Shut off the engine. Remove the oil drain plug from the bottom of the lubricating oil pan. Do **not** remove the plugs on either side of the oil pan to drain the oil. They will **not** allow the oil to drain completely.



NOTE: Fittings used in the bottom drain opening of the oil pan other than Cummins-specified parts **must not** exceed the following size and weight limits:

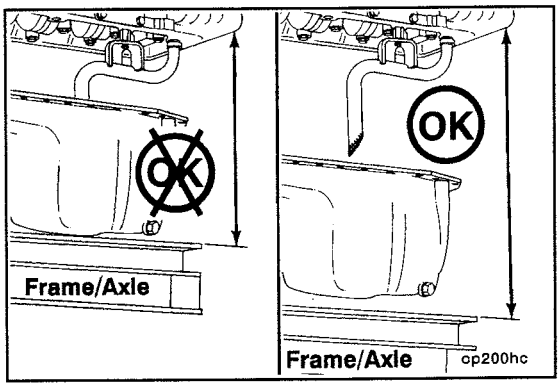
Oil Drain Fitting Specs		
Length	63.50 mm	[2.500 in]
Diameter	41.28 mm	[1.625 in]
Weight	0.363 mm	[0.80 lbf]

Do **not** use fittings other than the Cummins-supplied fittings in the side drain location.

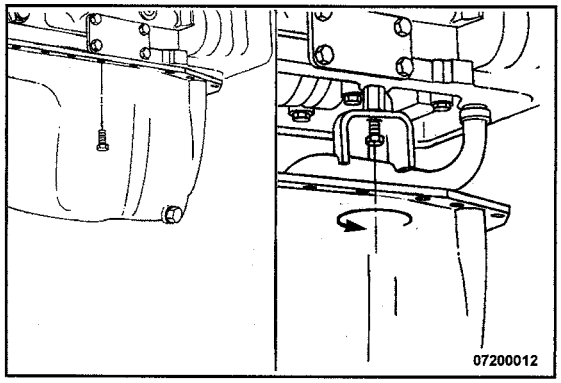
Remove (007-025-002)

Front Sump Pan

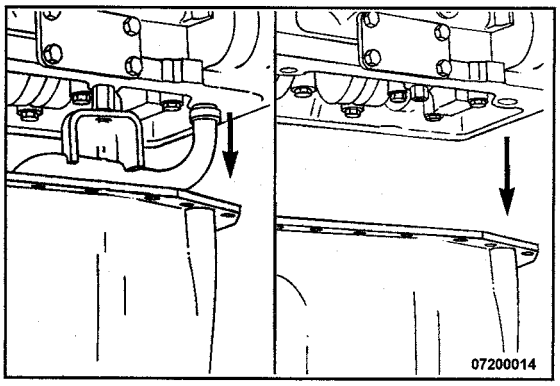
Front sump oil pans have a block-mounted suction tube, which requires approximately 610-mm [24-in] clearance between the vehicle frame or axle and the cylinder block oil pan mounting flange to remove the oil pan.



If an application will **not** allow the oil pan to be lowered that much, the suction tube **must** be removed from the cylinder block before the oil pan can be removed from the chassis.

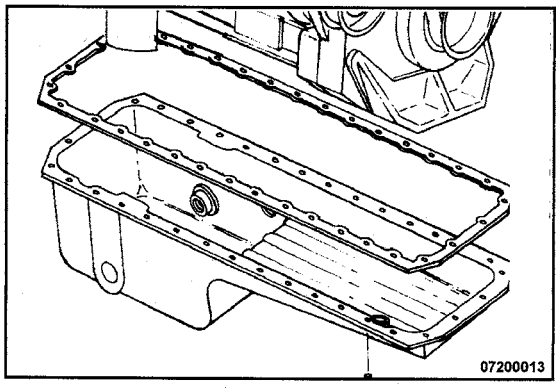


Remove the oil pan mounting capscrews. Lower the oil pan far enough to allow one hand to reach inside the engine and remove the suction tube mounting capscrew.



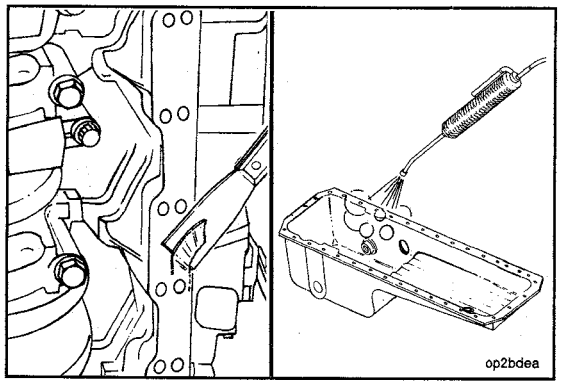
Remove the suction tube from the cylinder block, and let it drop into the oil pan.

Remove the oil pan from the chassis.



Rear Sump Pan

Remove the capscrews and the oil pan.



Clean (007-025-006)

Remove all gasket material from the cylinder block and oil pan surfaces.

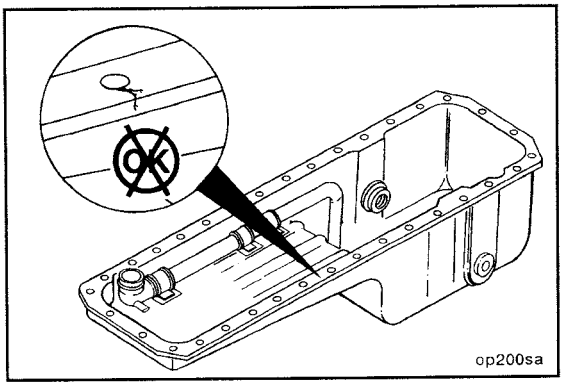
Steam-clean the oil pan and dry with compressed air.

Inspect for Reuse (007-025-007)

Inspect the oil pan, suction tube, and tube braces for cracks or damage.

NOTE: If cracks are found, replace the damaged part. Do **not** attempt to repair the oil pan by welding.

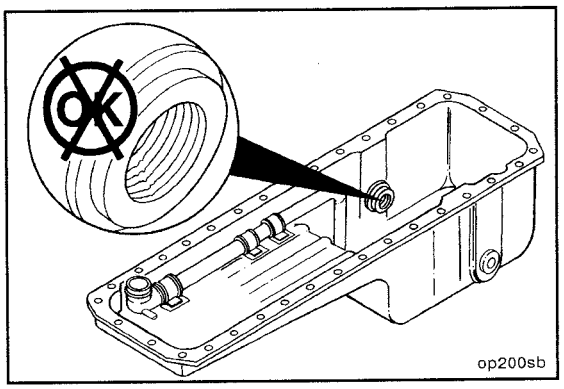
Inspect the oil transfer tube. Refer to Procedure 007-040.



Inspect the threaded holes for damage. Damaged threads can be chased with the following taps.

Oil Pan Threaded Holes	
Thread Location	**Tap Size**
Temperature Gauge	3/8 in NPTF
Oil Sump Heater	1-18 NS-3B
Oil Drain	1 in NPTF

NOTE: If the threaded holes can**not** be repaired with the taps listed above, the oil pan **must** be replaced.

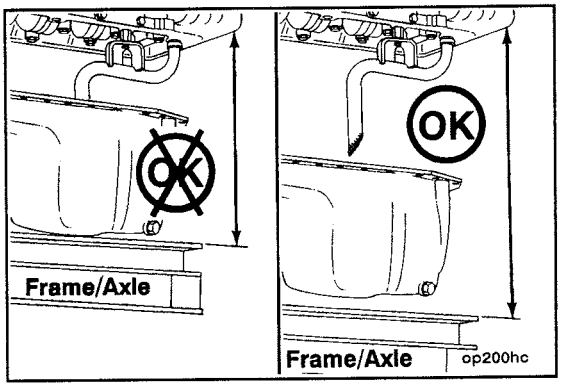


Install (007-025-026)

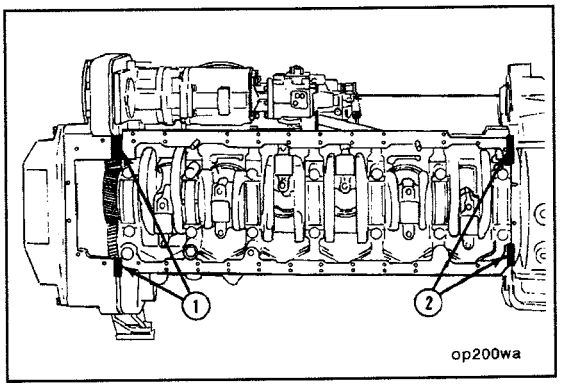
Front Sump Pan

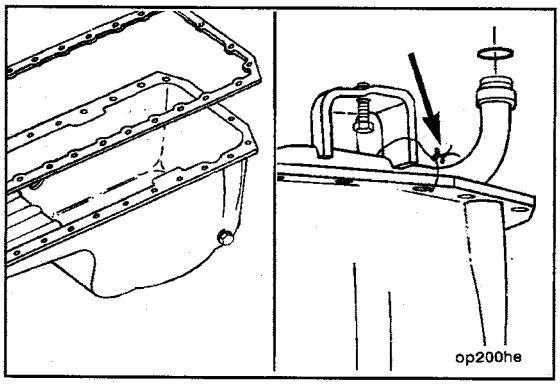
On front sump oil pans, if the application does **not** allow approximately 610 mm [24 in] clearance between vehicle frame or axle and the cylinder block oil pan mounting surface during installation, the suction tube and oil pan will need to be installed together as an assembly. Installation requires approximately this much clearance to maneuver the oil pan over the frame or axle and under the block-mounted suction tube when installing the pieces separately. Follow all the steps as outlined on the following pages.

If the application does allow approximately 610-mm [24-in] clearance, install the suction tube first by itself, then the oil pan.



Apply a 2-mm [1/16-in] bead of sealant, Part No. 3823494, to the oil pan mounting surfaces at the cylinder block to gear housing joint (1) and flywheel housing to cylinder block joint (2).

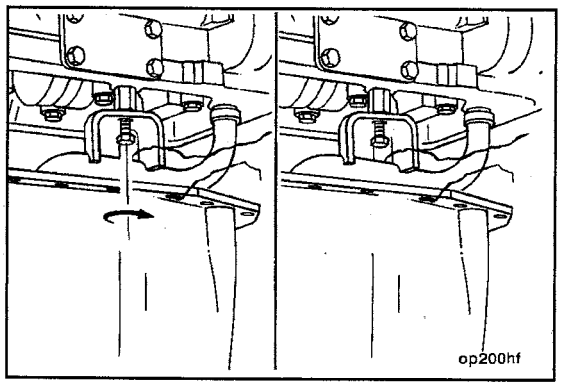




Install a new o-ring to the oil suction tube. Use clean 15W-40 engine oil to lubricate the o-ring.

Place a new gasket on the oil pan mounting flange.

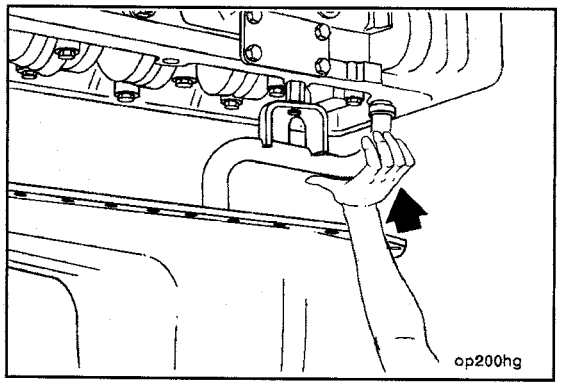
Attach the suction tube to the oil pan mounting flange with a piece of wire. This will hold the suction tube and oil pan together as one assembly until the tube is fastened to the cylinder block.



Maneuver the assembly into place under the engine in the chassis.

Align the suction tube with the cylinder block suction tube hole. Reach inside the engine, and start the capscrew into the mounting hole to hold the suction tube in place.

After the capscrew is started in the mounting hole by several threads, the wire holding the suction tube to the oil pan can be removed and the oil pan can be lowered to allow more hand clearance to complete the suction tube installation.



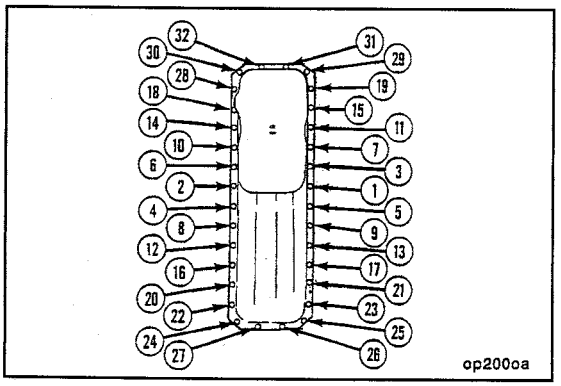
△ CAUTION △

Do not use the capscrew to pull the suction tube into place during installation. Doing so will cause misalignment of the suction tube, which can cause damage to the engine.

Reach inside the engine, and push the suction tube completely up into place in the cylinder block suction tube mounting hole by hand.

Complete the suction tube retaining capscrew installation.

Torque Value: 61 N•m [45 ft-lb]

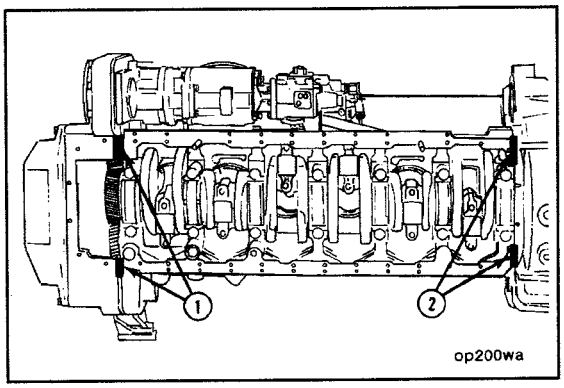


Install the oil pan. Tighten the capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]

Rear Sump Pan

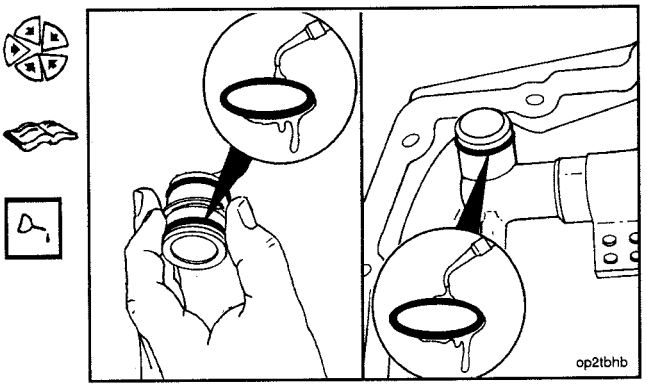
Apply a 2-mm [1/16-in] bead of sealant, Part No. 3823494, to the oil pan mounting surfaces at the cylinder block to gear housing joint (1) and flywheel housing to cylinder block joint (2).



Install new o-rings on the oil transfer tube.

Use clean 15W-40 oil to lubricate the o-rings.

Install the transfer tube in the oil pan.

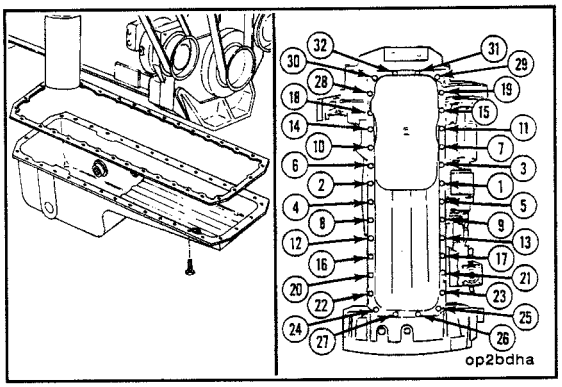


Be sure the transfer tube is aligned with the cylinder block suction tube hole when installing the oil pan.

Use a new gasket, and install the oil pan.

Install and tighten the capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]



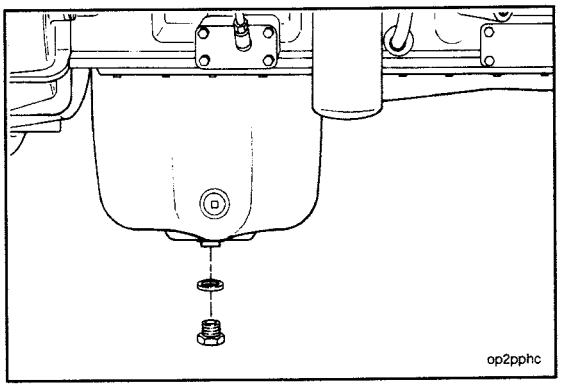
Fill (007-025-028)

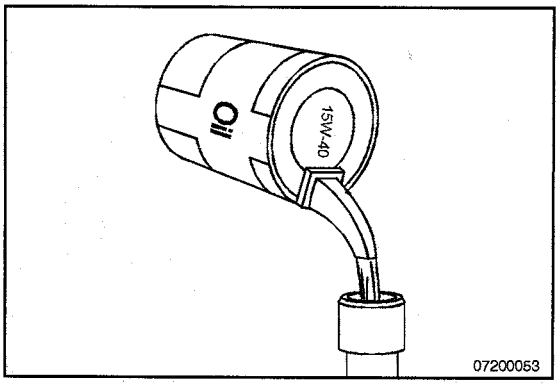
Clean and check the oil drain plug threads and the seal surface.

Install the oil drain plug in the lubricating oil pan.

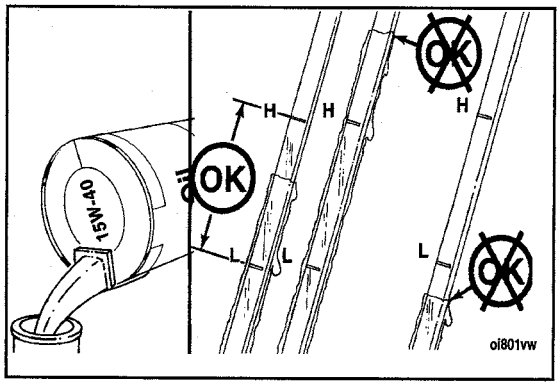
Torque Value: 88 N•m [65 ft-lb]

NOTE: Check the torque of the side and bottom drain plug to be sure **both** are tight.





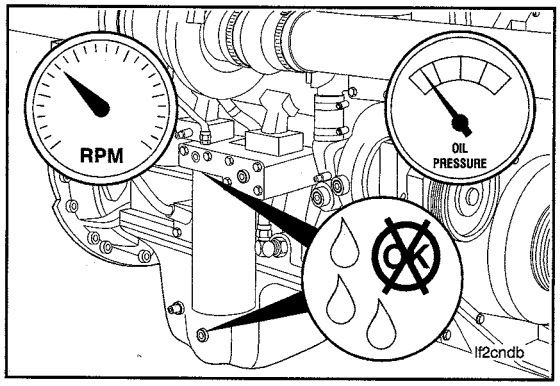
Fill the engine with clean 15W-40 oil. Choose the correct oil for your operating climate as outlined in Section V of the ISM Operation and Maintenance Manual, ISM Series Engines, Automotive/Transit Buses, Bulletin No. 3666319.



Fill the engine with clean oil to the H (high) mark on the dipstick. Total system capacity including filter is approximately 39 liters [10.3 gal].

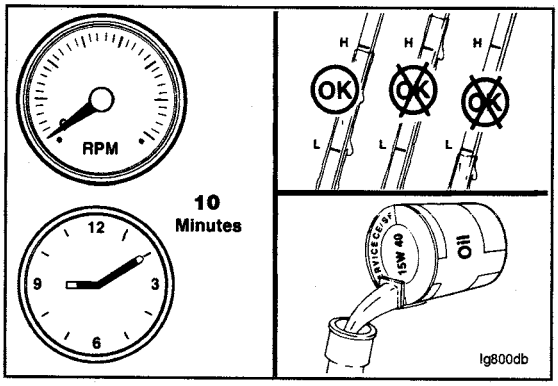
NOTE: The oil pan capacity is 34 liters [9 gal].

NOTE: Check Centinel™ makeup tank oil level, if equipped.



Operate the engine at idle speed to inspect for leaks at the filter(s) and the drain plug.

NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.



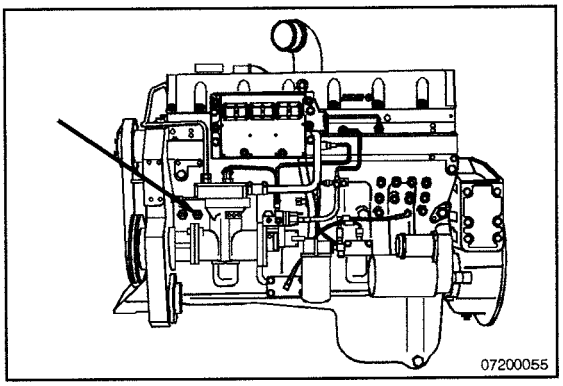
Shut off the engine. Wait approximately 10 minutes for the oil to drain back from the upper parts of the engine to the oil pan.

Check the oil level again. Add oil as necessary to bring the level up to the H (high) mark on the dipstick.

Lubricating Oil Pressure Gauge (007-028)

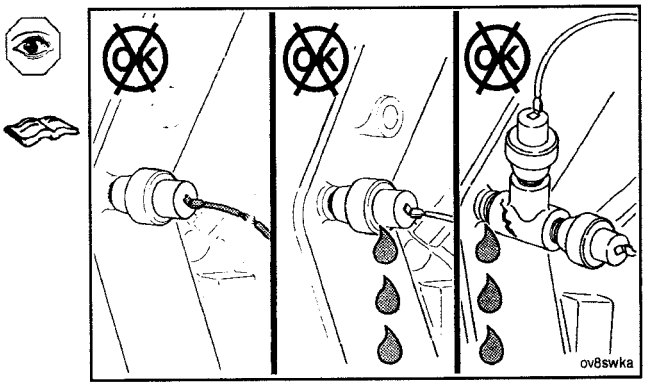
Test (007-028-012)

NOTE: The combination oil pressure and oil temperature sensor is located on the engine block directly above the accessory drive.



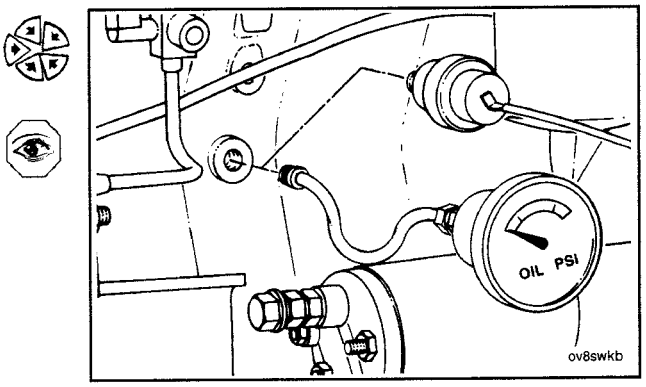
Check the following for defects:

- Electrical wiring broken
- Sending unit malfunction
- Plumbing loose or broken.



To check for a sending unit malfunction:

- Use Compulink™ to verify the readings of the suspect gauge.
- If readings from the engine sensors are suspected, use a master gauge of known accuracy to verify.
- Connect the line from the master gauge to the main oil rifle on the fuel pump side of the engine.
- Replace the sending unit or sensor if it is defective.

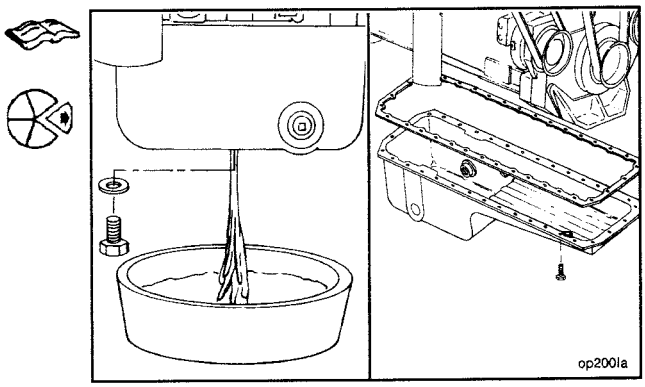


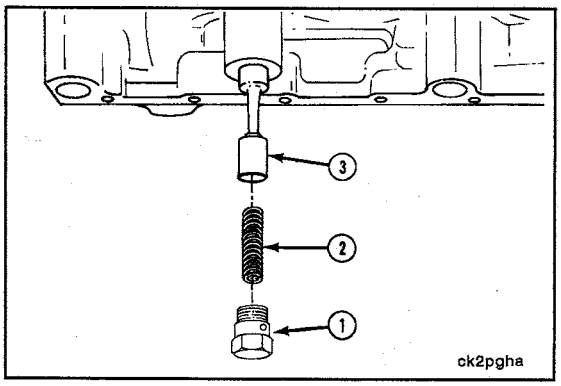
Lubricating Oil Pressure Regulator (Main Rifle) (007-029)

Remove (007-029-002)

Drain the lubricating oil. Refer to Procedure 007-025.

Remove the oil pan. Refer to Procedure 007-025.



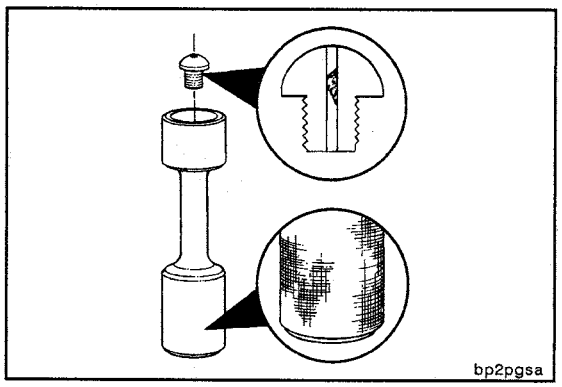


⚠ WARNING ⚠

Carefully remove the retainer plug. The pressure regulator spring is under compression. Personal injury can result. Wear face and eye protection.

Remove the retainer plug (1), regulator spring (2), and regulator plunger (3).

Remove the orifice from the plunger.



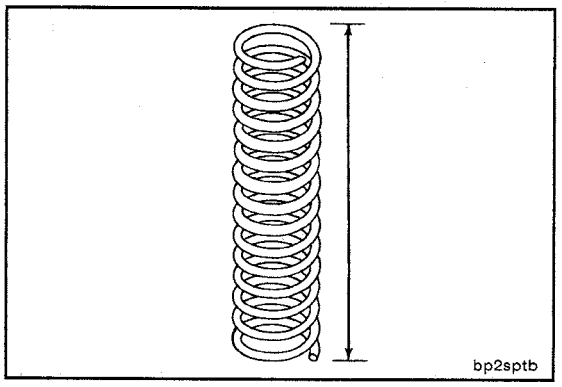
Inspect for Reuse (007-029-007)

Inspect the regulator plunger for scratches or scoring. If scratches are deep enough to be felt with a fingernail, the plunger **must** be replaced.

Check the orifice in the plunger to make sure it is **not** plugged. If the orifice is plugged, clean it before replacing.

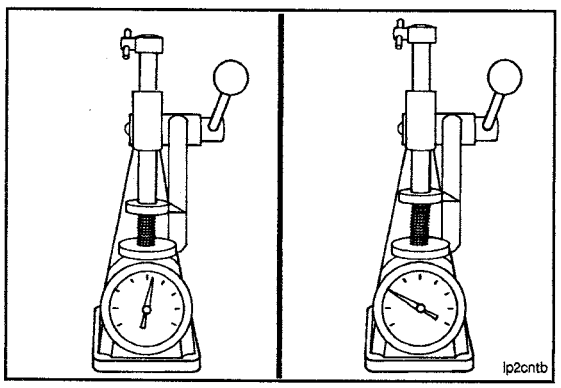
NOTE: The orifice is threaded into the plunger.

Torque Value: 1 N•m [6 in-lb]



Measure the free length of the regulator spring.

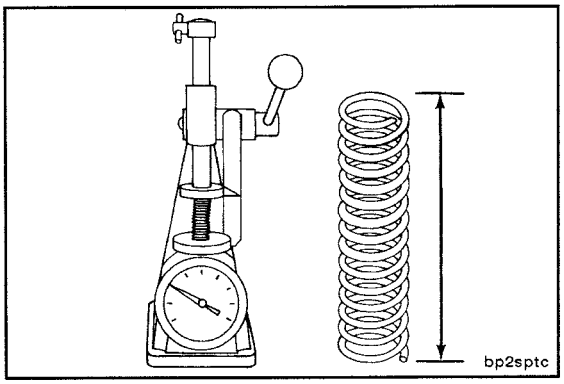
Regulator Spring Free Length		
mm		in
84.1	NOMINAL	3.31



Use a spring compression tester to determine if the spring is defective.

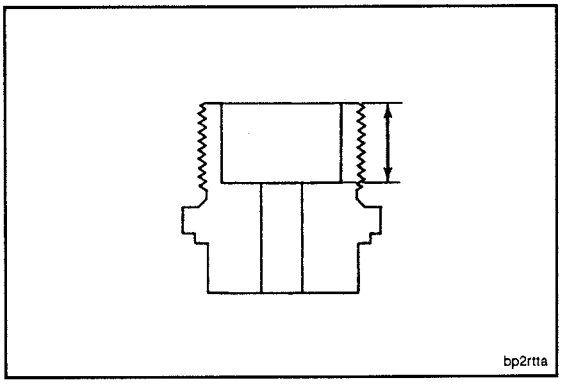
Replace the spring with a new spring if it is defective.

Main Oil Pressure Regulator Spring Load at 48.3 mm [1.90 in]		
N		lbf
91.1	MIN	20.50
94.7	MAX	21.30



Measure the retainer plug to determine if it is defective. If it does **not** meet the specification, replace it with a new one.

Main Oil Pressure Regulator Retainer Plug		
mm		in
11.1	MIN	0.44
13.4	MAX	0.53



Install (007-029-026)

⚠ WARNING ⚠

The regulator spring must be compressed to install the retainer plug. Personal injury can result. Wear face and eye protection.

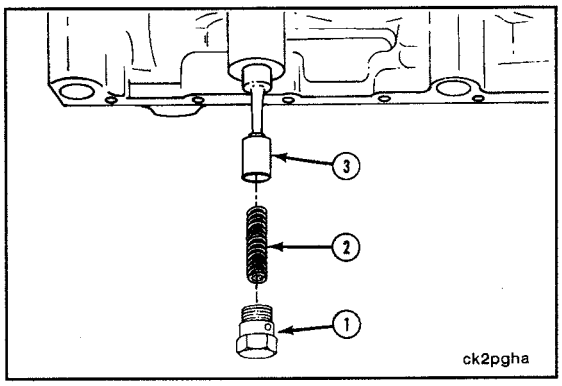
NOTE: A counterbore plunger and orifice is unique to engines with a viscosity sensor. Low oil pressure will result if a solid plunger is used with a viscosity sensor.

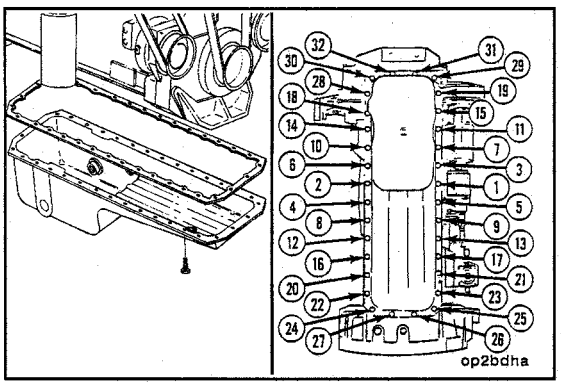
Install the regulator plunger (3) and regulator spring (2).

Install and tighten the retainer plug (1).

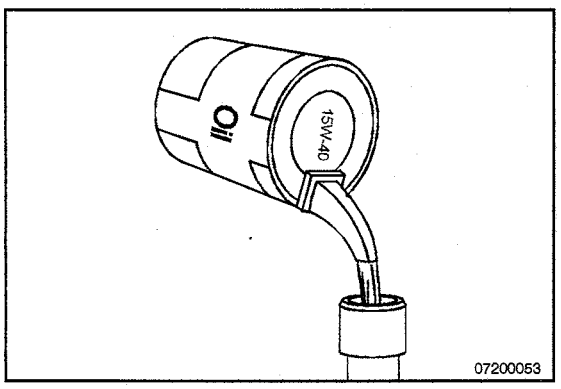
Torque Value:

Rear Sump Oil Pan	75 N•m	[55 ft-lb]
Front Sump Oil Pan	122 N•m	[90 ft-lb]

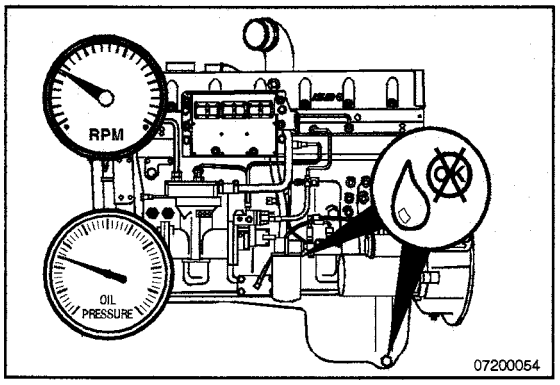




Install the oil pan. Refer to Procedure 007-025.

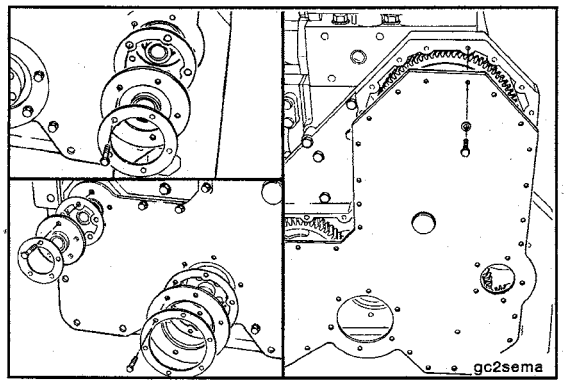


Fill the engine with clean 15W-40 oil. Refer to Procedure 007-025.



NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

Operate the engine at idle speed for 3 minutes to inspect for leaks.



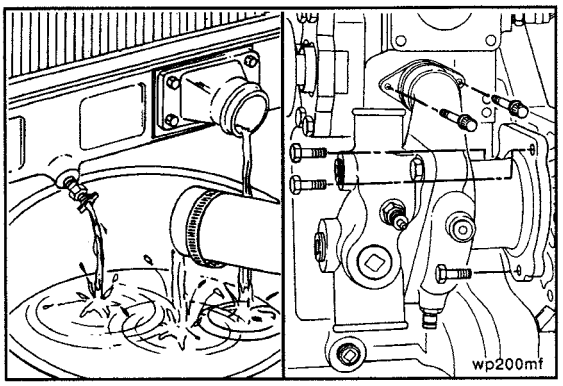
Lubricating Oil Pump (007-031)

Remove (007-031-002)

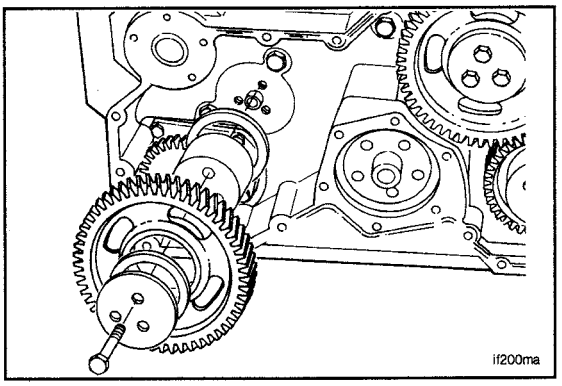
Remove the gear cover. Refer to Procedure 001-031.

The water pump **must** be removed to remove the water pump idler gear.

Drain the cooling system, and remove the water pump. Refer to Procedure 008-018 and 008-062 respectively.



Remove the water pump idler gear. Refer to Procedure 001-040.

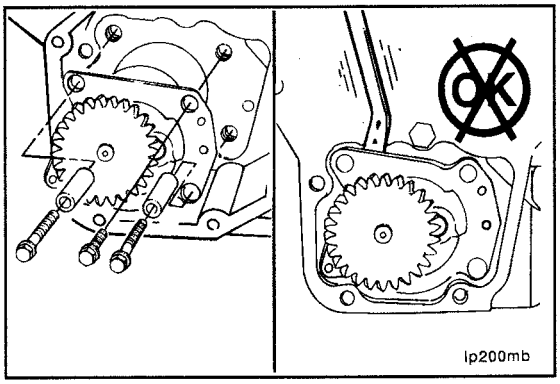


⚠ CAUTION ⚠

Do not pry on the gear or pump flange. This can result in damage to the pump.

Remove the three mounting capscrews and spacers.

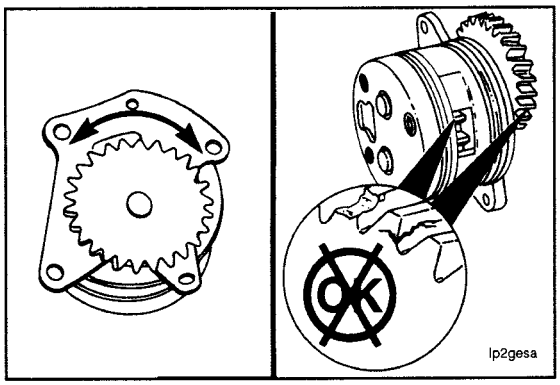
Use both hands to pull, or insert, two capscrews (M8 X 1.25) into the puller holes to push the pump from the engine.

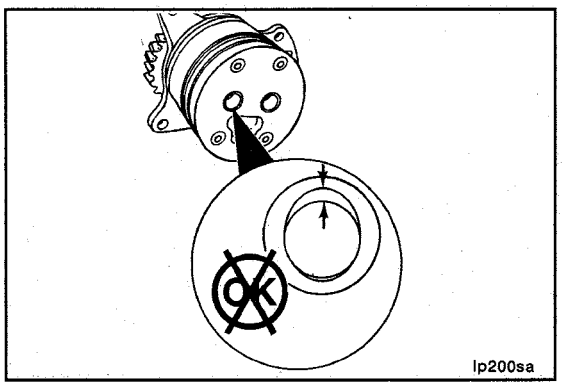


Inspect for Reuse (007-031-007)

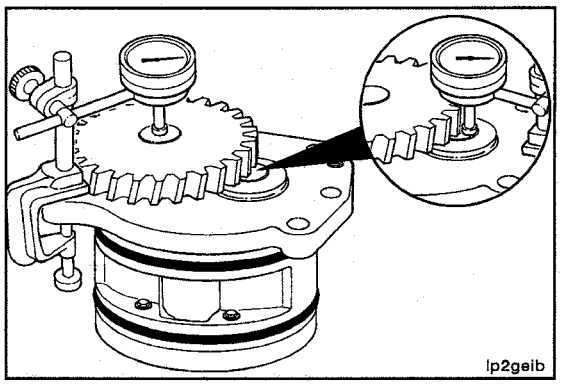
Turn the main drive gear by hand to check the gears for freedom of rotation.

Inspect the gears for cracked, worn, or broken teeth.





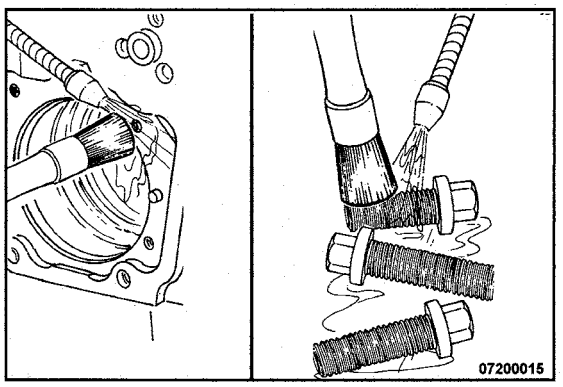
Inspect the rear cover plate shaft bores for excessive wear or discoloration due to overheating or shaft seizure.



Measure the driveshaft and driven shaft end clearance.

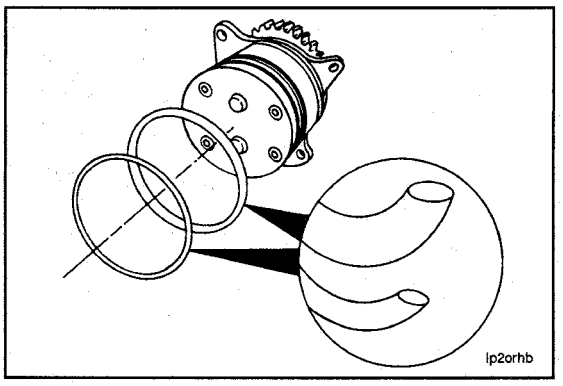
Driveshaft End Clearance		
mm		in
0.064	MIN	0.0025
0.269	MAX	0.0106

If the gears are damaged, the shaft does **not** turn freely by hand, or the end clearance is **not** within the specifications given, the oil pump **must** be replaced.



Install (007-031-026)

Clean the threaded lubricating pump mounting holes in the cylinder block and capscrew threads with solvent. Dry with compressed air.



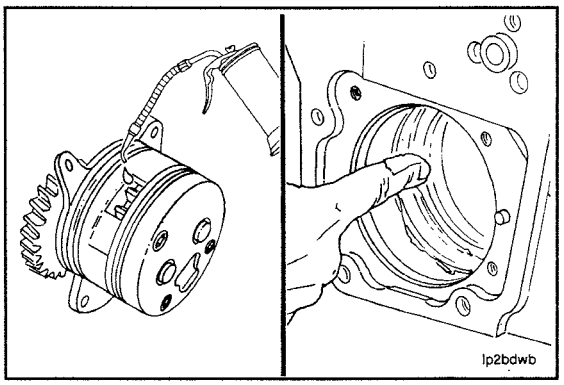
Install two new o-rings on the oil pump body.

Install the thickest o-ring into the groove nearest the oil pump drive gear.

NOTE: Do **not** lubricate the two oil pump body o-rings. The o-rings will swell, and the pump can**not** be installed.

Use clean 15W-40 oil to lubricate the oil pump gears.

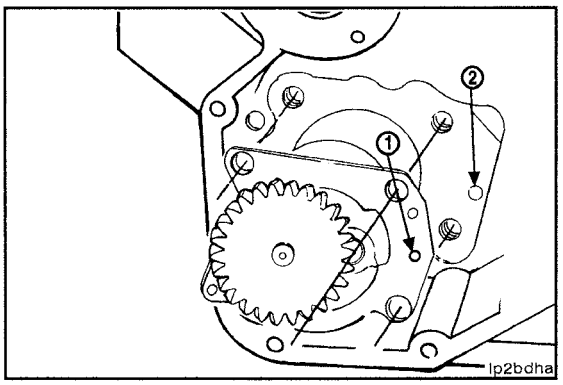
Apply a film of grease to the oil pump bore in the cylinder block.



⚠ CAUTION ⚠

The dowel pin bore in the oil pump flange (1) must be aligned with the dowel pin in the cylinder block (2) to prevent damage to the oil pump flange during installation. Do not use the mounting capscrews to pull the oil pump into the bore. This can damage the mounting flange of the oil pump.

Install the oil pump by hand.



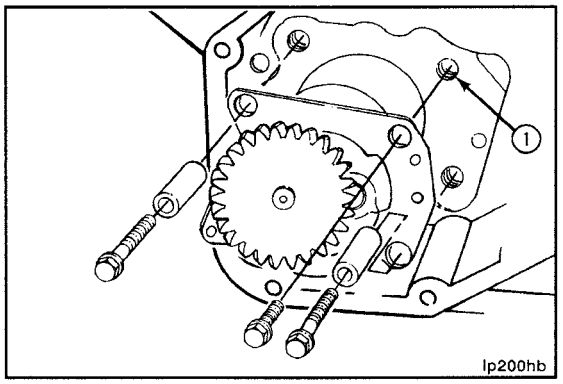
Sealant, Part No. 3824038, or equivalent, **must** be used to coat the threads of the three mounting capscrews to prevent air from being drawn past the capscrews during engine operation.

⚠ CAUTION ⚠

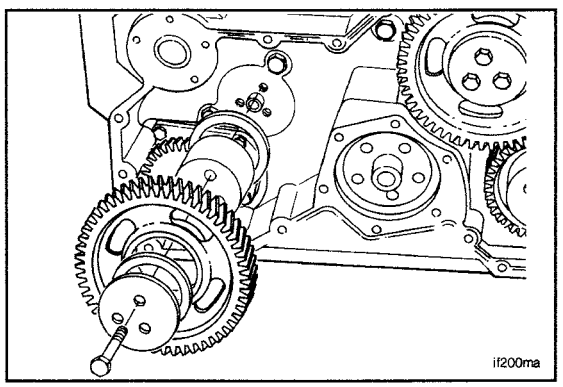
The shorter flange head capscrew must be used in the upper right-hand mounting hole (1) to prevent the idler gear from contacting the head of the capscrew and causing damage to the lubricating oil pump.

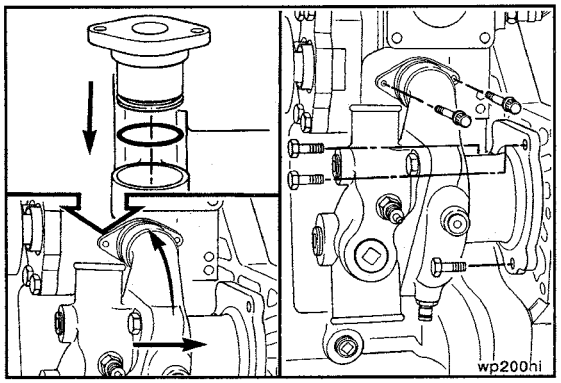
Install the three capscrews and spacers. Use the short flange head capscrew in the upper right hand mounting hole (1). Use the longer flange head capscrews and spacers in the other two holes.

Torque Value: 41 N•m [30 ft-lb]

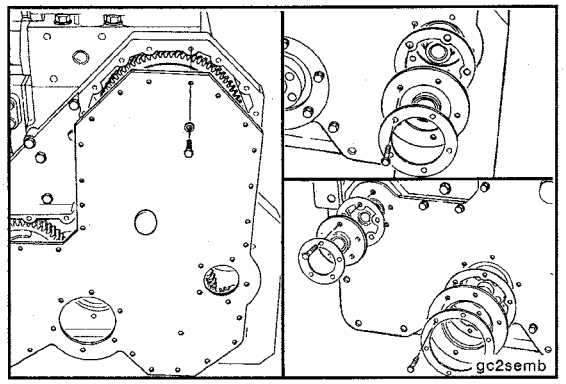


Install the water pump idler gear. Refer to Procedure 001-040.



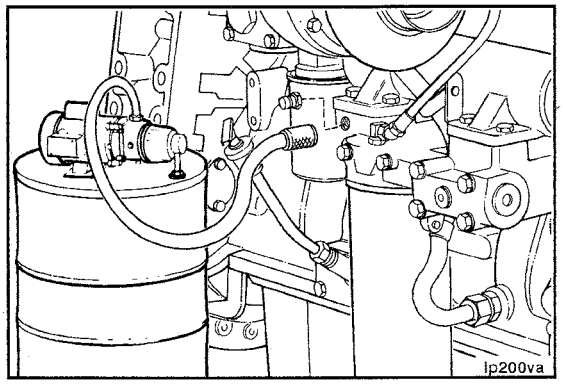


Install the water pump. Refer to Procedure 008-062.



Install the gear cover. Refer to Procedure 001-031.

Operate the engine and check for leaks.



Lubricating Oil System (007-037)

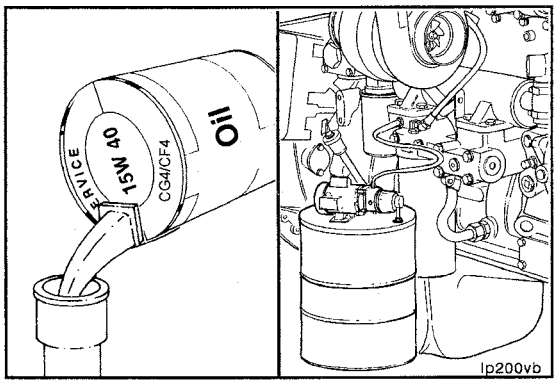
Prime (007-037-050)

△ CAUTION △

The lubricating oil system must be primed before operating the engine after a rebuild or extended shutdown to avoid internal component damage. If an external pressure pump is used, do not prime the system after the filter. The filter will be damaged.

Remove the plug at the "filter-in" fitting of the lubricating oil filter head. This will allow oil to flow in the correct direction through the filter.

Install an oil supply line connected to a source of clean 15W-40 lubricating oil in the Compuchek® fitting drilling of the filter head.



Prime the lubricating system until the oil pressure gauge indicates a positive pressure.

NOTE: The oil pressure **must not** exceed the maximum of 276 kPa [40 psi].

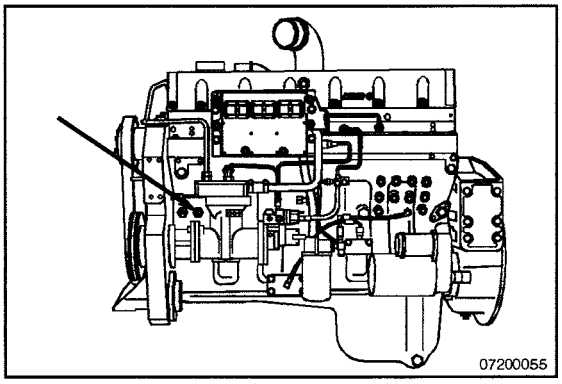
Remove the oil supply and install the Compuchek® fitting.

Torque Value: 54 N•m [40 ft-lb]

Lubricating Oil Temperature Gauge (007-038)

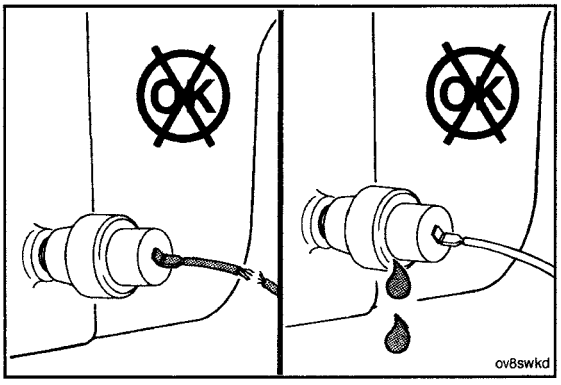
Test (007-038-012)

NOTE: The combination oil pressure and oil temperature sensor is located on the engine block directly above the accessory drive.



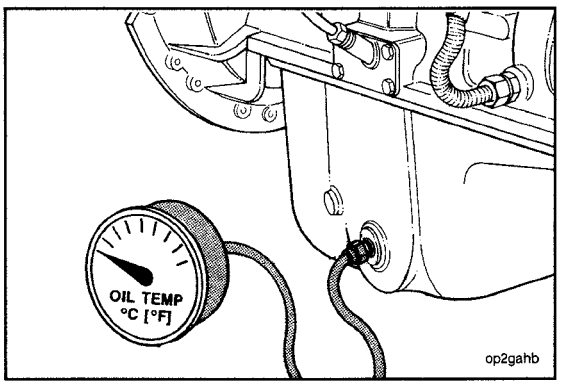
Check the following for defects.

- Electrical wiring broken
- Sending unit malfunction.



To check for a sending unit malfunction:

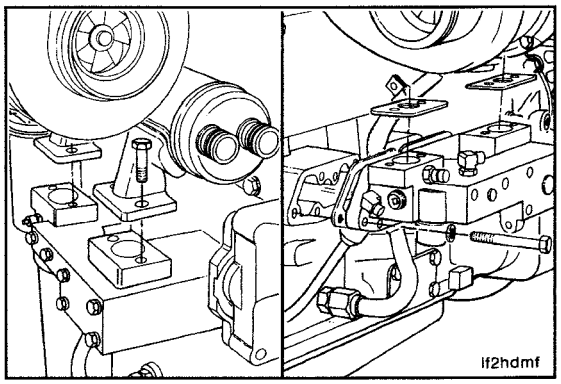
- Use a master gauge of known accuracy to verify the reading of the suspect gauge.
- Drain the oil pan.
- Remove the pipe plug on the side of the oil pan, and install the master oil temperature gauge sending unit.
- Fill the oil pan with 15W-40 oil.
- Replace the sending unit if it is defective.

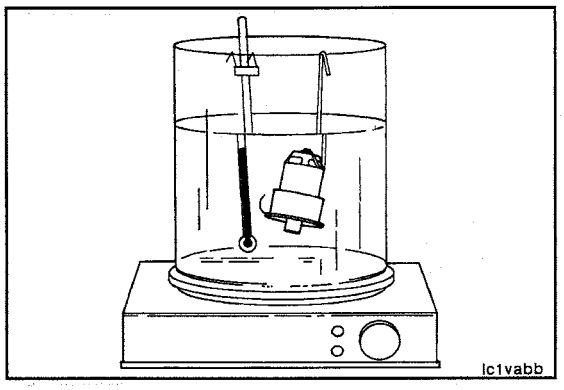


Lubricating Oil Thermostat (007-039)

Remove (007-039-002)

Remove the lubricating oil filter head. Refer to Procedure 007-015.





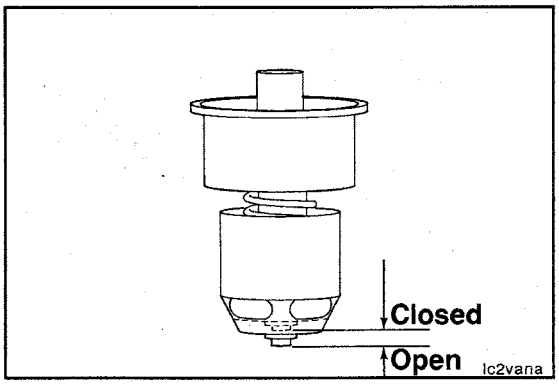
Inspect for Reuse (007-039-007)

⚠ WARNING ⚠

The flash point of new lubricating oil is approximately 221°C [430°F]. Do not allow the oil temperature in the container to exceed 149°C [300°F]. Do not allow water droplets to enter the container of hot oil. Water droplets will cause a violent reaction, which can cause personal injury.

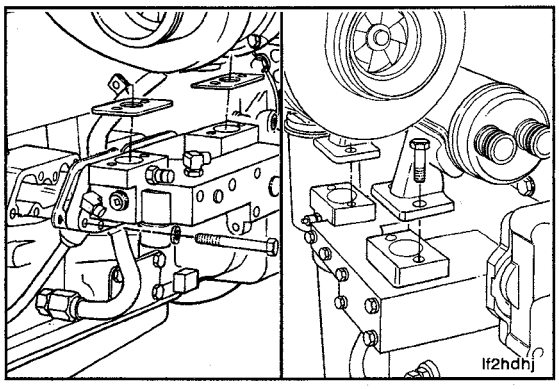
Suspend the thermostat and a 116°C [240°F] thermometer in a container of new lubricating oil. Do **not** allow the thermostat or the thermometer to touch the sides of the container.

Heat the lubricating oil.



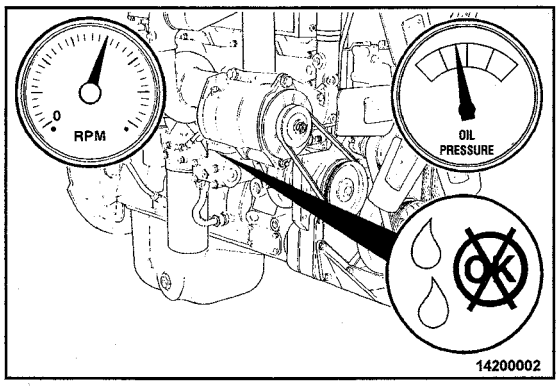
Write down the temperature at which the valve is fully extended. The valve **must** be fully extended to at least 6 mm [0.250 in] from the closed position when the temperature reaches 116°C [240°F].

Replace the thermostat if it does **not** operate as described.



Install (007-039-026)

Install the filter head onto the engine. Refer to Procedure 007-015.



Operate the engine at idle speed for 3 minutes to inspect for leaks at the filter head.

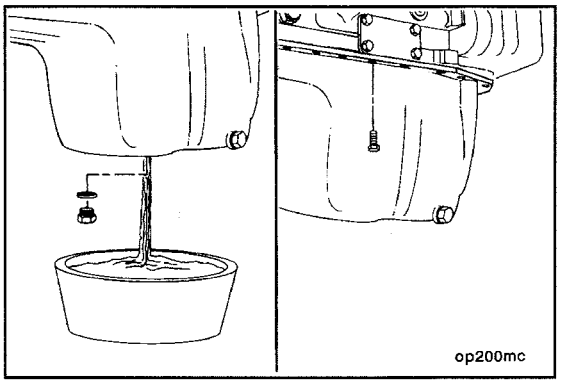
NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

Lubricating Oil Transfer Tube (007-040)

Remove (007-040-002)

Drain the lubricating oil. Refer to Procedure 007-025.

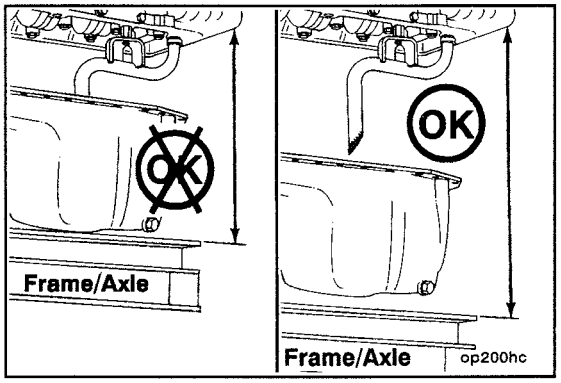
Remove the oil pan mounting capscrews. Refer to Procedure 007-025.



Most front sump oil pans have a block-mounted suction tube, which requires approximately 610-mm [24-in] clearance between the vehicle frame or axle and the cylinder block oil pan mounting flange to remove the oil pan.

If the application will **not** allow this much clearance, lower the oil pan as much as possible, and reach inside the pan and remove the suction tube retaining capscrew from the cylinder block.

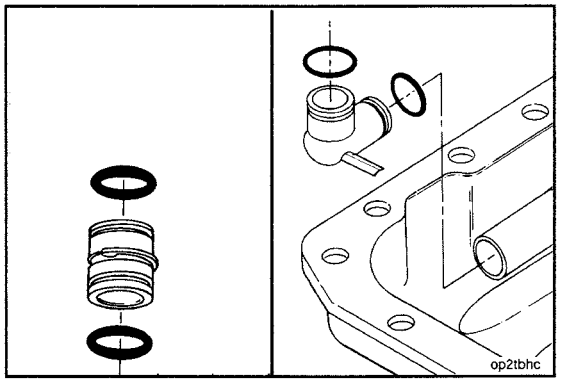
Let the suction tube lie inside the oil pan while the pan is removed from the chassis.



On rear sump pans, remove the oil transfer tube.

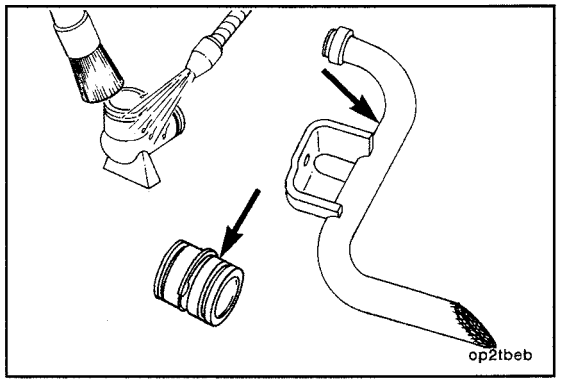
Remove and discard the o-ring(s) on the transfer tube or the suction tube.

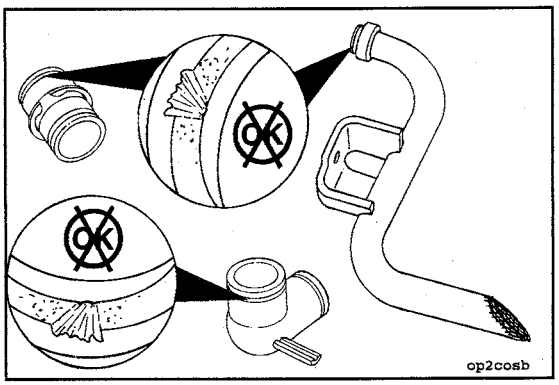
NOTE: The straight transfer tube is used on some aluminum front sump oil pan applications.



Clean (007-040-006)

Use solvent to clean the oil transfer tube and locating snap ring. Dry with compressed air.



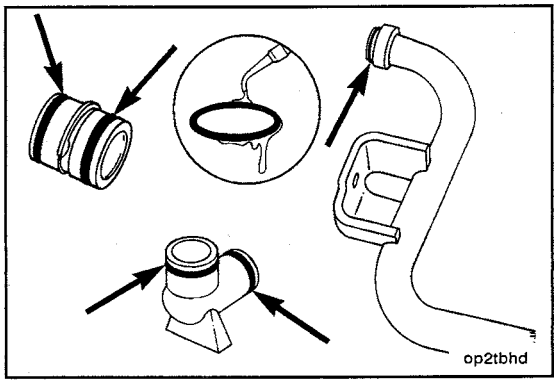


Inspect for Reuse (007-040-007)

Inspect the oil transfer tube for cracks or damage.

Inspect the o-ring grooves for cavitation or damage.

If cracks, damage, or cavitation is found, the oil transfer tube **must** be replaced.

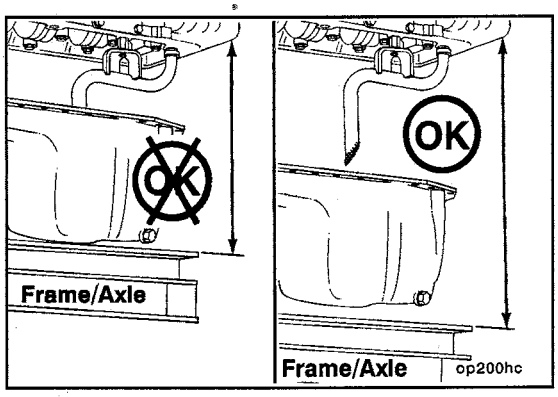


Install (007-040-026)

Install new o-ring(s) on the transfer tube or suction tube.

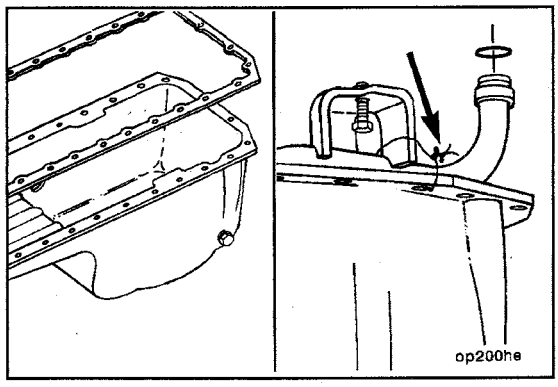
Use clean 15W-40 oil to lubricate the o-ring(s).

On rear sump oil pans, install the transfer tube in the oil pan.



On front sump oil pans, if the application does **not** allow approximately 610-mm [24-in] clearance between vehicle frame or axle and the cylinder block oil pan mounting surface during installation, the suction tube and oil pan will need to be installed together as an assembly. Installation requires approximately this much clearance to maneuver the oil pan over the frame or axle and under the suction tube when installing separately. Follow all the steps as outlined on the following pages.

If the application does allow approximately 610- mm [24-in] clearance, install the suction tube first by itself, then the oil pan.



Install a new o-ring to the oil suction tube. Use clean 15W-40 engine oil to lubricate the o-ring.

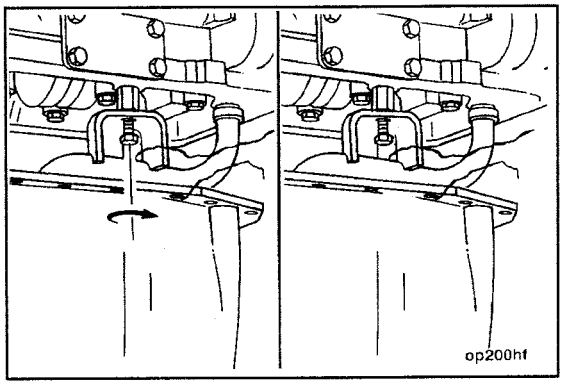
Place a new gasket on the oil pan mounting flange.

Attach the suction tube to the oil pan mounting flange with a piece of wire. This will hold the suction tube and oil pan together as one assembly until the tube is fastened to the cylinder block.

Maneuver the assembly into place under the engine in the chassis.

Align the suction tube with the cylinder block suction tube hole. Reach inside the engine, and start the capscrew into the mounting hole to hold the suction tube in place.

After the capscrew is started in the mounting hole by several threads, the wire holding the suction tube to the oil pan can be removed, and the oil pan can be lowered to allow more hand clearance to complete the suction tube installation.



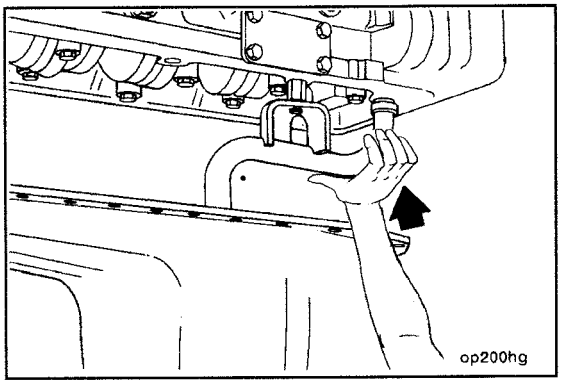
⚠ CAUTION ⚠

Do not use the capscrew to pull the suction tube into place during installation. Doing so will cause misalignment of the suction tube which can cause damage to the engine.

Reach inside the engine, and push the suction tube completely up into place in the cylinder block suction tube mounting hole by hand.

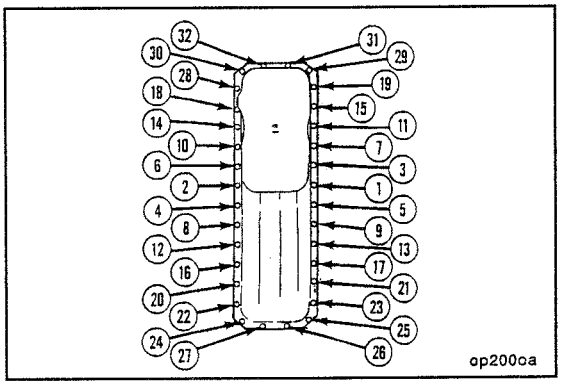
Complete the capscrew installation.

Torque Value: 61 N•m [45 ft-lb]

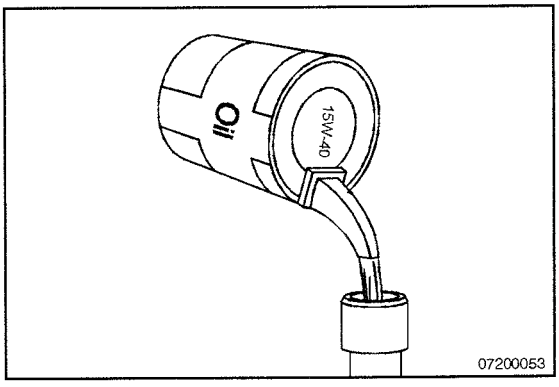


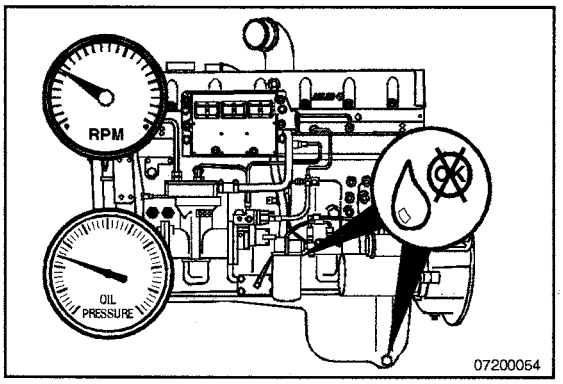
Install the oil pan. Tighten the capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]



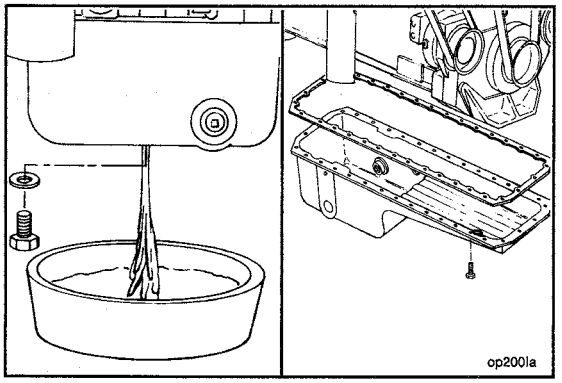
Fill the engine with clean 15W-40 oil. Refer to Procedure 007-025.





NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

Operate the engine at idle speed for 3 minutes to inspect for leaks.

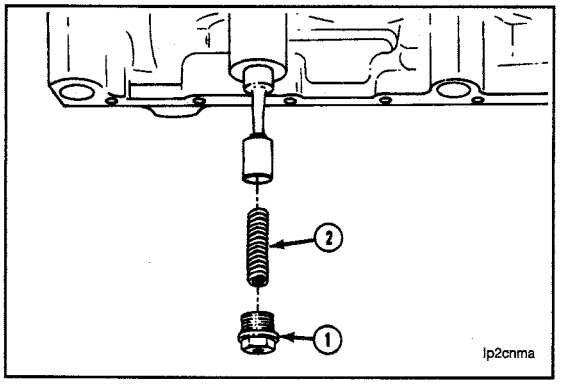


Lubricating Oil Viscosity Sensor (007-041)

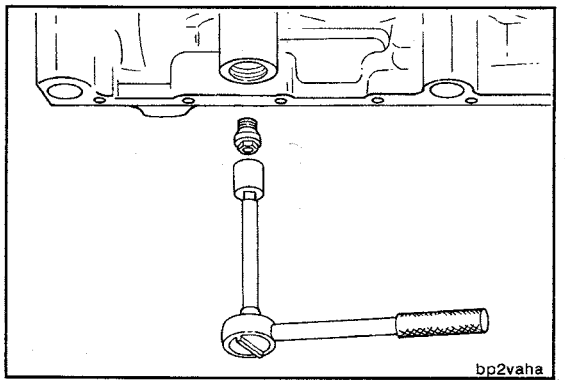
Remove (007-041-002)

Drain the lubricating oil. Refer to Procedure 007-025.

Remove the oil pan. Refer to Procedure 007-025.



Remove the main oil pressure regulator. Refer to Procedure 007-029.

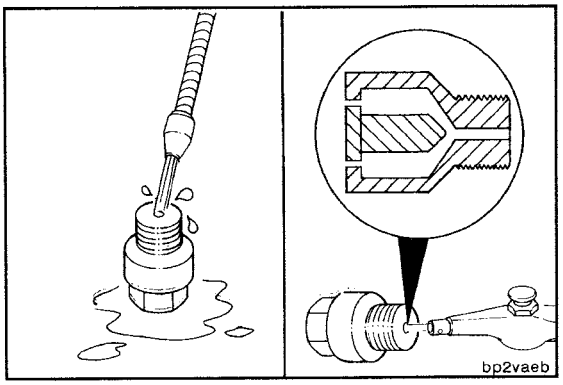


Remove the viscosity sensor with a 7/16-inch socket, an extension, and ratchet.

Inspect for Reuse (007-041-007)

If the viscosity sensor is plugged or contains debris, it **must** be cleaned.

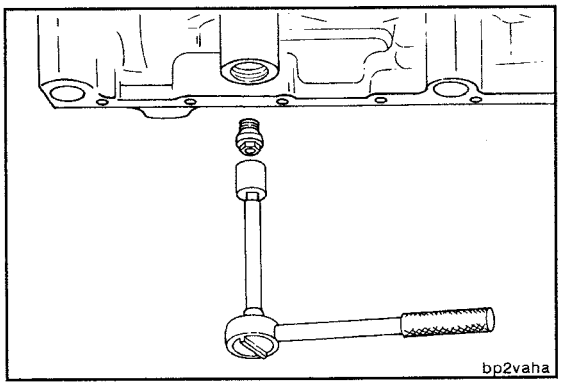
Use solvent and compressed air to remove the debris. If the viscosity sensor can**not** be cleaned of all debris, it **must** be replaced.



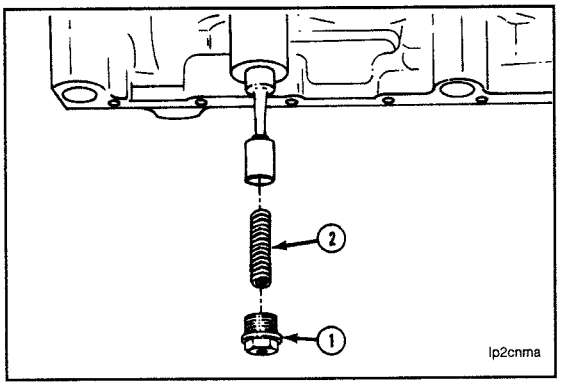
Install (007-041-026)

Install the viscosity sensor in the cylinder block.

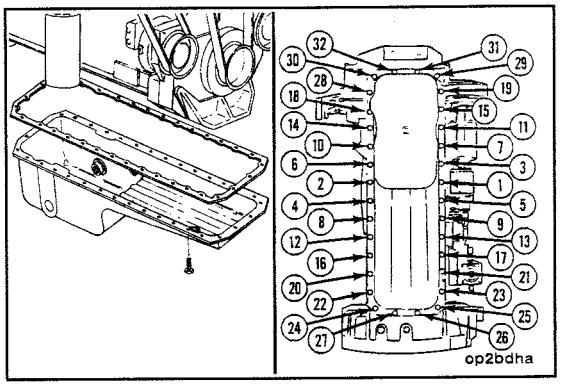
Torque Value: 24 N•m [18 ft-lb]

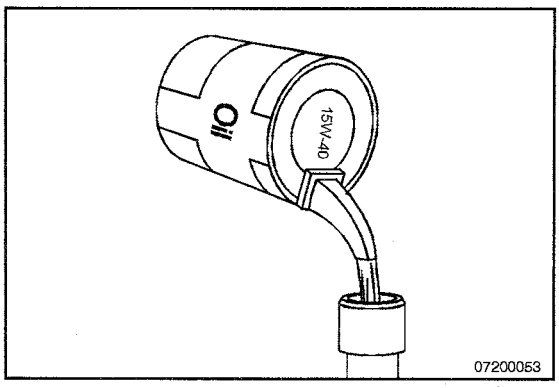


Install the main oil pressure regulator. Refer to Procedure 007-029.

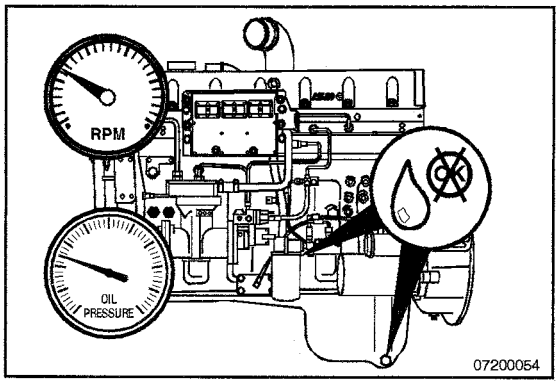


Install the oil pan. Refer to Procedure 007-025.



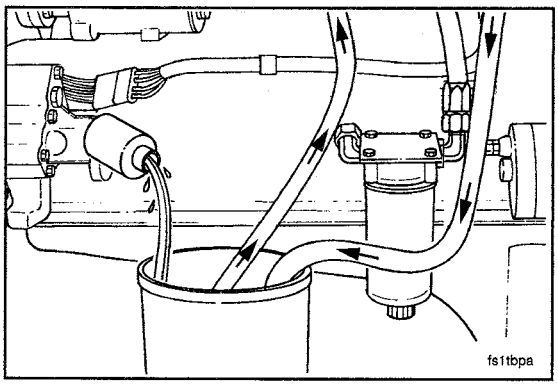


Fill the engine with clean 15W-40 oil. Refer to Procedure 007-025.



NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

Operate the engine at idle speed for 3 minutes to inspect for leaks.

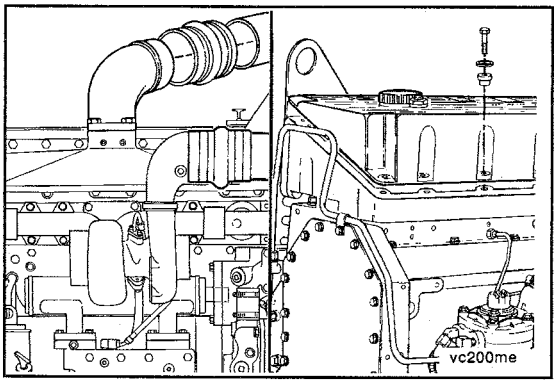


Lubricating Oil Contamination (007-044)

Fluorescent Dye Tracer (007-044-054)

NOTE: This test is **not** effective on a cold engine, less than 21°C [70°F] coolant temperature, or with a loose overhead setting.

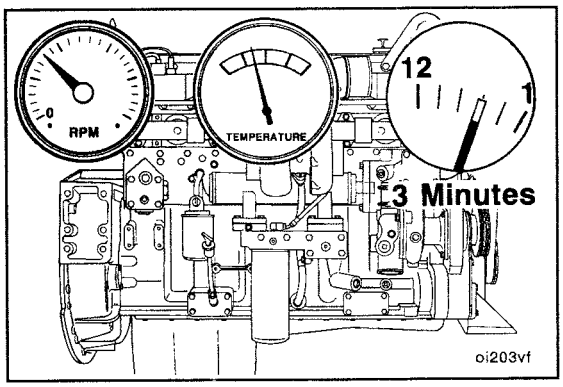
Install an isolated fuel supply tank to the inlet and drain lines. Add fluorescent tracer, Part No. 3376891, to the fuel supply tank.



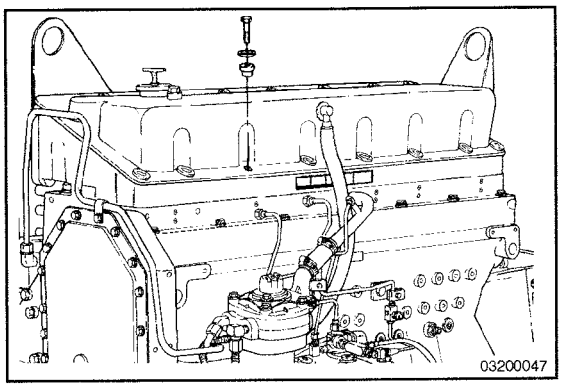
Remove the valve cover mounting hardware, but do **not** remove the valve cover.

Start the engine, and operate it at high idle for 30 seconds. Let the engine go to low idle.

Complete the next step within 5 minutes.

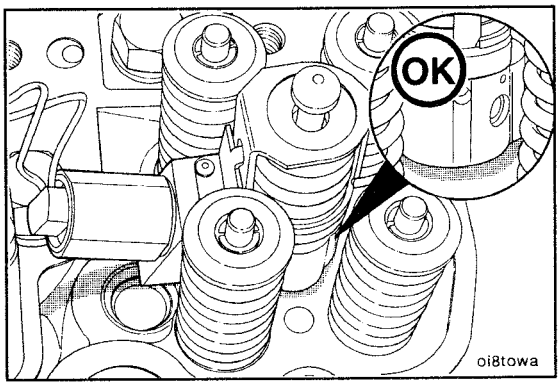


While the engine is operating at low idle, remove the valve cover. Refer to Procedure 003-011.



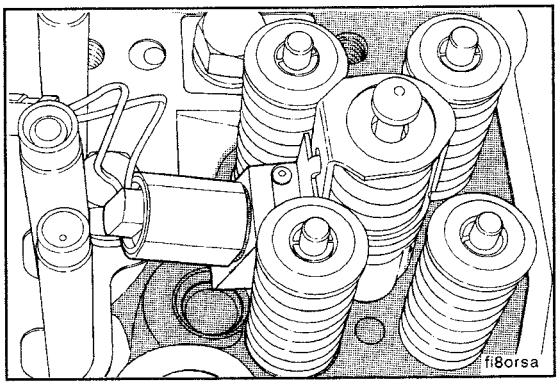
Use black light, Part No. 3377253 or 3377394, to find fuel leaks from inside or around the injector. Refer to the black light operating instructions.

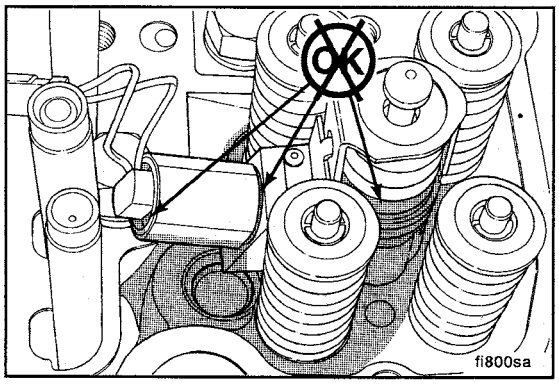
NOTE: Injectors normally have a small amount of fuel leakage.



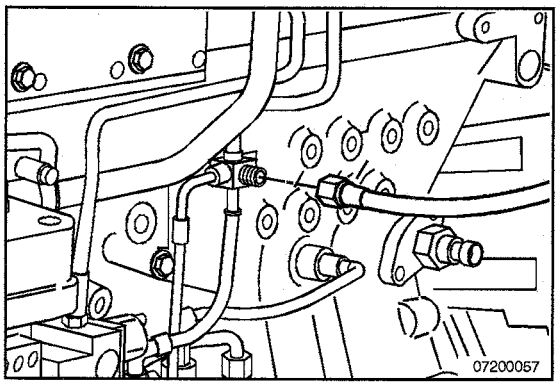
If there is excess leakage around the outside of the injector, check the top o-ring for damage.

Remove the injector and replace all three o-rings. Refer to Procedure 006-026.



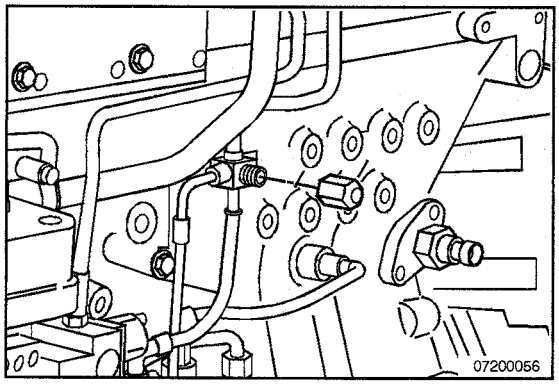


If there is excess leakage from inside the injector, replace the injector. Refer to Procedure 006-026.

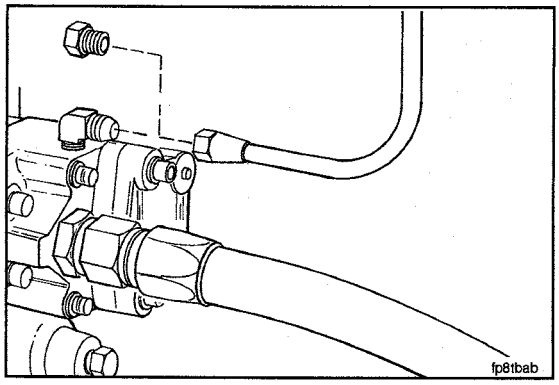


Fuel Pressure Test (007-044-061)

Remove the fuel drain line from the fuel drain tee fitting.



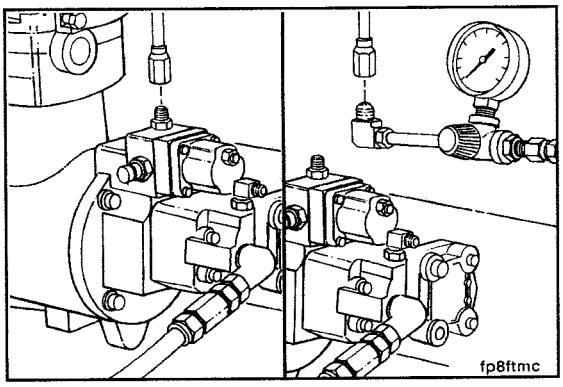
Install a cap on the tee fitting.



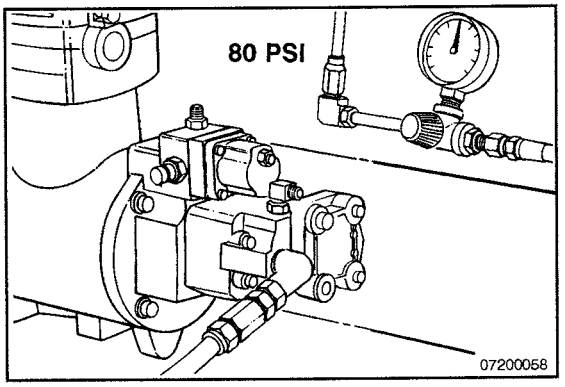
Remove the fuel drain line from the gear pump check valve. Install a plug in the fuel line.

Remove the fuel supply line from the fuel supply pump shutoff valve.

Install a regulated air supply to the fuel supply line.

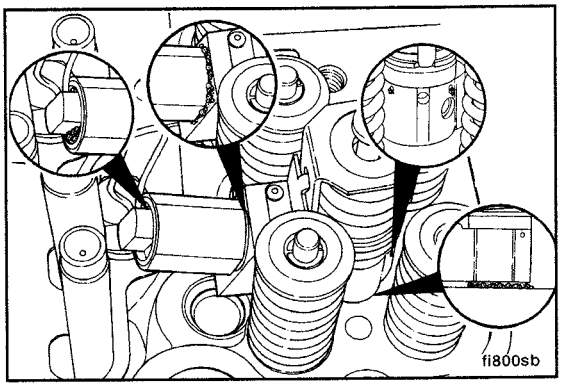


Apply air pressure to the cylinder head. The maximum air pressure is 552 kPa [80 psi].



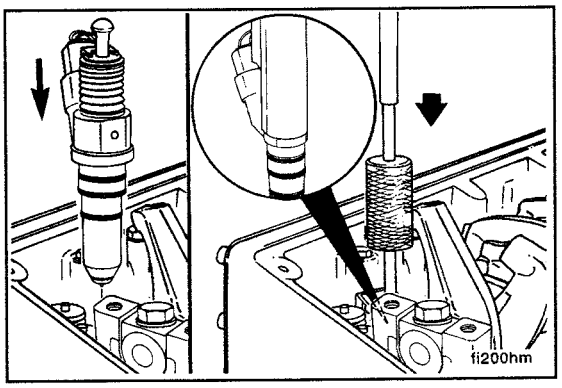
Check for fuel leaks at each injector.

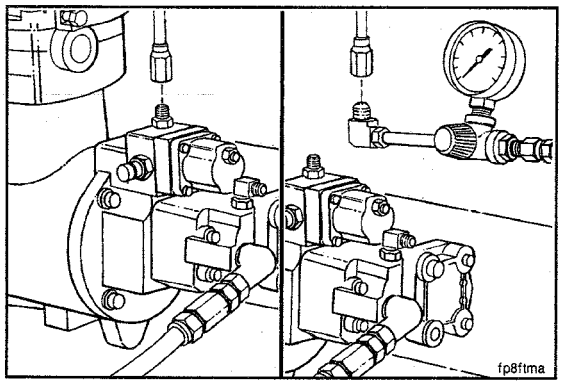
NOTE: A little engine oil is helpful for exposing fuel leaks. Some leaks can be heard.



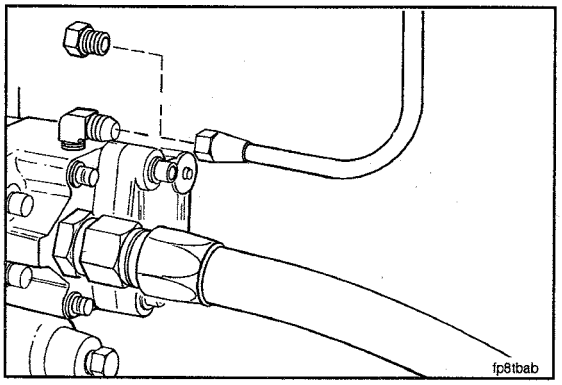
Replace the leaking injector, or replace all three outer o-rings. Refer to Procedure 006-026.

Check the injector for normal leakage.



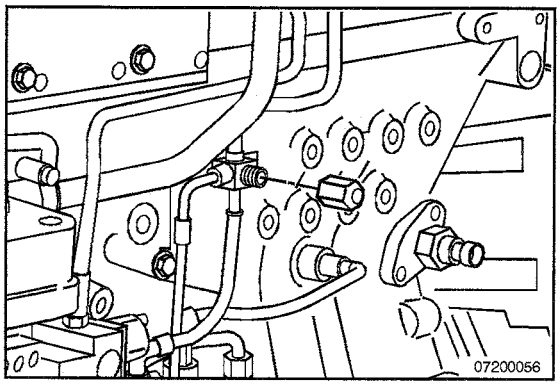


Remove the air line, and install the fuel supply line.

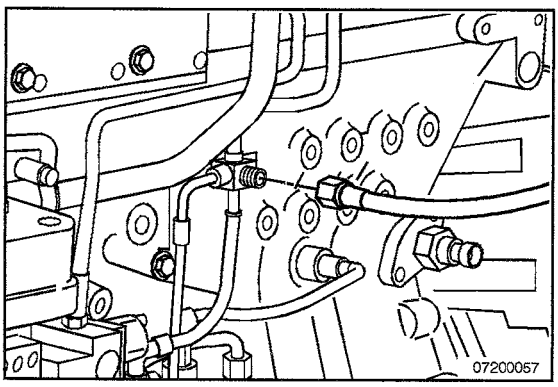


Remove the plug from the gear pump drain line.

Install the drain line on the gear pump check valve.



Remove the cap from the fuel drain line fitting.



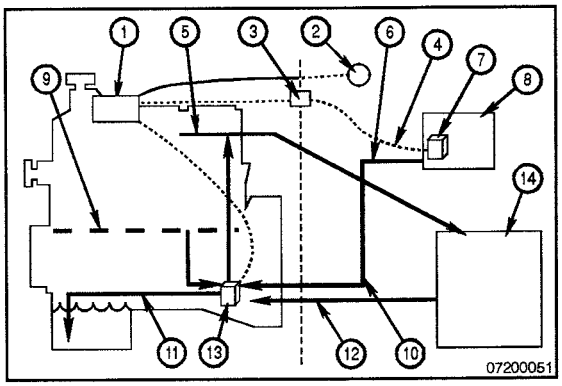
Install the fuel drain line.

Centinel System (ISM Engines) (007-071)

General Information

The integrated Centinel™ system is a continuous oil replacement system of electromechanical design. The Centinel™ system extends oil and filter change intervals through continuous oil exchange. This is accomplished by injecting engine oil at a controlled rate, proportional to fuel consumed, into the fuel system for consumption. Makeup oil (fresh) is introduced into the engine at a rate equal to the oil consumed by Centinel™. The Centinel™ System also monitors the oil level in the makeup tank.

1. Control module
2. Maintenance/fluids lamp
3. 31 pin connector
4. Makeup tank wiring harness
5. Return fuel line
6. Fresh oil to oil control valve
7. Remote oil level switch
8. Makeup oil tank
9. Main oil rifle
10. Hose from makeup oil tank to oil control valve
11. Fresh oil to oil pan
12. Fuel/lube oil blend to engine
13. Oil control valve
14. Vehicle fuel tank.

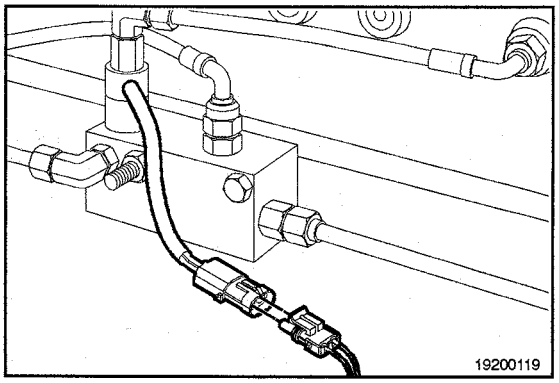


System Description

The integrated Centinel™ system consists of an oil management valve, remote oil level switch, makeup tank, plumbing and wiring.

The control valve is mounted on the engine and is electronically controlled by the ECM. The ECM controls the timing and number of oil management pump piston strokes based on the engine's duty cycle. By using the engine's ECM, any integrated Centinel™ faults light the Maintenance (Fluids) lamp on the dash (INSITE™ also reads these faults and Road Relay displays them). The lamp also illuminates for low oil level in the makeup tank. The oil control valve is plumbed to the engine oil rifle, block (or hand hole cover) and fuel drain connection. There is also a makeup port (1-1/16-12 UNF-2B; straight thread o-ring) in the oil control valve for plumbing from the OEM supplied makeup tank.

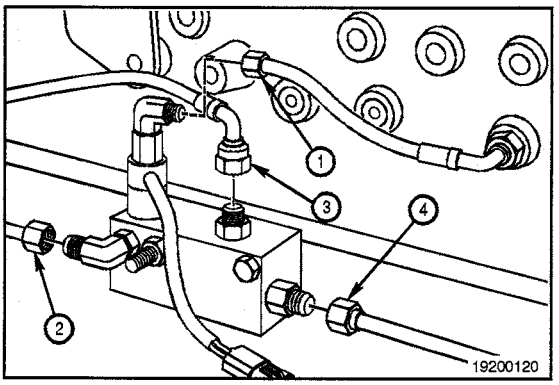
The makeup tank and plumbing is OEM supplied and mounted. In addition, the makeup tank has an OEM supplied remote oil level switch which is wired to the 31 pin OEM interface connector (31 pin connector pins 24 & 25). The makeup tank is plumbed to the oil management pump.



Remove (007-071-002)

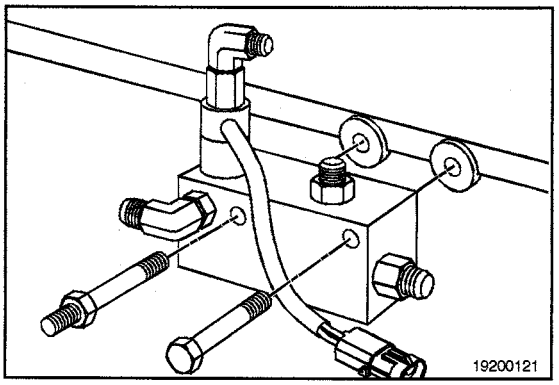
NOTE: With the additional function of controlling the integrated Centinel™ control valve by the ECM, a second fan clutch or Spicer Automate-2 transmission cannot be used.

Disconnect the integrated Centinel™ jumper harness from the control valve unit.

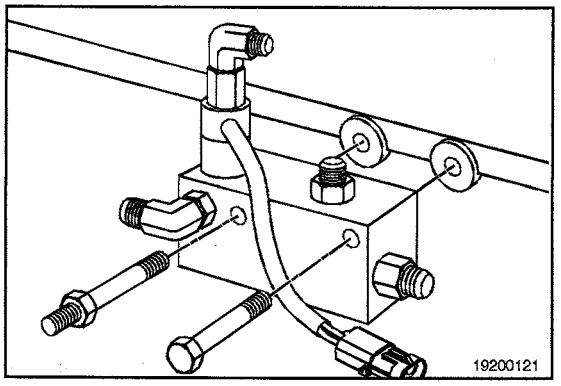


NOTE: Drain oil in makeup tank before disconnecting the fresh oil supply hose (4).

Remove the main engine oil rifle connection (1), fuel drain tee connection (2), oil replenishment hose (3), and fresh oil supply hose (4) from the control valve unit.



Remove one studded capscrew , one flange head capscrew, and the integrated Centinel™ control valve.



Install (007-071-026)

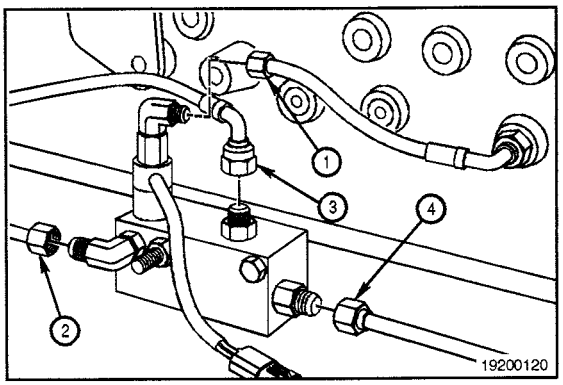
Install the integrated Centinel™ control valve with one studded (M10-1.5) and one flange head (M10-1.5) capscrew.

Tighten the two capscrews.

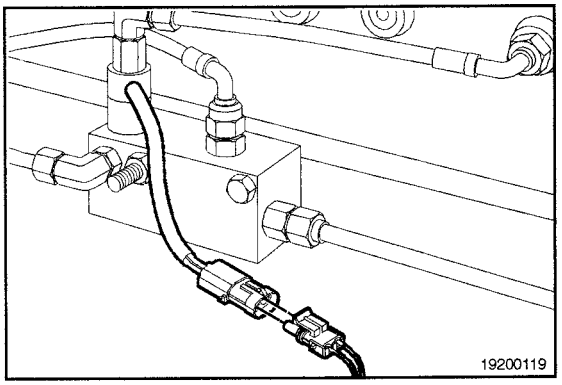
Torque Value: 47 N•m [35 ft-lb]

NOTE: Be sure to fill the makeup tank after installing the fresh oil supply hose.

Connect the main engine oil rifle connection (1), fuel drain tee connection (2), oil replenishment hose (3), and fresh oil supply hose (4) to the control valve unit.



Connect the integrated Centinel™ jumper harness to the control valve unit.

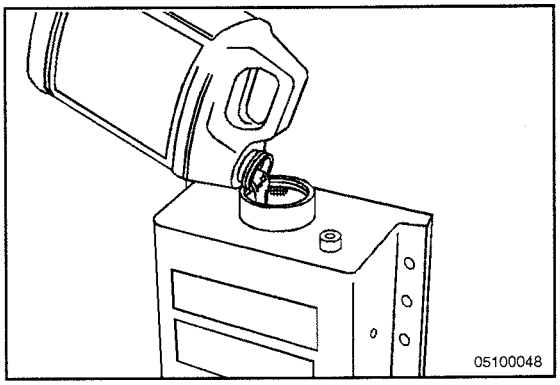


Prime (007-071-050)

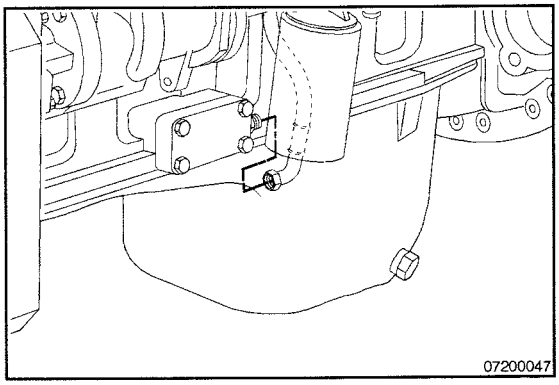
⚠ WARNING ⚠

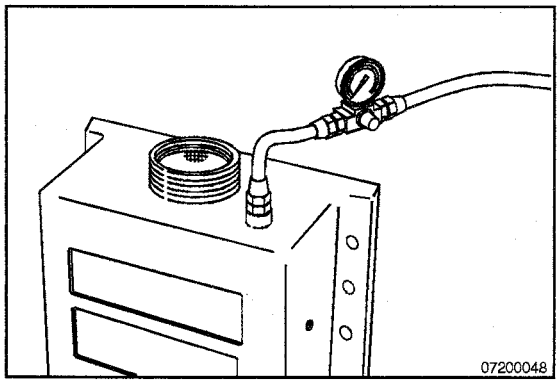
Improper priming may result in no fresh oil replenishment from the makeup tank due to trapped air in the makeup system.

Fill the makeup tank with oil.

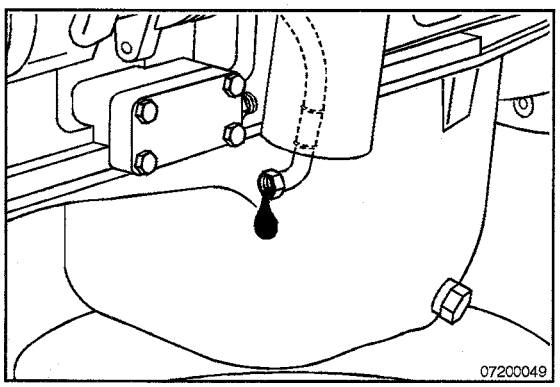


Disconnect the oil replenishment hose from the hand-hole cover and route into an oil container.



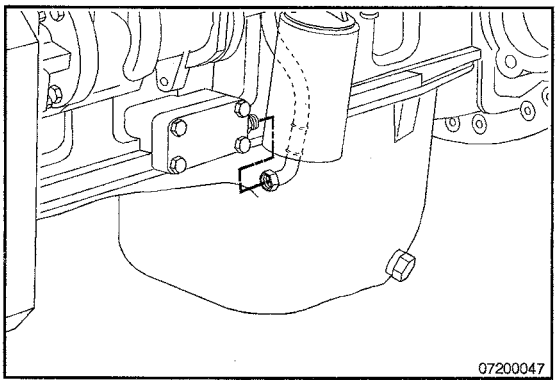


Apply 70 kPa of regulated shop air to the makeup tank to force oil through the hoses and valve. Temporarily plug any makeup tank vents if necessary. Regulated shop air pressure may need to be increased in 13-20 kPa increments, **not** to exceed 103 kPa.

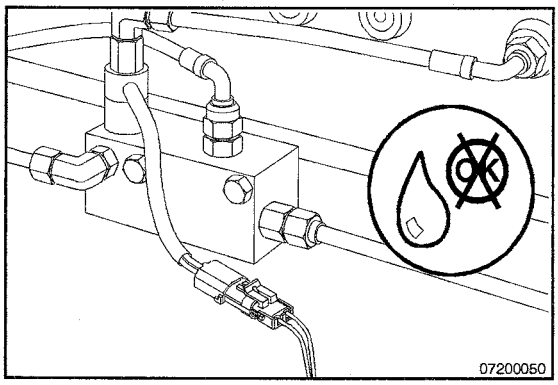


NOTE: Oil flow from the oil replenishment hose may take a few minutes depending on length of fresh oil supply line. If oil will not flow, check the outlet valve on the Centinel™ valve.

Monitor the disconnected oil replenishment hose for oil flow.



Once oil flows out of the hose, the system has been primed. Disconnect the shop air supply from the makeup tank and reconnect the oil replenishment hose to the hand-hole cover. Unplug the makeup tank vent(s) if necessary and replace the fill cap.



Check all oil hoses and fittings for leaks. Tighten fittings if necessary.

Section 8 - Cooling System - Group 08

Section Contents

Page

Coolant Filter 8-16
Install 8-17
Remove 8-16

Coolant Filter Head 8-19
Clean 8-19
Inspect for Reuse 8-19
Install 8-20
Remove 8-19

Coolant Heater Housing 8-21
Clean 8-22
Inspect for Reuse 8-22
Install 8-22
Remove 8-21

Coolant Temperature Gauge 8-16
Initial Check 8-16

Coolant Thermostat 8-23
Inspect for Reuse 8-26
Install 8-27
Leak Test 8-23
Remove 8-25

Coolant Thermostat Housing Support 8-28
Clean 8-30
Inspect for Reuse 8-30
Install 8-30
Remove 8-28

Coolant Thermostat Seal 8-33
Clean 8-33
Inspect for Reuse 8-33
Install 8-34
Remove 8-33

Coolant Vent Lines 8-35
Initial Check 8-35

Cooling System 8-36
Clean 8-36
Drain 8-36
Fill 8-39
Pressure Test 8-41

Cooling System - Air or Combustion Gas Test 8-42
Initial Check 8-42
Air in Cooling System 8-42
Leak Test 8-43
Air Compressor 8-44
Combustion Gas Leak 8-45
Fan, Shutter, or Heater Air Control Valve 8-43

Cooling System - General Information 8-1
General Information 8-1

Cooling System Diagnostics 8-48
Analyzing the Data 8-52
General Information 8-48
Setup 8-49
Test 8-50
Operational Worksheet 8-51

Cooling System Precharge 8-53
Customer Precharge Method 8-54
Factory Precharge Method 8-53
General Information 8-53

Page

Drive Belt, Cooling Fan 8-14
Inspect for Reuse 8-14
Install 8-15
Remove 8-14

Fan Clutch, Air-Disengaged 8-54
Maintenance Check 8-54

Fan Clutch, Air-Engaged 8-54
Maintenance Check 8-54

Fan Clutch, Electric 8-55
Inspect for Reuse 8-56
Install 8-57
Remove 8-55

Fan Clutch, On-Off 8-58
General Information 8-58
Initial Check 8-59

Fan Clutch, Viscous 8-60
General Information 8-60
Initial Check 8-60
Install 8-64
Remove 8-63

Fan, Cooling 8-69
Inspect for Reuse 8-69
Install 8-70
Remove 8-69

Fan Drive Idler Pulley Assembly 8-64
Initial Check 8-64
Install 8-65
Remove 8-64

Fan Hub, Belt Driven 8-66
Initial Check 8-66
Install 8-67
Remove 8-66

Fan Shroud Assembly 8-67
Initial Check 8-67

Fan Spacer and Pulley 8-68
Inspect for Reuse 8-68
Install 8-68
Remove 8-68

Flow Diagram, Cooling System 8-2
Flow Diagram 8-2

Radiator 8-70
Initial Check 8-70

Radiator Hoses 8-71
Inspect for Reuse 8-71

Radiator Pressure Cap 8-71
Inspect for Reuse 8-71

Radiator Shutter Assembly 8-72
Initial Check 8-72

Service Tools 8-12
Cooling System 8-12

Specifications 8-3
Coolant Replacement Requirements 8-11
Cooling System 8-3
Cooling System Sealing Additives 8-6
Cooling System Soluble Oils 8-6
Fleetguard® DCA4 Service Filters and Liquid Precharge 8-8
Fully Formulated Coolant/Antifreeze 8-5
General Information 8-4

Page

Supplemental Coolant Additive (SCA) 8-7
Test Intervals 8-10
Testing SCA Concentration Level CC-2602 Test Kit 8-9
Thermo Control Settings 8-4

Torque Converter Cooler 8-79
General Information 8-79

Water Pump 8-72
Clean 8-75
Inspect for Reuse 8-75
Install 8-76
Remove 8-72

Wiring Harness, Cummins Electric Fan Clutch 8-80
General Information 8-80
Initial Check 8-80
Install 8-86
Remove 8-84

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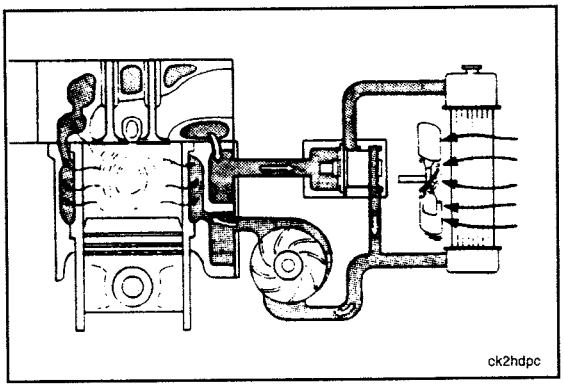
Cooling System - General Information

General Information

The primary function of the cooling system is to remove the heat created by the engine and its support components. The excess heat energy that is **not** removed by the cooling system is carried away by exhaust gases and radiation into the atmosphere.

The coolant **must** be made up of proper proportions of water, antifreeze and supplemental coolant additives (SCA) to properly perform these functions.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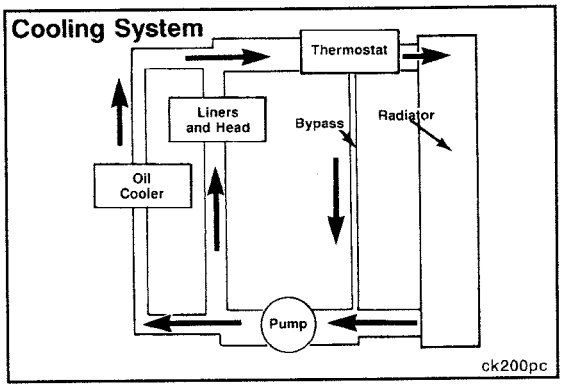
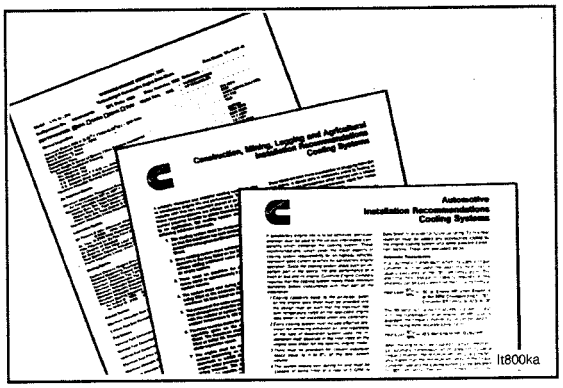
The accompanying chart illustrates the coolant flow through the engine. For more detail, refer to the coolant flow diagrams.

- Charge Air Cooled Engines



The following publications, available through Cummins Distributors or Dealers, provide cooling system installation recommendations and specifications approved by Cummins Engine Company, Inc.:

- Automotive Installation Recommendations (Cooling System), Bulletin No. 3382413.
- Construction, Mining, Logging, and Agriculture Installation Recommendations (Cooling System), Bulletin No. 3382171.
- Data Sheets for specific engine models.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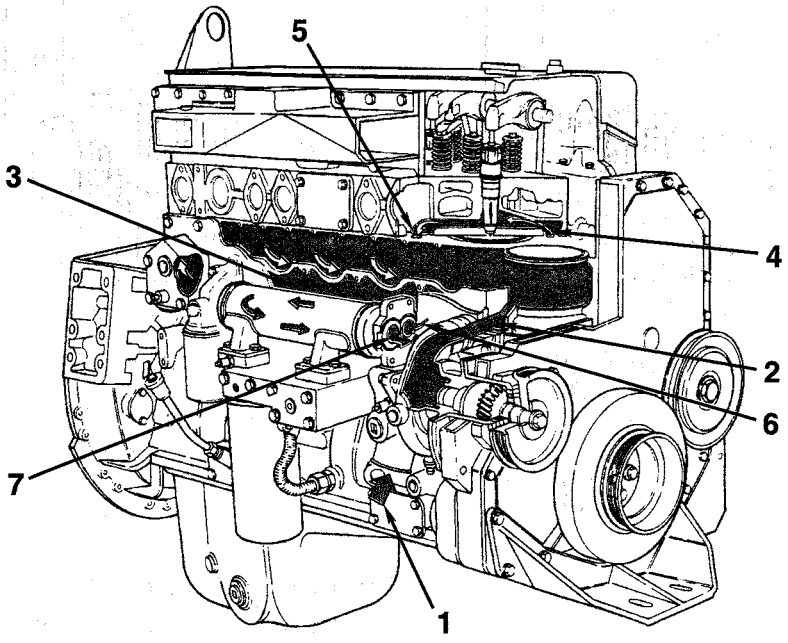
Flow Diagram, Cooling System

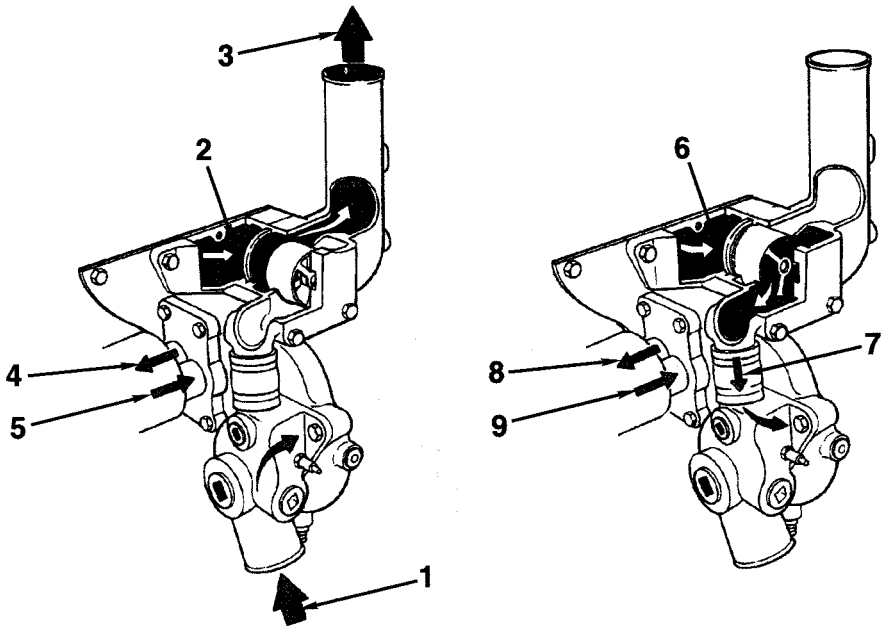
Flow Diagram

CHARGE AIR COOLED ENGINES



08200086

1. Water Pump Coolant Inlet
2. Coolant to Lower Manifold Cavity
3. Coolant to Cylinder Liner Block Cavity
4. Coolant to Cylinder Head
5. Coolant to Upper Manifold Cavity
6. Lower Manifold Coolant to Oil Cooler
7. Oil Cooler to Upper Manifold Cavity.



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THERMOSTAT OPEN

1. Water Pump Coolant Inlet
2. Upper Manifold Cavity
3. Coolant Outlet
4. Lower Manifold Cavity to Cooler
5. Cooler to Upper Manifold Cavity (before thermostat).

THERMOSTAT CLOSED

6. Upper Manifold Cavity (coolant to thermostat)
7. Coolant Bypass (return to water pump)
8. Lower Manifold Cavity to Cooler
9. Cooler to Upper Manifold Cavity (before thermostat).

Specifications

Cooling System

Coolant Capacity (engine **only**) ..... 9.5 liters [10 qt]

Standard Modulating Thermostat Range ..... 82 to 93°C [180 to 200°F]

Cylinder Block Coolant Pressure (pressure cap removed):

Minimum
Closed Thermostat - 1800 rpm - No Load ..... 138 kPa [20 psi]

Maximum
Closed Thermostat ..... 275 kPa [40 psi]

Maximum Allowable Operating Coolant Temperature ..... 100°C [212°F]

Minimum Recommended Operating Coolant Temperature ..... 70°C [160°F]

Minimum Recommended Pressure Cap ..... 48 kPa [7 psi]

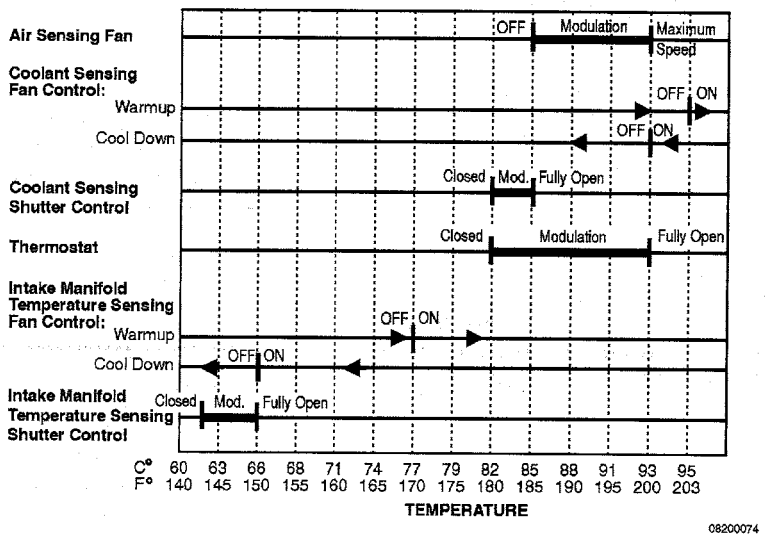
Maximum Allowable Coolant Flow to Accessories (liters/minute [gpm]) ..... 75.7 Liters [20 gal]

Coolant Sensing Fan Control:

On ..... 96°C [205°F]
Off ..... 91°C [195°F]

Thermo Control Settings

The temperatures listed in this chart for coolant temperature sensing fan control and intake manifold temperature sensing fan control are correct for vehicles that allow the ECM to control the on/off operation of the cooling fan. Consult your local OEM for other types of control.



General Information

Cummins recommends the use of fully formulated antifreeze or coolant containing a precharge of supplemental coolant additive (SCA). The antifreeze or coolant **must** meet the specifications outlined in The Maintenance Council (TMC) Recommended Practice (RP) 329 (ethylene glycol) or RP 330 (propylene glycol). The use of fully formulated antifreeze or coolant significantly simplifies cooling system maintenance.

Copies of TMC specifications can be obtained through Cummins Engine Company, Inc., or by contacting:

The Maintenance Council
American Trucking Association
2200 Mill Road
Alexandria, VA 22314-5388
Phone: (703) 838-1763
Fax (703) 836-6070

Fully formulated **antifreeze** contains balanced amounts of antifreeze, SCA, and buffering compounds, but does **not** contain 50-percent water. Fully formulated **coolant** contains balanced amounts of antifreeze, SCA, and buffering compounds already premixed 50/50 with deionized water.

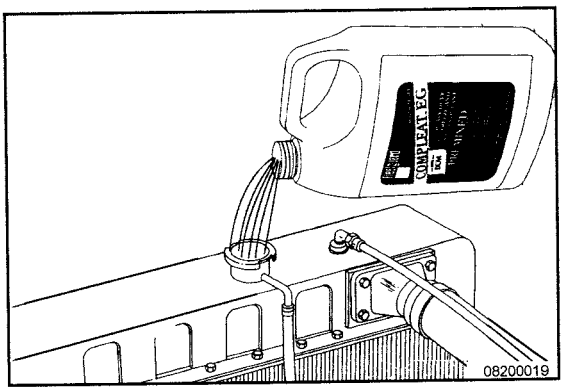
The following pages will give an explanation of water, antifreeze, and SCA's. They will also explain how to test antifreeze and SCA levels.

This section also contains information on cooling system maintenance and a coolant treatment chart that is used to determine the correct SCA service filter.

Alternative maintenance practices for cooling systems can be found in Cummins Coolant Requirements and Maintenance, Bulletin No.3666132.

Fully Formulated Coolant/Antifreeze

Cummins Engine Company, Inc., recommends using either a 50/50 mixture of good-quality water and fully formulated antifreeze, or fully formulated coolant when filling the cooling system. The fully formulated antifreeze or coolant **must** meet TMC RP 329 or TMC RP 330 specifications.



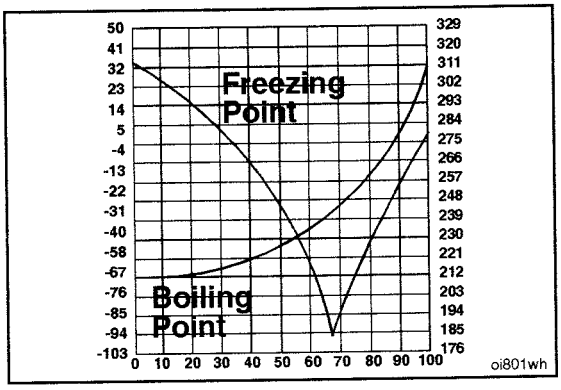
Good-quality water is important for cooling system performance. Excessive levels of calcium and magnesium contribute to scaling problems, and excessive levels of chlorides and sulfates cause cooling system corrosion.

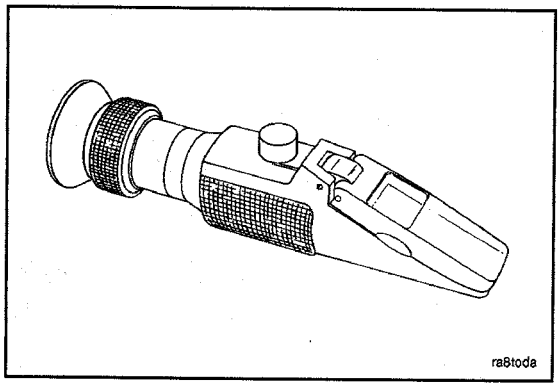
Water Quality	
Calcium Magnesium (Hardness)	Maximum 170 ppm as ($CaCO_3$ + $MgCO_3$)
Chloride	40 ppm as(Cl)
Sulfur	100 ppm as (SO_4)

18200001

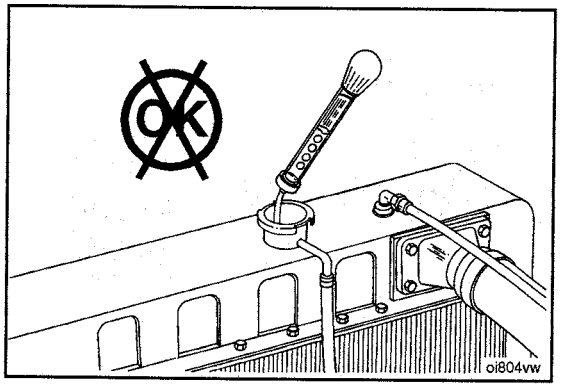
Cummins Engine Company, Inc., recommends using Fleetguard® Compleat. It is available in both glycol forms (ethelyne and propylene) and complies with TMC RP 329 or TMC RP 330 standards.

Fully formulated antifreeze **must** be mixed with good-quality water at a 50/50 ratio (40- to 60-percent working range). A 50/50 mixture of antifreeze and water gives a -36°C [-34°F] freezing point and a boiling point of 110°C [228°F], which is adequate for locations in North America. The actual lowest freezing point of ethylene glycol antifreeze is at 68 percent. Using higher concentrations of antifreeze will raise the freezing point of the solution and increase the possibility of a silica gel problem.

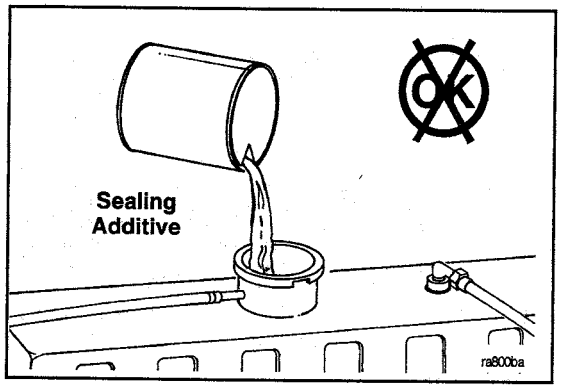




A refractometer, Part No. CC-2800, **must** be used to measure the freezing point of the coolant accurately.



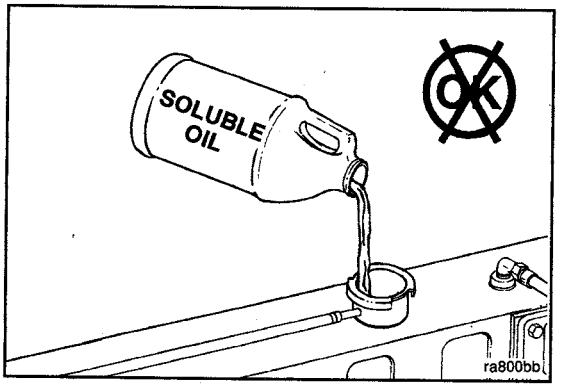
Do **not** use a floating ball hydrometer. Using floating ball hydrometers can give an incorrect reading.



Cooling System Sealing Additives

Do **not** use sealing additives in the cooling systems. The use of sealing additives will:

- Build up in coolant low-flow areas
- Clog coolant filters
- Plug radiator and oil cooler.



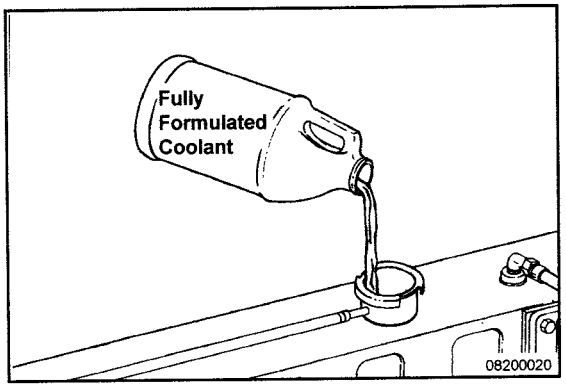
Cooling System Soluble Oils

Do **not** use soluble oils in the cooling system. The use of soluble oils will:

- Allow cylinder liner pitting
- Corrode brass and copper
- Damage heat transfer surfaces
- Damage seals and hoses.

Supplemental Coolant Additive (SCA)

Fully formulated products contain SCA and are required to protect the cooling system from fouling, solder blooming, and general corrosion. The cooling filter is required to protect the coolant system from abrasive materials, debris, and precipitated coolant additives.

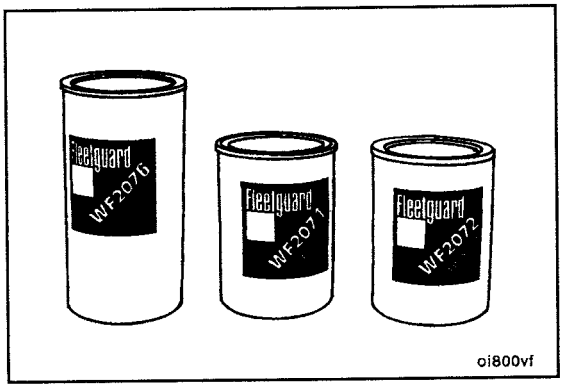


Supplemental coolant additives, or equivalent, are used to prevent liner pitting, corrosion, and scale deposits in the cooling system.

Use the correct Fleetguard® coolant filter to maintain the recommended SCA concentration in the system.

Maintain the correct concentration by changing the service filter at each oil drain interval.

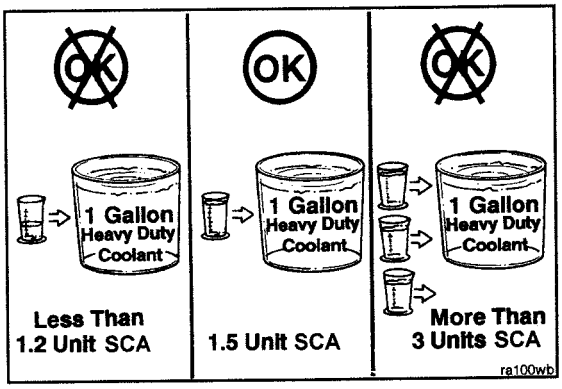
NOTE: The correct filter is determined by the total cooling system capacity and oil drain interval. Refer to the Coolant Capacity Specifications in this section.



⚠ CAUTION ⚠

Insufficient concentration of the coolant additives will result in liner pitting and engine failure.

The SCA concentration **must not** fall below 1.2 units or exceed 3 units per gallon of cooling system capacity.



Fleetguard® DCA4 Service Filters and Liquid Precharge

DCA4[1] Service Filters:		DCA[1] (Fleetcool) Service Filters:	
Part No.	SCA Units	Part No.	SCA Units
WF2070	2	WF2050	2
WF2071	4	WF2051	4
WF2072	6	WF2052	6
WF2073	8	WF2053	8
WF2074	12	**Not**Available	12
WF2075	15	WF2054	15
WF2076	23	WF2055	23
WF2077	(blank filter without SCAs)	WF2077	(blank filter without SCAs)

Note:

(1) DCA4 (phosphate/nitrite/molybdate chemistry) and DCA (borate/nitrite chemistry) meets Cummins requirements for supplemental coolant additives.

Part No.	DCA4 Liquid Size	SCA Units	Part No.	DCA (Fleetcool) Liquid Size	SCA Units
DCA60L	0.47 liters [1 pt]	5	DCA30L	0.47 liters [1 pt]	5
DCA65L	1.89 liters [2 qt]	20	DCA35L	1.89 liters [2 qt]	20
DCA70L	3.78 liters [1 gal]	40	DCA40L	3.78 liters [1 gal]	40
DCA75L	18.9 liters [5 gal]	200	DCA45L	18.9 liters [5 gal]	200
DCA80L	208 liters [55 gal]	2200	DCA50L	208 liters [55 gal]	2200

Maintenance Intervals for Cooling Systems up to 76 Liters [20 Gallons]

Install service filter(s) and/or liquid containing number of SCA units below:

Service Interval			System Size in Liters [U.S. Gallons]			
Kilometers	[Miles]	[Hours]	4 to 19 [1 to 5]	19 to 38 [6 to 10]	42 to 57 [11 to 15]	60 to 76 [16 to 20]
72,001 to 80,000	[45,001 to 50,000]	1126 to 1250	8	12	23	30
64,001 to 72,000	[40,001 to 45,000]	1001 to 1125	4	12	15	26
56,001 to 64,000	[35,001 to 40,000]	876 to 1000	4	8	12	23
48,001 to 56,000	[30,001 to 35,000]	751 to 875	4	6	12	20
40,001 to 48,000	[25,001 to 30,000]	626 to 750	4	6	10	18
32,001 to 40,000	[20,001 to 25,000]	501 to 625	2	6	8	15
24,001 to 32,000	[15,001 to 20,000]	376 to 500	2	4	6	12
16,001 to 24,000	[10,001 to 15,000]	251 to 375	2	4	6	8
0 to 16,000	[0 to 10,000]	0 to 250	2	2	4	6

Maintenance Intervals for Cooling System up to 1514 Liters [400 Gallons]

Install service filter(s) and/or liquid containing number of SCA units below:

Service Interval	System Size in Liters [Gallons]									
	79 to 144	117 to 189	193 to 284	288 to 378	382 to 568	572 to 757	761 to 946	950 to 1135	1139 to 1325	1329 to 1574
Hours	[21 to 30]	[31 to 50]	[51 to 75]	[76 to 100]	[101 to 150]	[151 to 200]	[201 to 250]	[251 to 300]	[301 to 350]	[351 to 400]
751 to 1000	25	50	80	100	150	200	250	300	350	400
501 to 750	20	35	60	75	110	150	190	225	260	300
251 to 500	15	25	40	50	75	100	125	150	175	200
0 to 250	10	15	20	25	40	50	65	75	90	100

Notes:

A. Consult the vehicle equipment manufacturer's maintenance information for total cooling system capacity.

B. When draining and replacing the coolant, **always** precharge the cooling system to an SCA level of 1.5 units per gallon. This concentration level **must never** be allowed to go below 1.2 units and **must** be controlled when the level is greater than 3 units. Action needed when the level goes below 1.2 is a filter and liquid precharge from 1.2 to 3 units, filter **only**; above 3, test at every oil change until level falls to 3 or below.

NOTE: When performing service that requires draining the cooling system, take special precautions to collect it in a clean container, seal it to prevent contamination, and save for reuse.

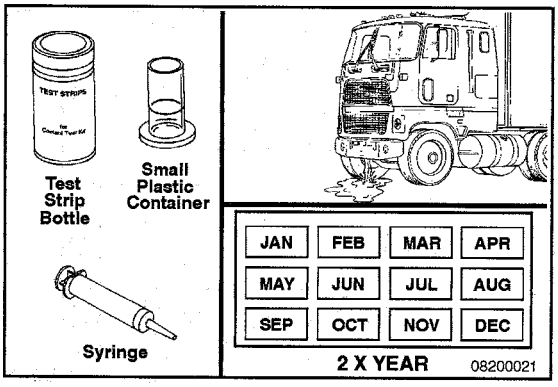
C. Change coolant filters at each oil change to protect the cooling system. Consult the coolant capacity chart to determine the correct coolant filter for a given cooling system capacity and oil drain interval.

Testing SCA Concentration Level CC-2602 Test Kit

Carefully follow the instructions to test the coolant, and take the appropriate action recommended by the kit.

Precautions and Instructions for Proper Kit Use

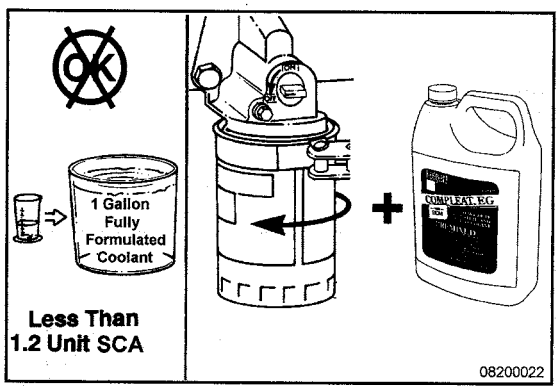
- The coolant sample to be tested **must** be between 10 and 54°C [50 and 130°F]. If the sample is too cold or too hot, you will get incorrect results.
- To get the best color match results, compare test strip pads to the color chart in daylight or under cool white fluorescent lighting. If unsure about a specific color match when a test does fall between two colors on the color chart, choose the lower numbered block. It is safer to underestimate your results than to overestimate.
- The test strips do have a limited shelf life and are sensitive to humidity and extreme heat. Proper handling and storage is necessary to protect the life of the strips.
- Keep the cap tightly sealed on the test strip bottle **except** when removing a strip. Store away from direct sunlight and in an area where the temperature will generally stay below 32°C [90°F].
- Do **not** use the test strips after the expiration date stamped on the bottle.
- Discard the kit if any of the pads on the unused strips have turned light brown or pink.
- Use one strip at a time and take care **not** to touch any of the pads on the strip. Doing so will contaminate the pads and skew the test results.
- If the strip container is left uncapped for 24 hours, moisture in the air will render the strips useless, even though no discoloration will be evident.
- **Only** use the color chart supplied with the kit.
- Clean and dry the sample cup and syringe after each use. This will prevent contamination of future samples.
- Following the correct test times is very important. Use a clock or stopwatch.
- Do **not** utilize the test kit to maintain minimum SCA concentration levels (i.e., 1.5 units).
- When performing service that requires draining the cooling system, take special precautions to collect coolant in a clean container, seal coolant to prevent contamination, and save for reuse.



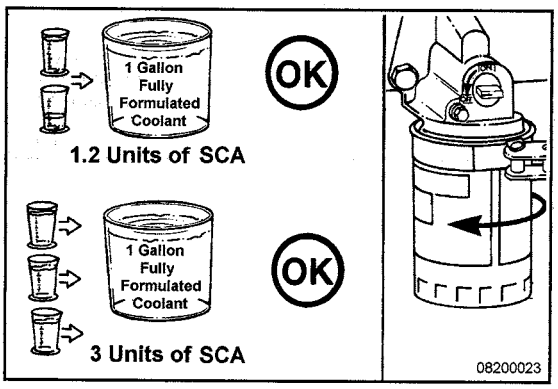
Test Intervals

Testing is recommended if the operator is **not** sure of his cooling system condition due to leaks, uncontrolled topping off of the system, or major coolant loss.

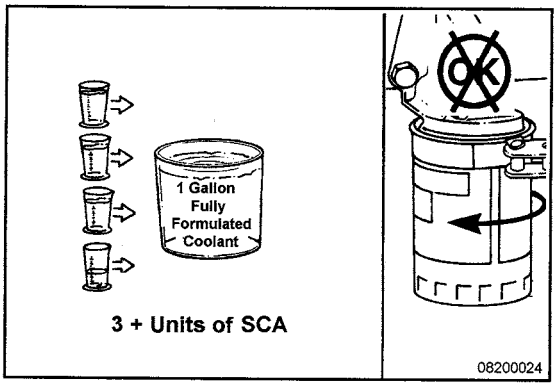
Testing is also recommended twice a year to monitor the SCA level. If the SCA level is above 3 units, test at subsequent oil drain intervals until the concentration is back under 3 units. When the concentration is back under 3 units, start installing the correct service filters at each drain interval.



If the concentration is below 1.2 units per gallon, replace the filter and precharge with liquid.



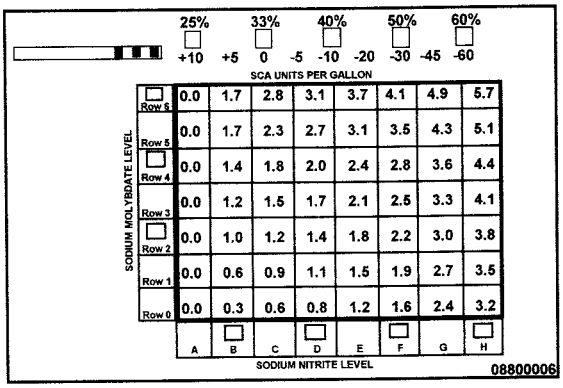
If the concentration is 1.2 to 3 units per gallon, replace the filter.



If the concentration is above 3 units per gallon, do **not** replace the service filter. Test the coolant at subsequent oil drain intervals until the concentration is back under 3 units. When the concentration is back under 3 units, start installing service filters at each oil change interval.

NOTE: Do **not** utilize the test kit to maintain minimum SCA concentration levels (i.e., 1.5 units).

NOTE: In some instances, the A or B reading can be high. However, it is the combined reading that is important. **So, always follow the chart.**

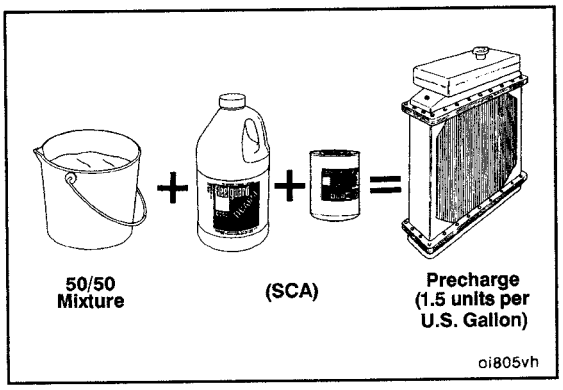


Cummins: **1-800-DIESELS** 1-800-343-7357 **1-800-22-FILTERS** 1-800-223-4583

Coolant Replacement Requirements

Drain and flush the cooling system after 6000 hours or 3 years of service. However, if Fleetguard's® ES Coolant and ES Filters are used, check chloride, sulfate, and pH levels according to Service Bulletin No. 3666209, to determine whether or **not** the coolant **must** be replaced. Refill with either new fully formulated coolant or ES Coolant.

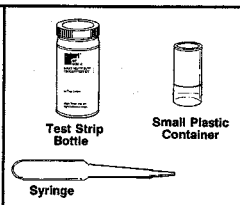
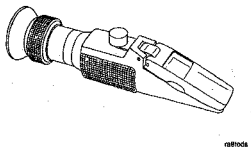
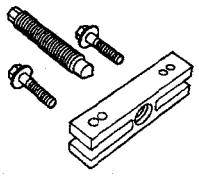
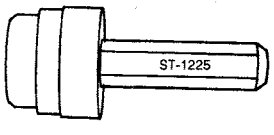
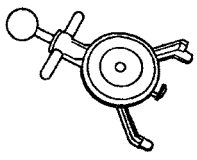
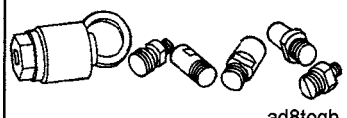
NOTE: Dispose of used coolant/antifreeze in accordance with federal, state, and local laws and regulations.

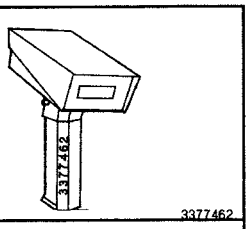
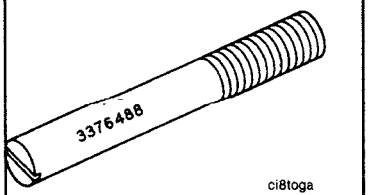
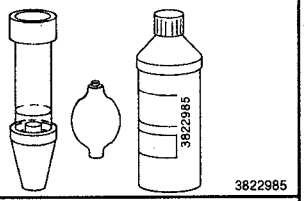
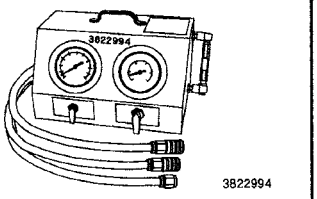
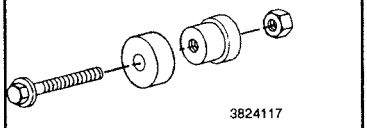


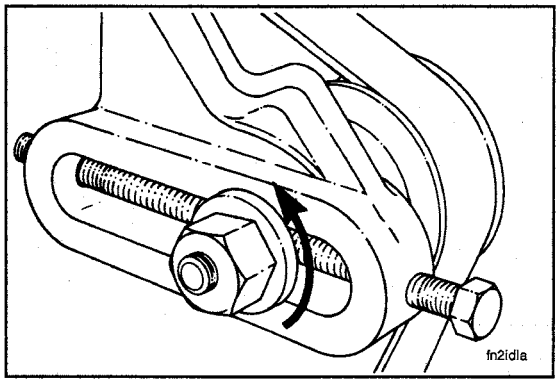
Service Tools

Cooling System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
CC-2602	**Cooling System Test Kit** The Fleetguard® coolant test kit is used to check the concentration of coolant additives in the cooling system.	
CC-2800	**Refractometer** The Fleetguard® refractometer is used to measure the freezing point protection and antifreeze concentration.	
ST-647	**Standard Puller** Remove the stamped steel water pump pulley. Use with two capscrews 5/16 x 18 x 2.	
ST-1225	**Thermostat Seal Mandrel** Install the thermostat seal in the thermostat housing.	
ST-1293	**Belt Tension Gauge** Measure the fan drive v-ribbed belt tension.	
3376326	**Pulley Installation Tool** Install drive pulleys. Use in conjunction with Part No. 3377401 adapter.	

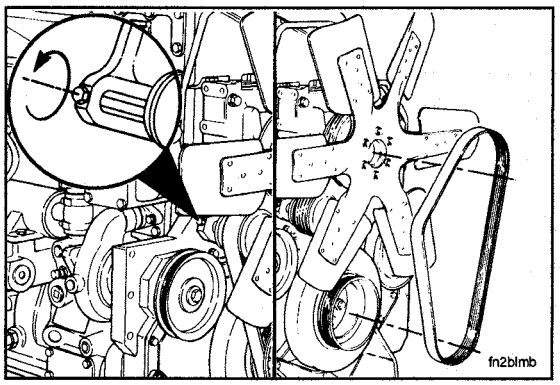
Tool No.	Tool Description	Tool Illustration
3377462	**Digital Optical Tachometer** Used to measure rpm of a viscous fan.	
3376488	**Guide Pin** Two guide pins are used to install the water heater plate.	
3822985	**Combustion Gas Leak Test Kit** Includes: Part No. 3822986, test fluid; Part No. 3822987, adapter; and Part No. 3877612, instructions.	
3822994	**Coolant Pressure/Temperature/Flow Analyzer Kit** Includes: Part No. 3822995 pressure gauge; Part No. 3822996, temperature gauge; Part No. 3822997, Flow Sight Glass, Part No. 3822998 Compuchek® fitting (Female); and Part No. 3377613, instructions. Optional: Part No. 3823099, hose extension kit, is also available.	
3824117	**Bearing Installation Tool** Used to replace the water pump drive needle bearing in the gear housing.	



Drive Belt, Cooling Fan (008-002)

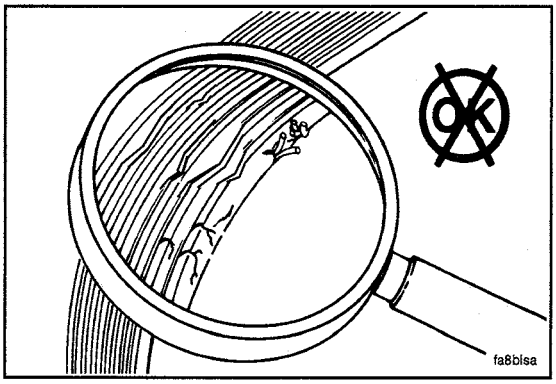
Remove (008-002-002)

Loosen the fan idler pulley shaft locknut.



Turn the adjusting screw **counterclockwise** to release the belt tension.

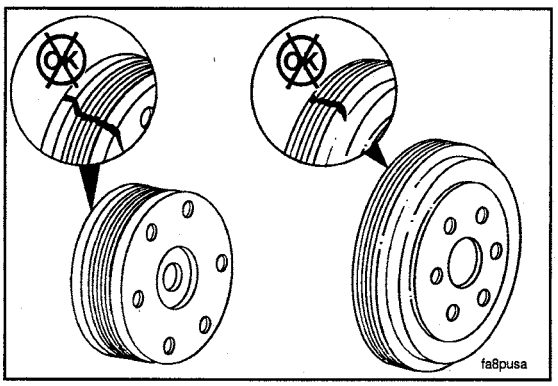
Move the fan idler pulley and fan pulley centers as close as possible. The belt can then be removed without excessive force.



Inspect for Reuse (008-002-007)

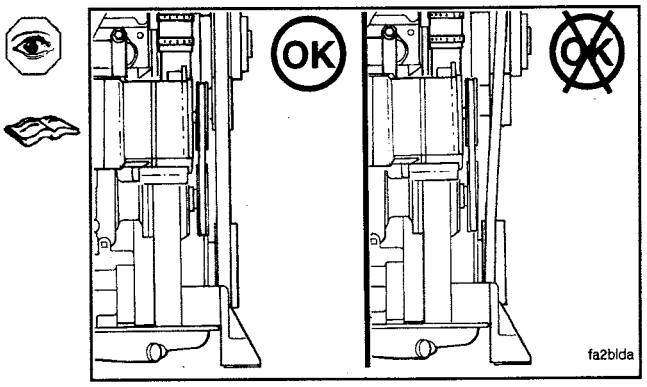
Inspect the belt for:

- Cracks
- Glazing
- Tears or cuts
- Excessive wear.



Inspect the fan idler pulley and the fan drive pulley for cracks or broken grooves. Replace the pulleys if necessary. Refer to Procedures 008-030 and 008-039.

Inspect pulley alignment. Replace the fan idler pulley and fan hub pulley if they are **not** in alignment. Refer to Procedures 008-030 and 008-039.

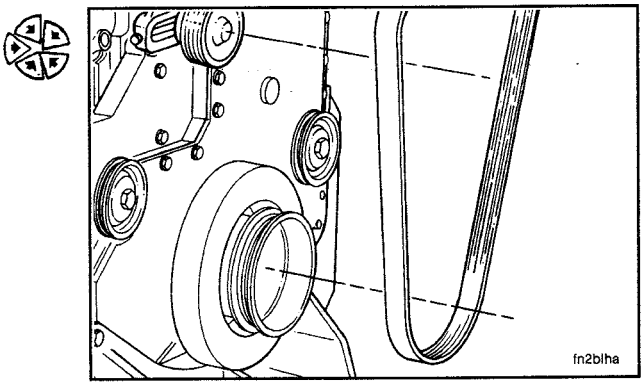


Install (008-002-026)

CAUTION

To prevent damage to the pulley and new belt, do not roll the belt over the pulley or pry it on with a tool.

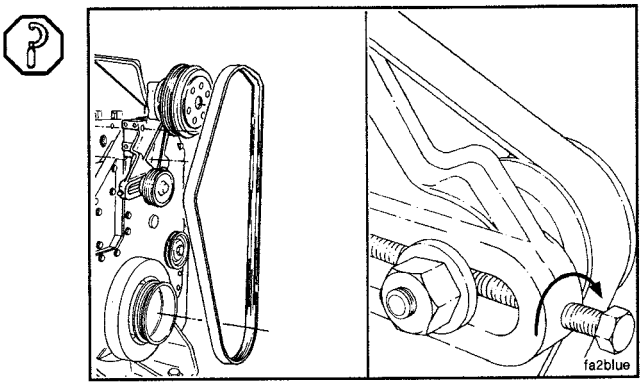
Install a new fan belt on the pulleys.



Use belt tension gauge, Part No. ST-1293, to measure the belt tension. Refer to Drive Belt Tension in Section V of the Operation and Maintenance Manual, ISM Series Engines, Automotive/Transit Bus, Bulletin No. 3666319.

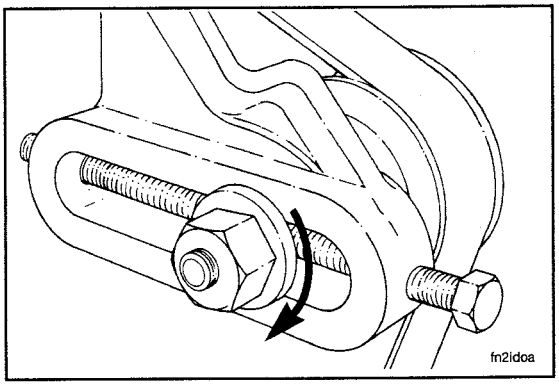
Turn the adjusting screw to adjust the belt tension.

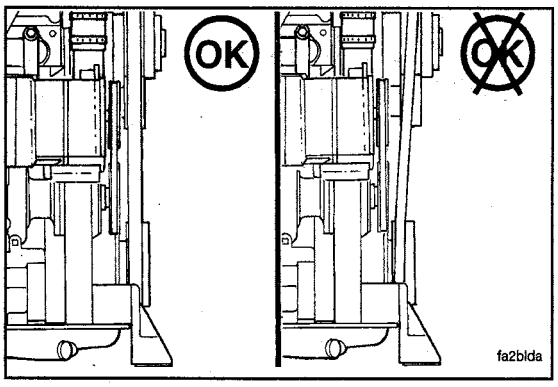
NOTE: A belt is considered used if it has been in operation 10 minutes or longer. If used belt tension is below the minimum value, tighten the belt to the maximum value. Replace the belt if it will **not** maintain correct tension.



Tighten the idler pulley shaft locknut.

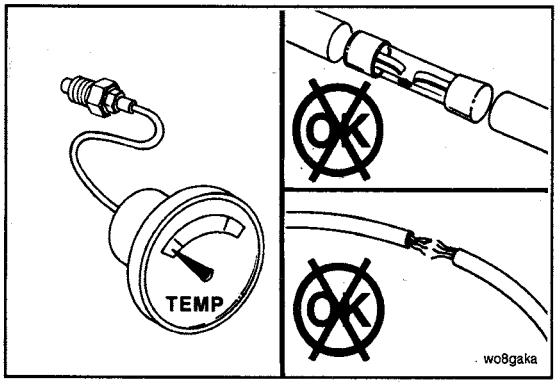
Torque Value: 190 N•m [140 ft-lb]





Inspect pulley alignment.

Pulley misalignment **must not** exceed 6 mm for each meter [1/16 inch for each 12 inches] of distance between the pulley centers.

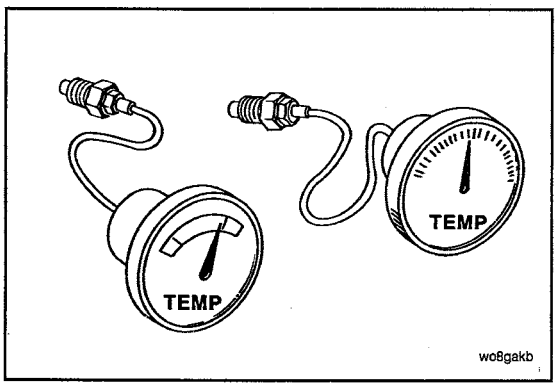


Coolant Temperature Gauge (008-004)

Initial Check (008-004-001)

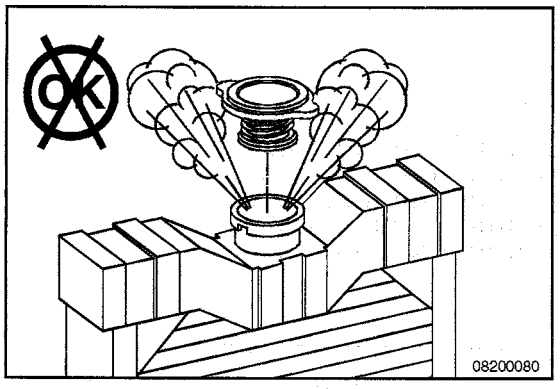
Check for a blown fuse.

Check the wiring from the gauge to the sending unit for a broken connection.



Use a temperature gauge of known accuracy to check the existing gauge.

Replace the gauge if it proves inaccurate..



Coolant Filter (008-006)

Remove (008-006-002)

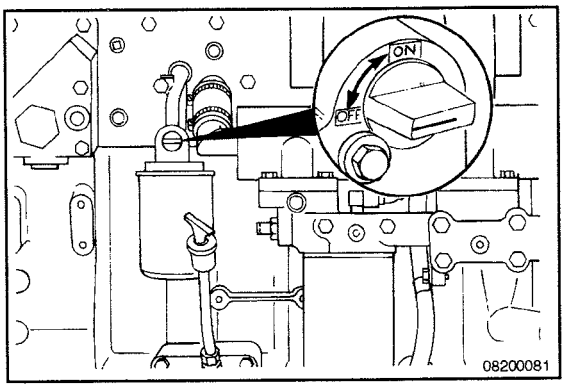
⚠ WARNING ⚠

Do not remove the cooling system pressure cap from a hot engine. Hot steam will cause serious personal injury. Remove the coolant system pressure cap, and close the shutoff valve(s), if equipped, before removing the coolant filter. Failure to do so can result in personal injury from hot coolant spray.

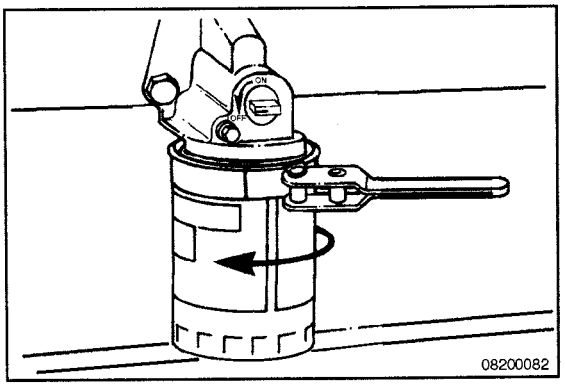
Do **not** use force to open or close the shutoff valve. If the valve does **not** turn freely, refer to Procedure 008-007.

Remove the cooling system pressure cap.

Turn the valve on the coolant filter head to the OFF position.



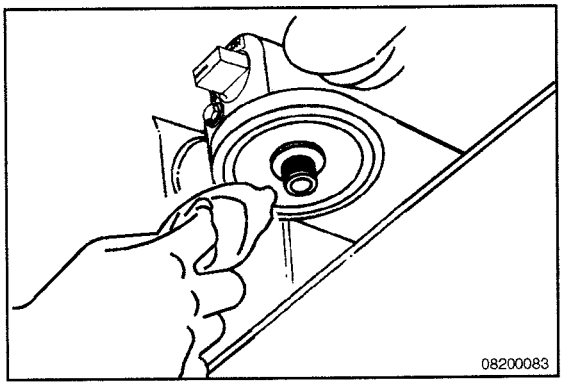
Remove and discard the coolant filter.



⚠ WARNING ⚠

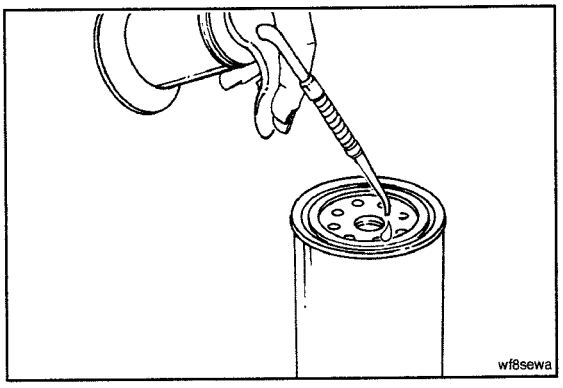
There could be slight coolant leakage with the valve in the OFF position. Use caution when cleaning the gasket surface to avoid contact with hot coolant. Failure to do so can result in personal injury from heated coolant.

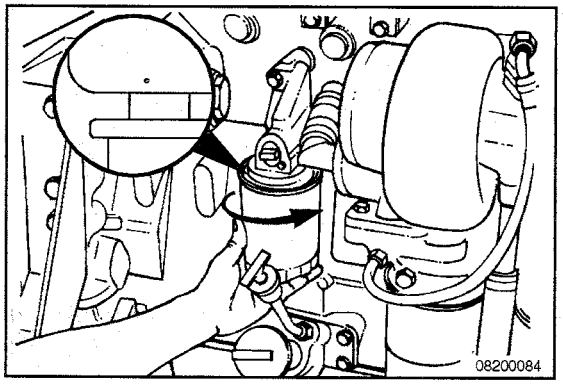
Clean the coolant filter head gasket's surface.



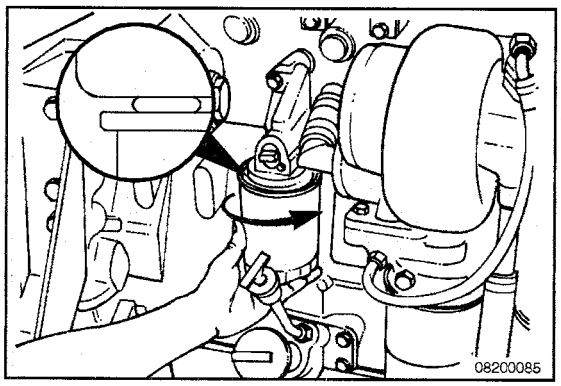
Install (008-006-026)

Apply a thin film of clean engine oil to the gasket sealing surface before installing the new coolant filter.





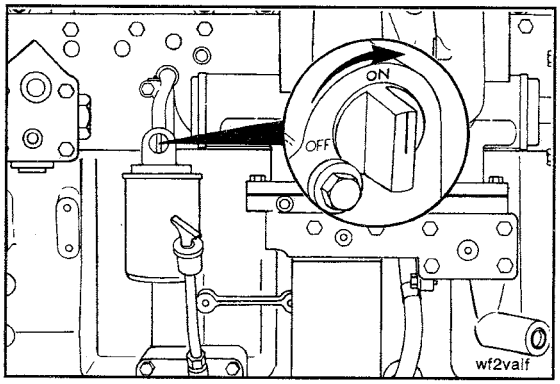
Install the new filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.



△ CAUTION △

Mechanical overtightening can distort the filter threads or damage the filter head.

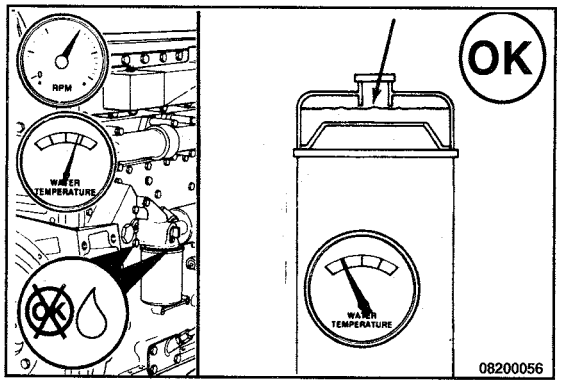
Tighten the filter an additional 1/2 to 3/4 of a turn, or as specified by the filter manufacturer.



△ CAUTION △

The valve must be in the ON position to prevent engine damage.

Turn the valve on the filter head to the ON position, and install the coolant system pressure cap.



Operate the engine and check for leaks.

After the air has been purged from the system, check the coolant level again.

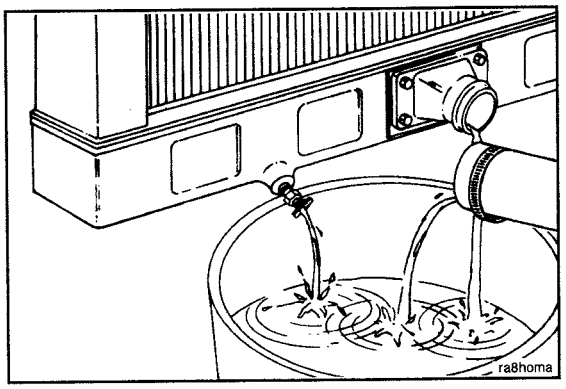
Coolant Filter Head (008-007)

Remove (008-007-002)

⚠ WARNING ⚠

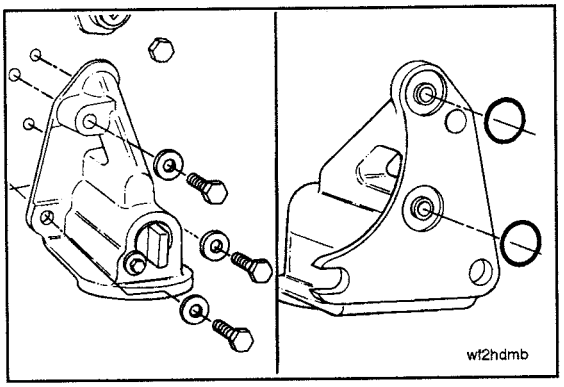
Coolant is toxic. Keep children and pets away. If the coolant is not going to be reused, dispose of it in accordance with federal, state, and local regulations.

Drain the cooling system. Refer to Procedure 008-018.



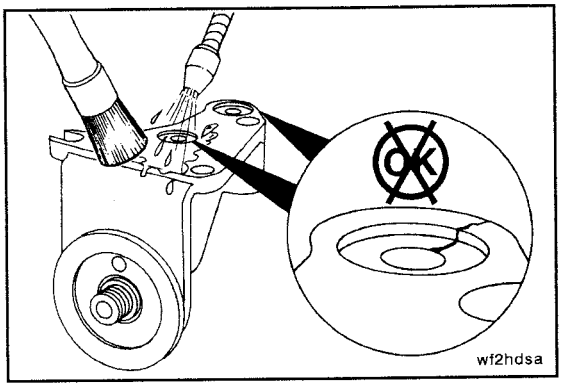
Remove the three capscrews and the filter head.

Remove the two o-rings.



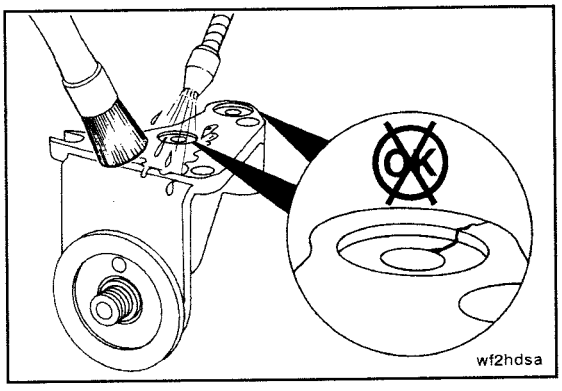
Clean (008-007-006)

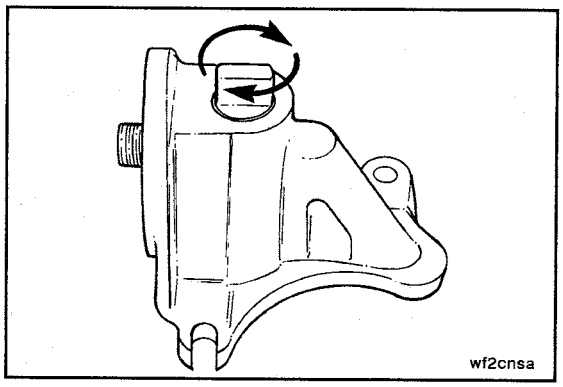
Use solvent to clean the filter head. Dry with compressed air.



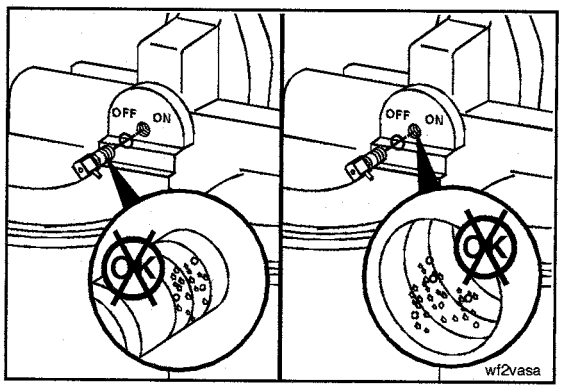
Inspect for Reuse (008-007-007)

Inspect the filter head for cracks or other damage.





Turn the control valve by hand. If the valve does **not** rotate freely, remove and inspect the valve.



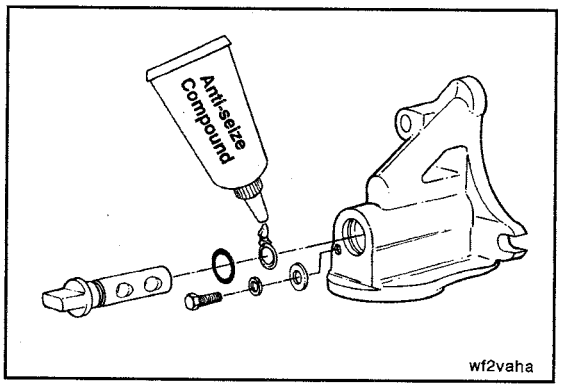
To remove the valve, remove the capscrew, and pull the valve out of the housing.

Remove the o-ring from the valve.

Inspect the valve for corrosion or pitting.

Inspect the housing bore for corrosion or pitting.

Clean or replace the valve and housing, if necessary.



Install (008-007-026)

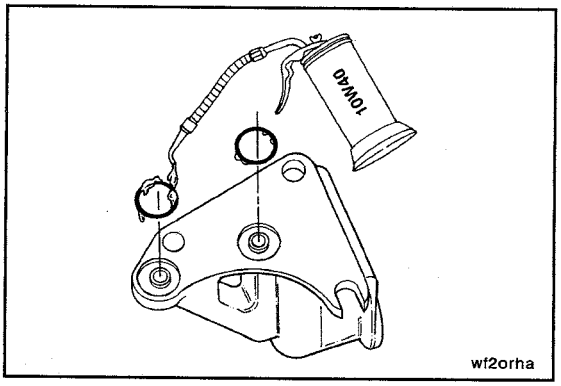
Install a new o-ring on the valve.

Lubricate the o-ring with a film of antiseize compound.

Install the valve in the filter head.

Tighten the capscrew.

Torque Value: 10 N•m [90 in-lb]



Use clean 15W-40 oil to lubricate the two new o-rings.

Install the o-rings on the filter head.

⚠ CAUTION ⚠

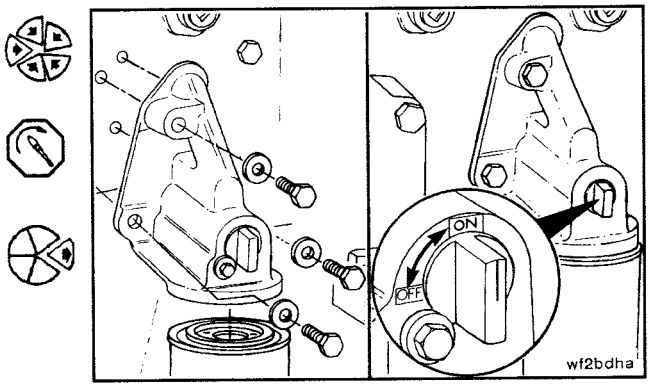
The control valve must be in the ON position to prevent engine damage.

Install the filter head and filter, if removed.

Tighten the capscrews.

Torque Value: 54 N•m [40 ft-lb]

Turn the control valve to the ON position.

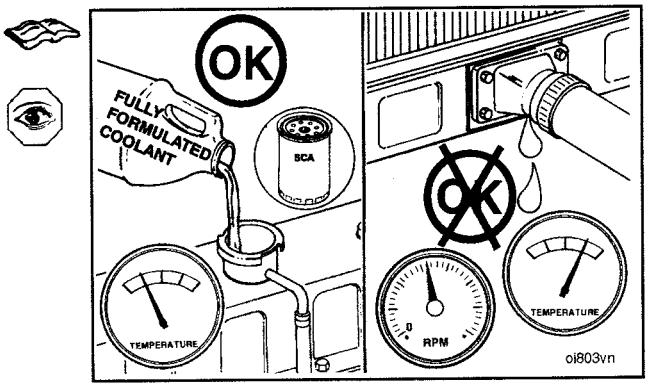


⚠ WARNING ⚠

Coolant is toxic. Keep children and pets away. If the coolant is not going to be reused, dispose of it in accordance with federal, state, and local regulations.

Fill the cooling system. Refer to Procedure 008-018.

Operate the engine until it reaches a temperature of 80°C [180°F] and check for coolant leaks.



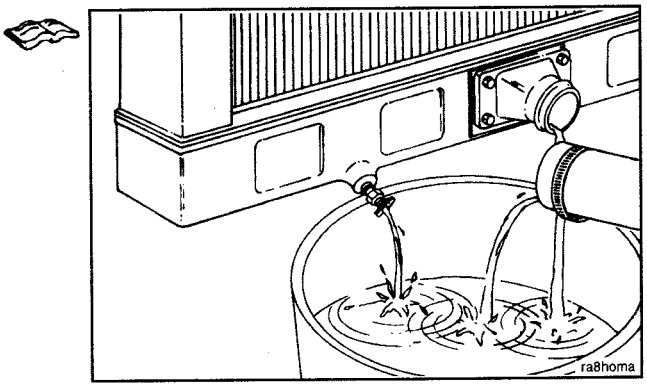
Coolant Heater Housing (008-012)

Remove (008-012-002)

⚠ WARNING ⚠

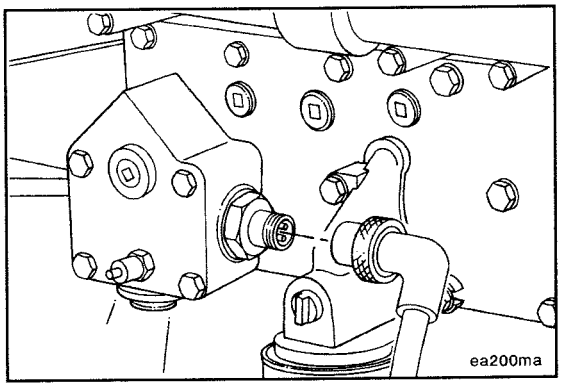
Coolant is toxic. Keep children and pets away. If the coolant is not going to be reused, dispose of it in accordance with federal, state, and local regulations.

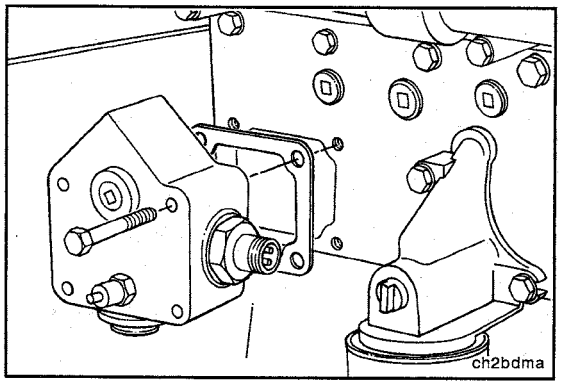
Drain the cooling system. Refer to Procedure 008-018.



Disconnect the electrical wiring from the cylinder block heater, if used.

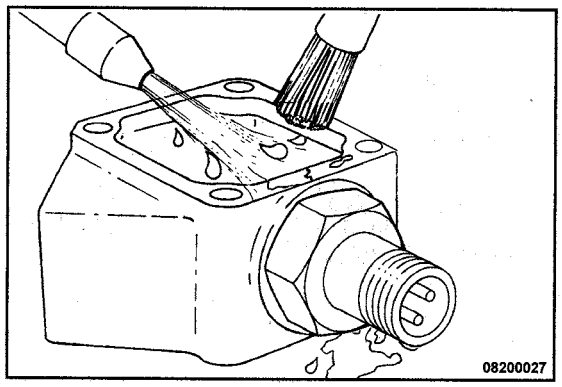
Remove any additional fittings or accessories from the housing.





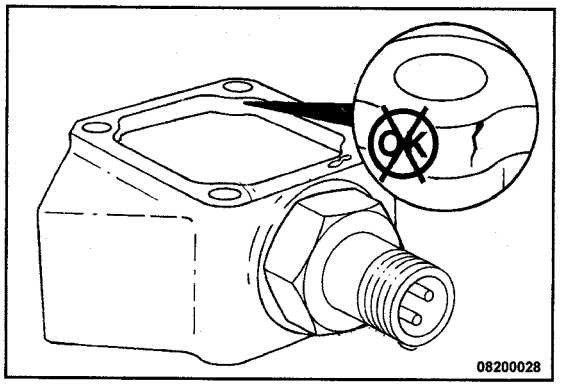
Remove the four mounting capscrews from the heater housing.

Remove the heater housing and gasket.



Clean (008-012-006)

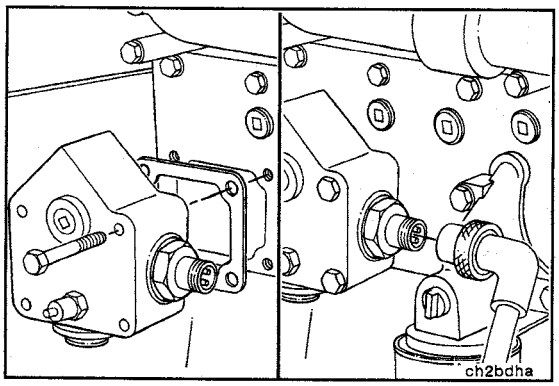
Use solvent to clean the heater housing. Dry with compressed air.



Inspect for Reuse (008-012-007)

Inspect the housing for cracks or other damage.

If the housing is cracked, it **must** be replaced.



Install (008-012-026)

Use a new gasket to install the heater housing.

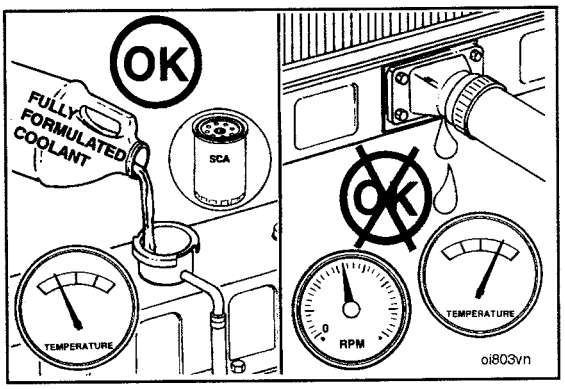
Install the four mounting capscrews and tighten.

Torque Value: 54 N•m [40 ft-lb]

Connect the electrical wiring to the heater, if used.

Fill the cooling system. Refer to Procedure 008-018.

Operate the engine until it reaches a temperature of 80°C [180°F] and check for leaks.

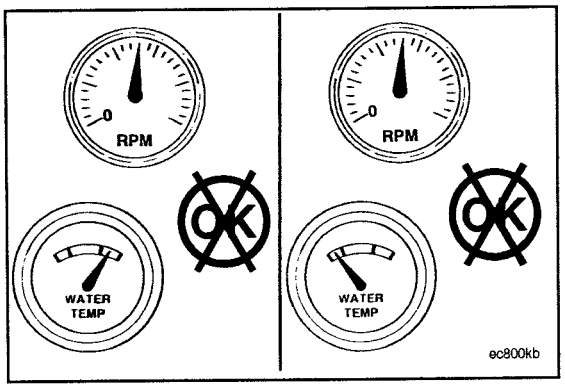


Coolant Thermostat (008-013)

Leak Test (008-013-014)

The engine thermostat and thermostat seal **must** operate properly in order for the engine to operate in the most efficient heat range. Overheating or overcooling will shorten engine life.

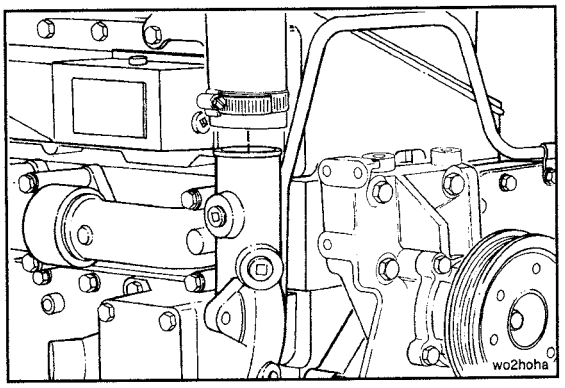
Refer to Procedure 008-016 to inspect the thermostat seal.



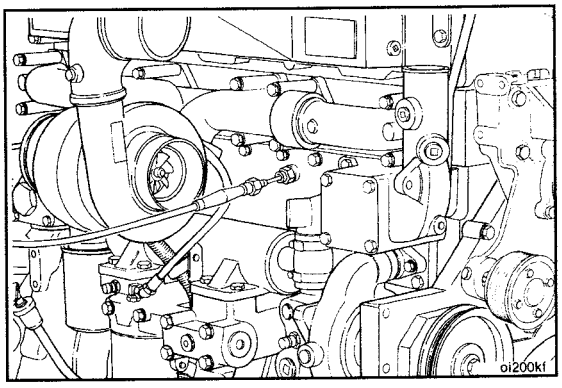
⚠ WARNING ⚠

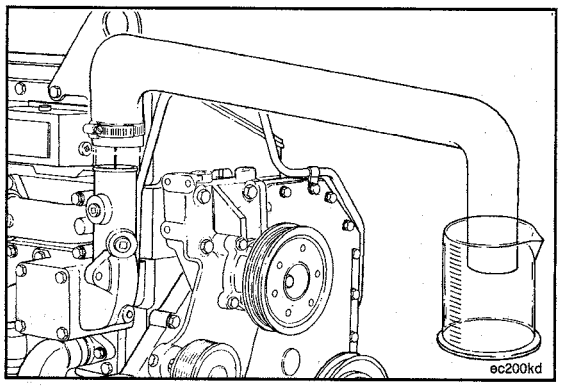
Complete this test with the engine coolant temperature below 50°C [120°F]. Hot steam can cause serious personal injury.

Remove the radiator hose from the thermostat housing.



Install a thermocouple or temperature gauge, which is known to be accurate, in the water header plate or engine side of the thermostat housing.

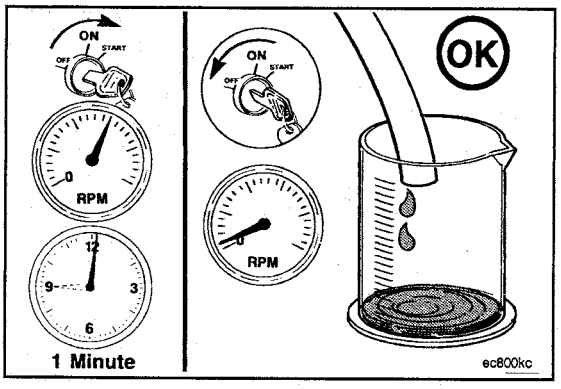




Install a hose of the same size on the thermostat housing outlet long enough to reach a remote, dry container used to collect coolant.

Install and tighten a hose clamp on the housing outlet.

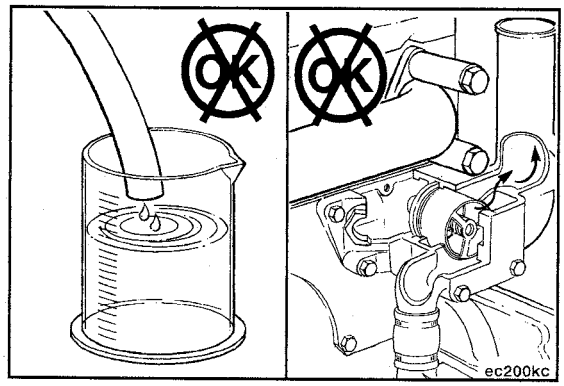
Place the other end of the hose in a dry container.



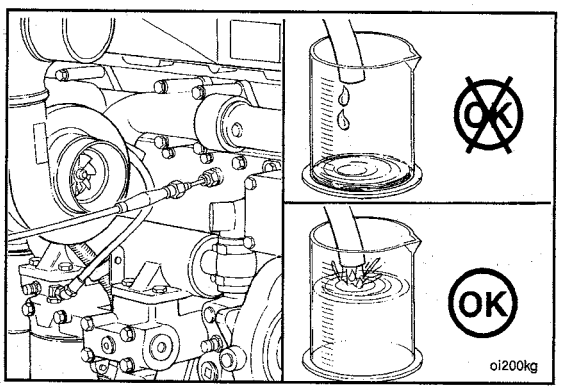
Operate the engine at rated rpm for 1 minute.

Shut off the engine, and measure the amount of coolant collected in the container.

The amount of coolant collected **must not** be more than 100 cc [3.3 fl oz].



If more than 100 cc [3.3 fl oz] of coolant is collected, the thermostat or thermostat seal is leaking and **must** be replaced. Refer to Procedure 008-016 to replace the thermostat seal.



Complete the following test in-chassis to test the thermostat opening temperature.

Start the engine and monitor the water temperature gauge and the container.

Thermostat Initial Opening Temperature		
°C		°F
81	MIN	178
83	MAX	182

Shut off the engine when the coolant starts to flow.

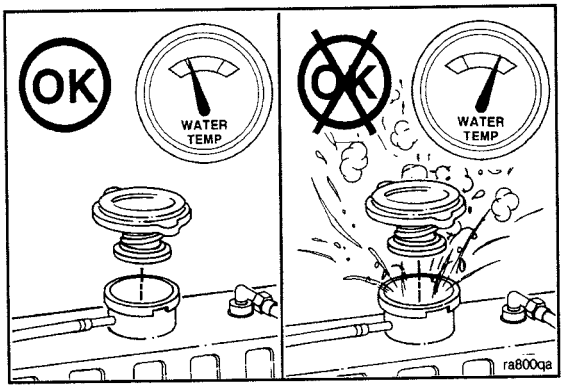
If coolant does **not** start flowing into the container during the initial opening temperature range, the thermostat **must** be replaced.

Remove (008-013-002)

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the coolant system pressure cap. Heated coolant spray or steam can cause personal injury.

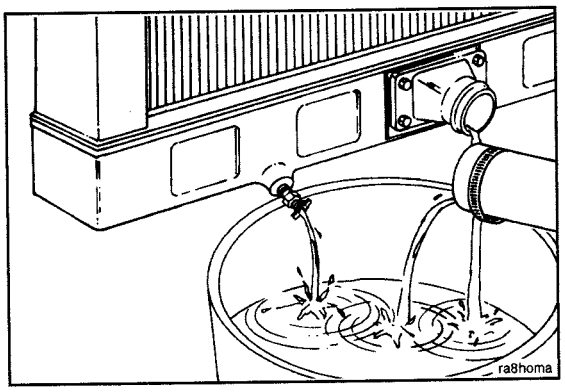
Remove the pressure cap when the engine is cool.



⚠ WARNING ⚠

Coolant is toxic. If not reused, dispose of in accordance with local environmental regulations.

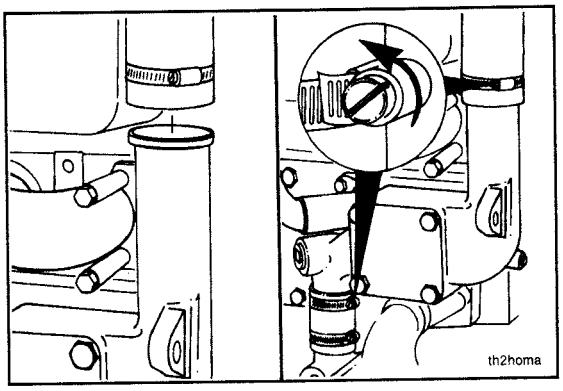
Drain the cooling system. Refer to Procedure 008-018.



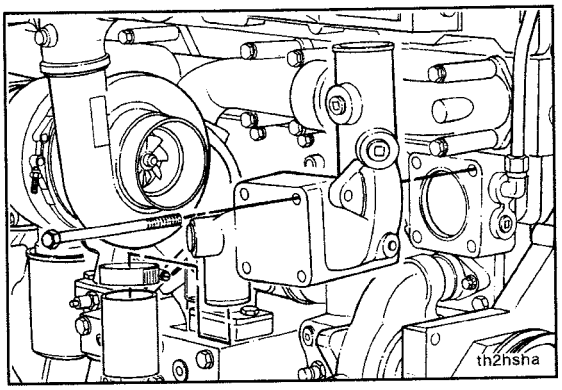
Remove the upper coolant hose from the thermostat housing.

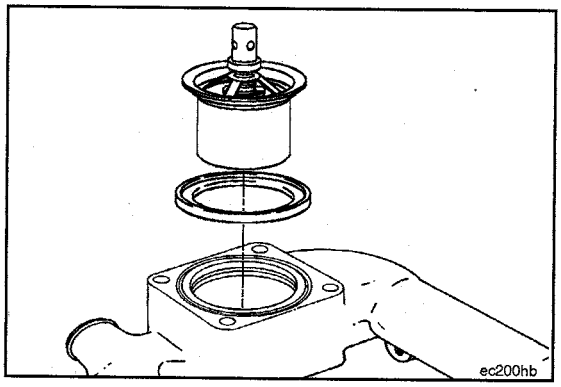
Loosen the coolant bypass hose clamps.

NOTE: Some models could have a converter cooler disc located in the bypass hose. Refer to Procedure 008-065.

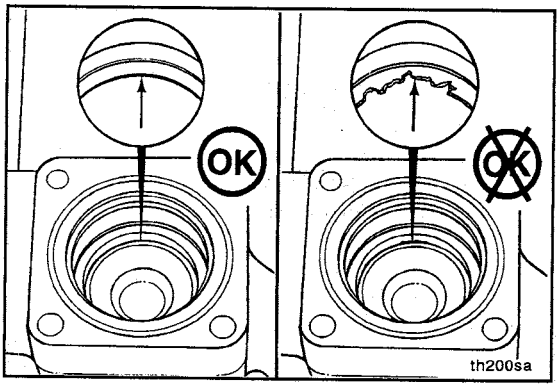


Remove the four thermostat housing mounting capscrews and the thermostat housing.





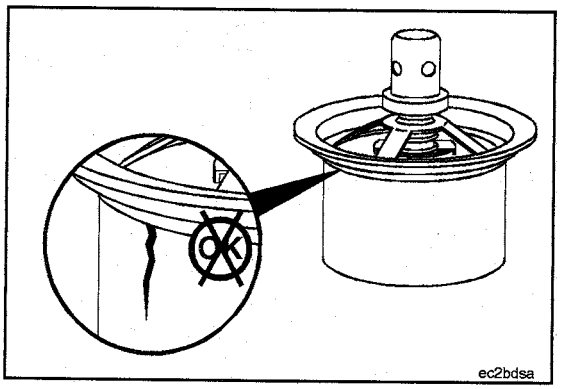
Remove the thermostat from the housing.



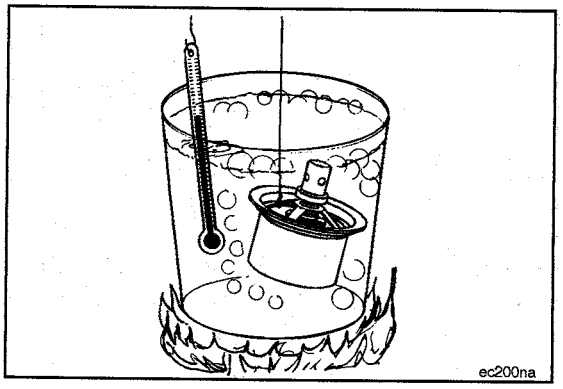
Inspect for Reuse (008-013-007)

Inspect the thermostat seal for cracks, corrosion, or other damage.

If the seal is damaged, it **must** be replaced. Refer to Procedure 008-016.



Inspect the thermostat for damage.



Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.

NOTE: Do **not** allow the thermostat or thermometer to touch the container.

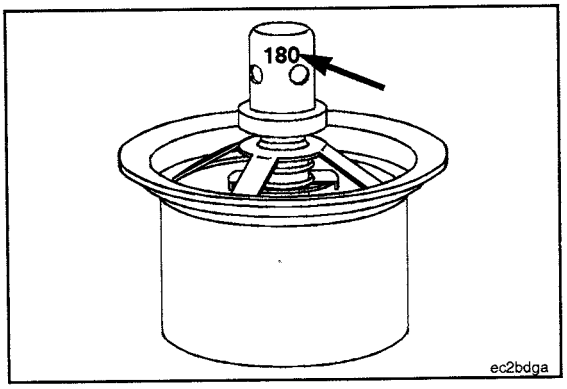
Heat the water, and check the thermostat as follows:

The nominal operating temperature is stamped on the thermostat.

- Thermostat **must** begin to open within 1°C [2°F] of nominal temperature.
- Thermostat **must** be fully open within 12°C [22°F] of nominal temperature.

The fully open distance between the thermostat flange and housing is 11 mm [0.435 in].

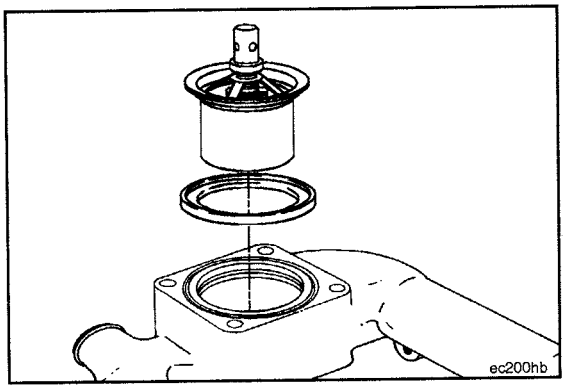
If the thermostat operates properly and more than 100 cc [3.3 fl. oz] leakage is detected during in-chassis test, replace the thermostat seal. Refer to Procedure 008-016.



Install (008-013-026)

Install the thermostat in the housing.

Install a new o-ring seal in the groove on the thermostat housing mounting surface.



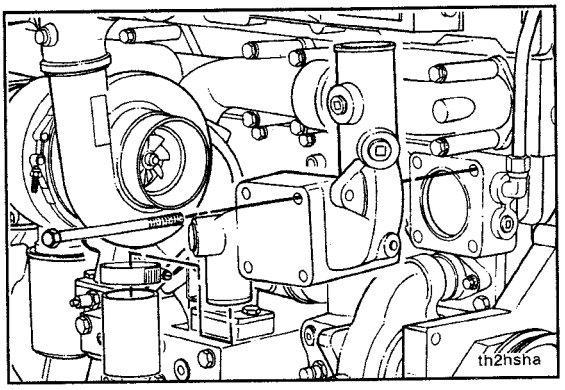
Install the hose on the thermostat housing bypass outlet.

Install the thermostat housing and four mounting capscrews.

Tighten the mounting capscrews.

Torque Value: 54 N•m [40 ft-lb]

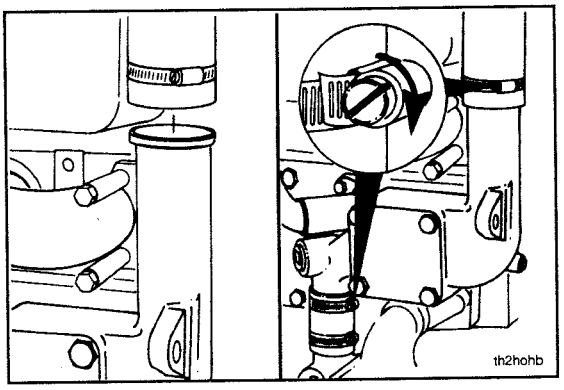
NOTE: If a torque converter cooler disc is used in the coolant bypass hose, refer to Procedure 008-065.

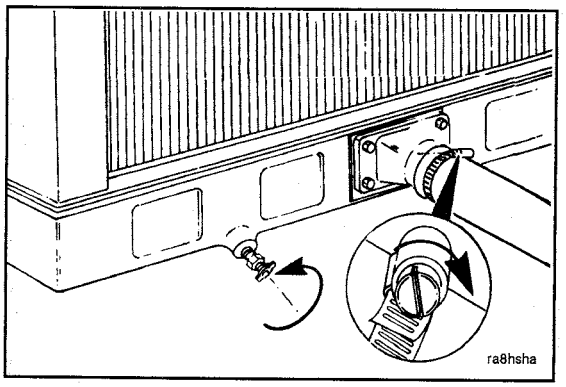


Install the upper coolant hose to the thermostat housing outlet. Refer to the OEM's specifications for the correct torque value.

Tighten the coolant bypass hose clamps.

Torque Value: 3 N•m [30 in-lb]

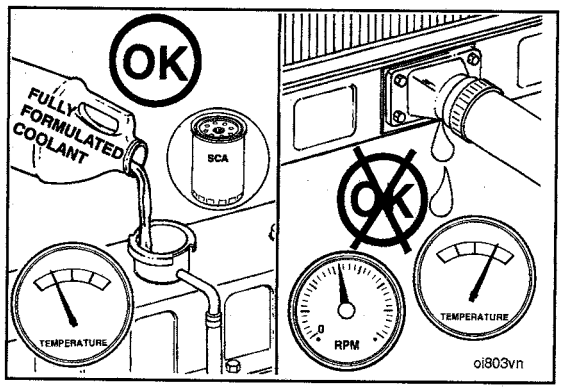




Close the cooling system draincock, and install the lower coolant hose.

Tighten the hose clamp.

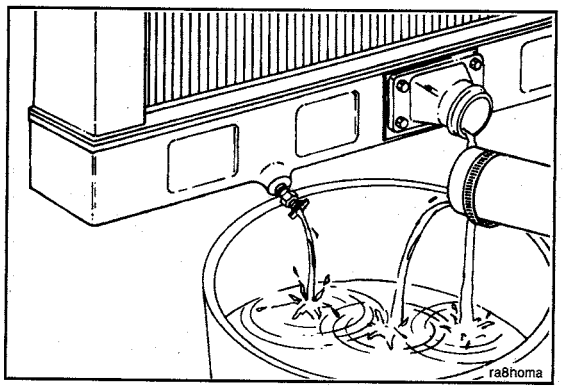
Refer to the OEM's specifications for the correct torque value.



The correct concentration of coolant additives **must** be used in the cooling system. Refer to Section V of the Operation and Maintenance Manual, ISM Series Engines, Automotive/Transit Bus, Bulletin No. 3666319.

Fill the cooling system.

Operate the engine until it reaches 80°C [180°F] and check for coolant leaks.



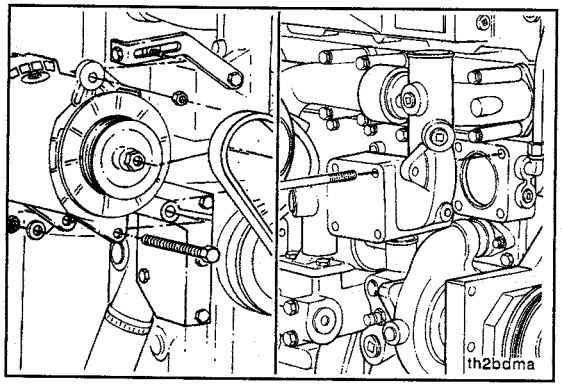
Coolant Thermostat Housing Support (008-015)

Remove (008-015-002)

⚠ WARNING ⚠

Coolant is toxic. Keep children and pets away. If the coolant is not going to be reused, dispose of it in accordance with federal, state, and local regulations.

Drain the cooling system. Refer to Procedure 008-018.

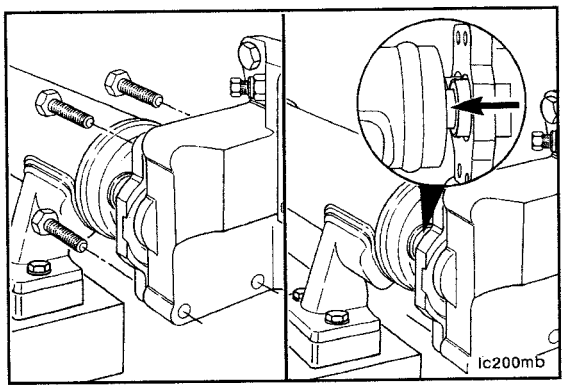


Remove the alternator drive belt and the alternator. Refer to Procedures 013-005 and 013-001.

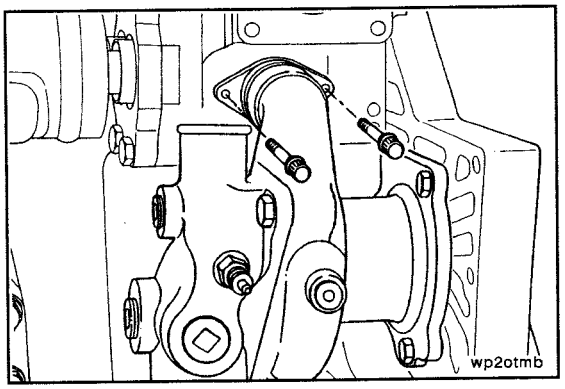
Remove the thermostat housing and bypass hose. Refer to Procedure 008-014.

Remove the four lubricating oil cooler thermostat support flange capscrews.

Push the water transfer tube connections into the lubricating oil cooler as far as possible.

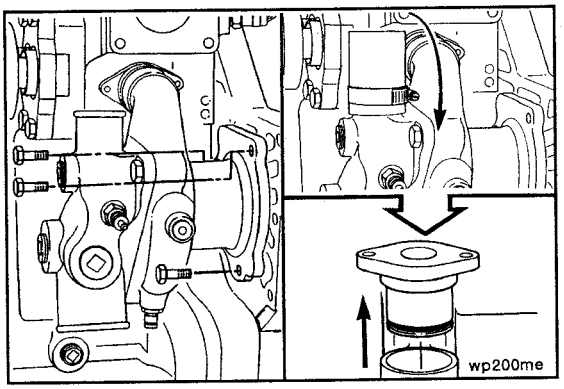


Remove the two water transfer tube mounting capscrews.



Remove the three water pump mounting capscrews.

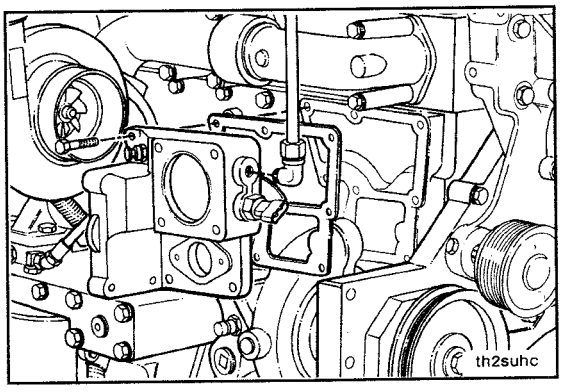
Twist the water pump outward, and remove the water transfer tube from the water pump body.

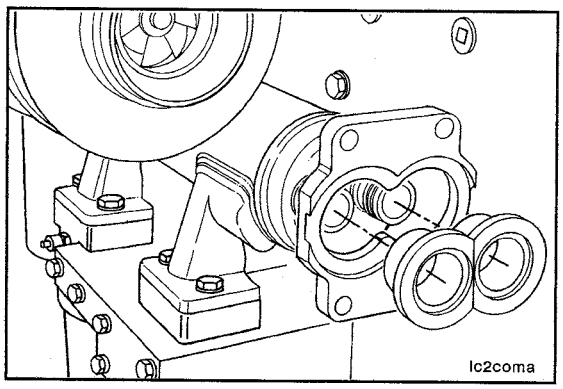


Remove the air compressor coolant supply line.

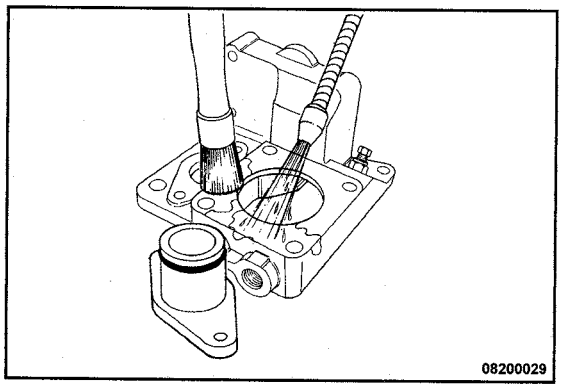
Remove the coolant temperature sensor.

Remove the remaining capscrews and the thermostat housing support.





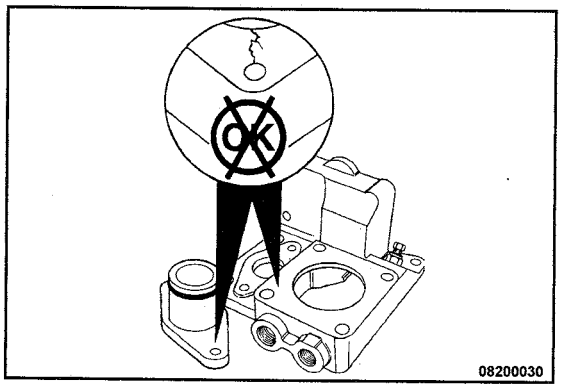
Remove the lubricating oil cooler water connection tubes from the cooler.



Clean (008-015-006)

Use solvent to clean the lubricating oil cooler water transfer tubes, water pump water transfer tubes, and thermostat housing support.

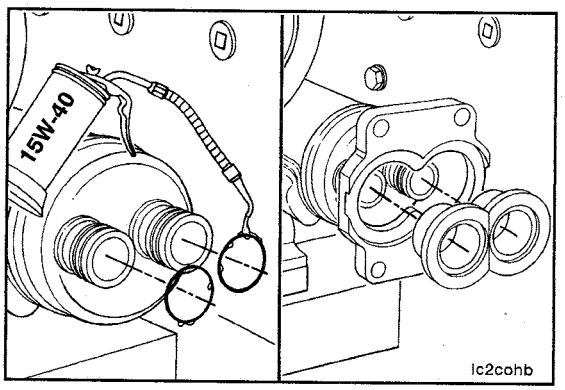
Dry with compressed air.



Inspect for Reuse (008-015-007)

Inspect the water transfer tubes and thermostat housing support for cracks or damage.

If any parts are damaged, they **must** be replaced.



Install (008-015-026)

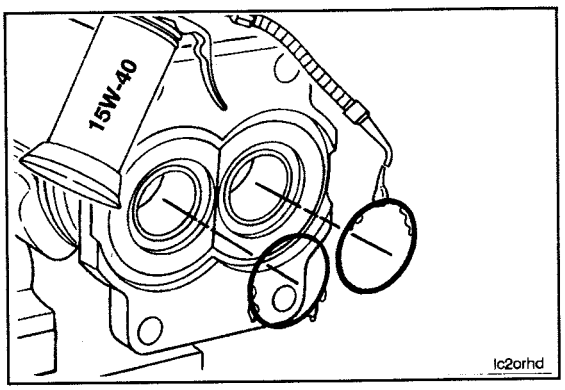
Install new o-rings on the lubricating oil cooler water connection tubes.

Use clean 15W-40 engine oil to lubricate the o-rings.

While holding the connection flange in place, install the water connections into the lubricating oil cooler. The straight edges of the connection **must** face each other.

Install two new o-rings on the end of the lubricating oil cooler water tube connections.

Lubricate the o-rings with clean 15W-40 engine oil.

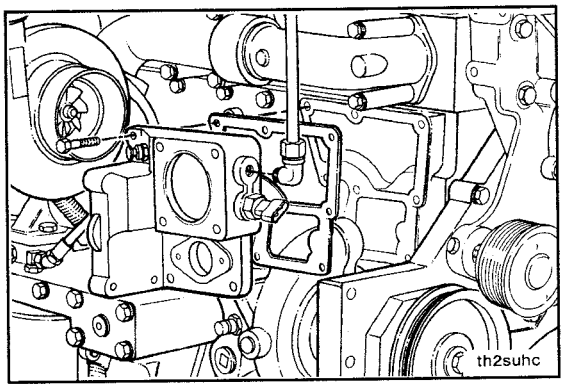


Use a new gasket, and install the thermostat housing support and capscrews.

Torque Value: 54 N•m [40 ft-lb]

Install the air compressor coolant supply line.

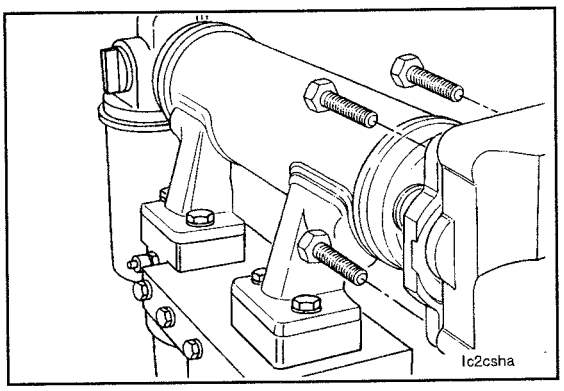
Install the coolant temperature sensor.



Install the four mounting flange capscrews. Alternately and evenly, tighten the four capscrews.

Torque Value: 47 N•m [35 ft-lb]

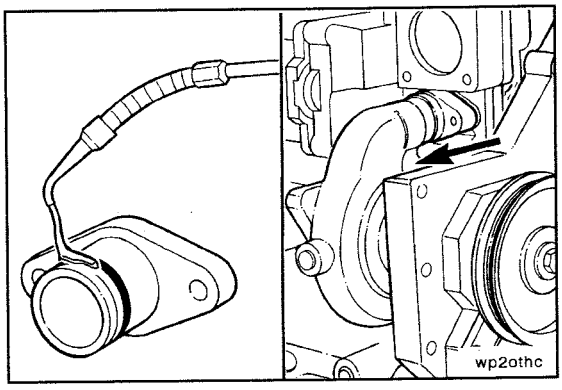
NOTE: Be sure the o-rings on the end of the connection tubes are located correctly.

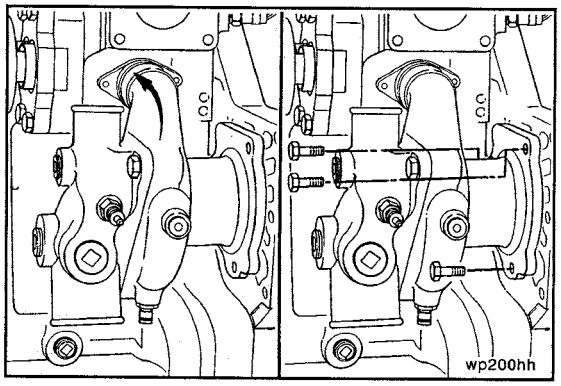


Install a new o-ring on the water pump water transfer tube.

Use clean 15W-40 oil to lubricate the o-ring.

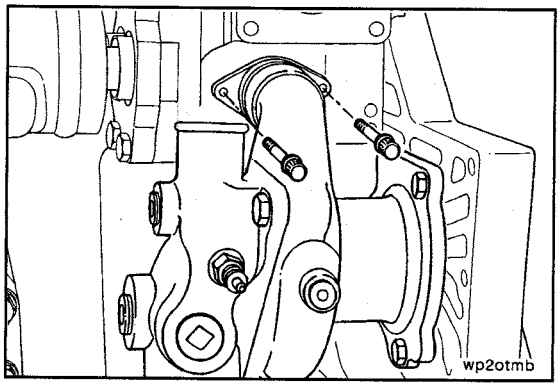
Install the water transfer tube and o-ring assembly in the water pump body.





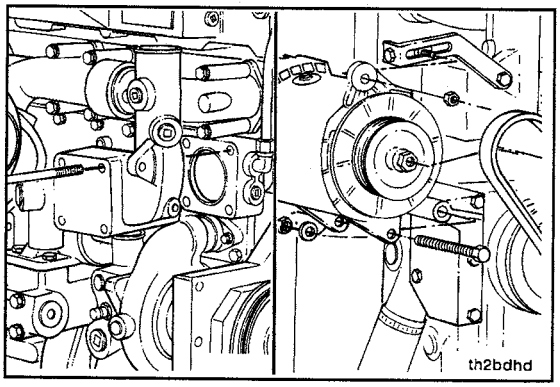
Rotate the water pump inward and install the three water pump mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]



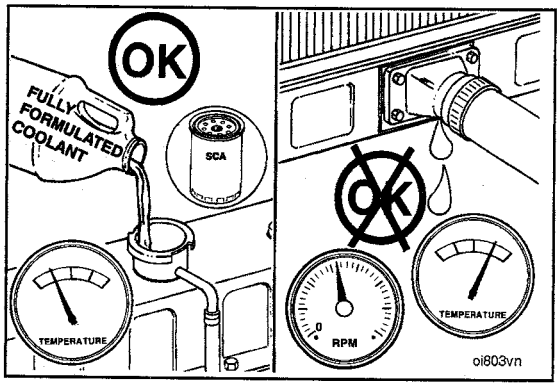
Use a new gasket, and install the water pump water transfer tube mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]



Install the thermostat and thermostat housing. Refer to Procedure 008-014.

Install the alternator and drive belt. Refer to Procedures 013-001 and 013-005.



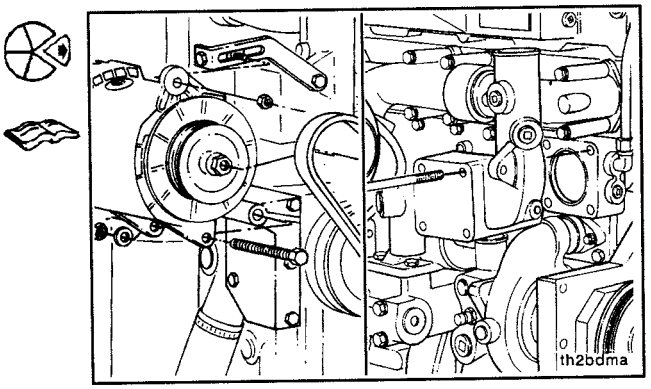
Fill the cooling system. Refer to Procedure 008-018.

Operate the engine until it reaches a temperature of 80°C [180°F] and check for coolant leaks.

Coolant Thermostat Seal (008-016)

Remove (008-016-002)

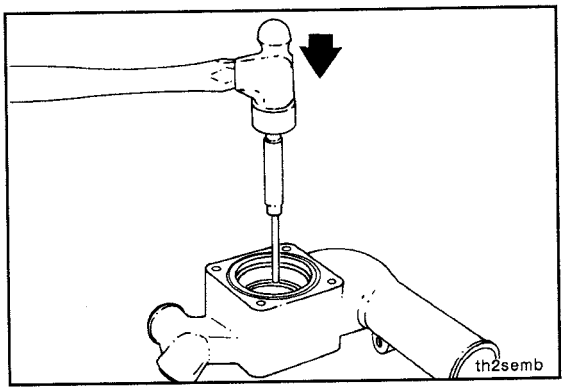
Remove the thermostat. Refer to Procedure 008-013.



⚠ CAUTION ⚠

Do not damage the thermostat housing when removing the thermostat seal.

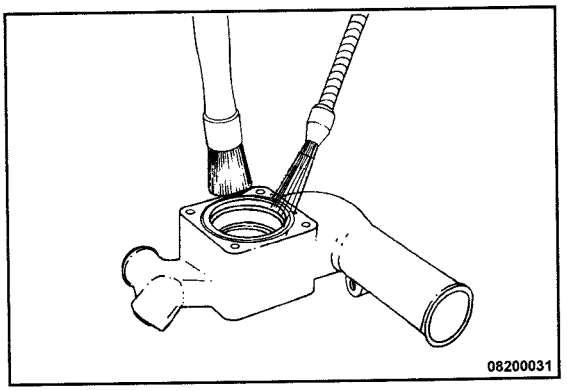
Use a punch and hammer to remove the seal from the housing.



Clean (008-016-006)

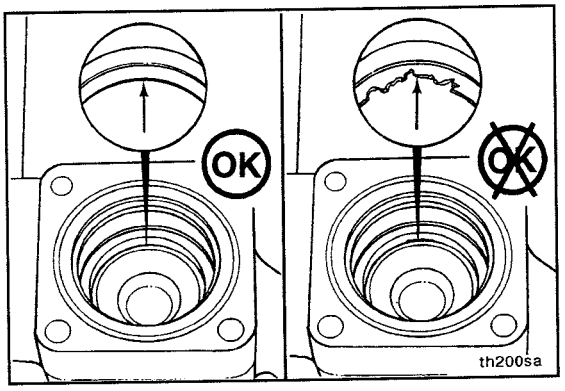
Use solvent to clean the thermostat housing.

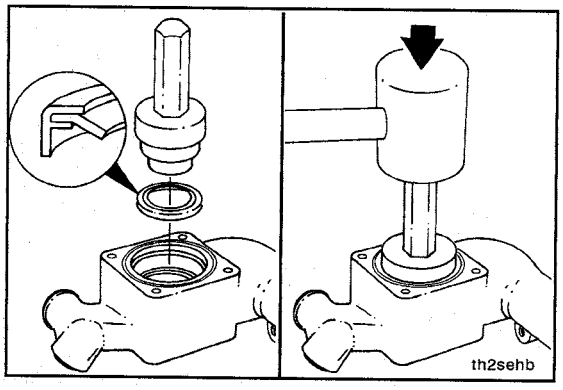
Dry with compressed air.



Inspect for Reuse (008-016-007)

Inspect the thermostat housing for cracks, pits, or other damage.

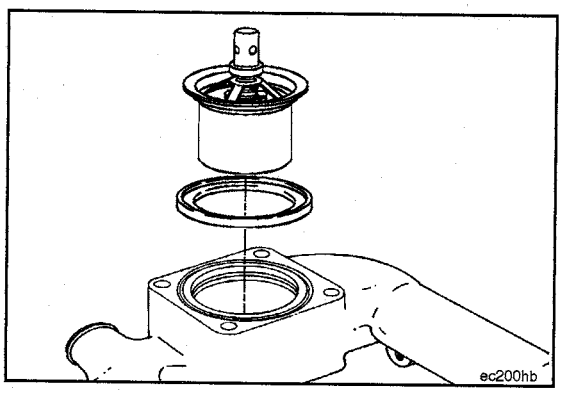




Install (008-016-026)

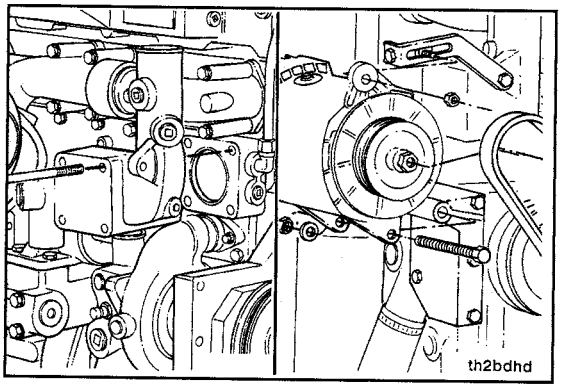
When installing a new seal, the flat side of the seal **must** be facing the mandrel.

Use thermostat seal mandrel, Part No. ST-1225, and a hammer to install the seal.



Install the thermostat in the housing.

Install a new seal in the groove on the thermostat housing mounting surface.

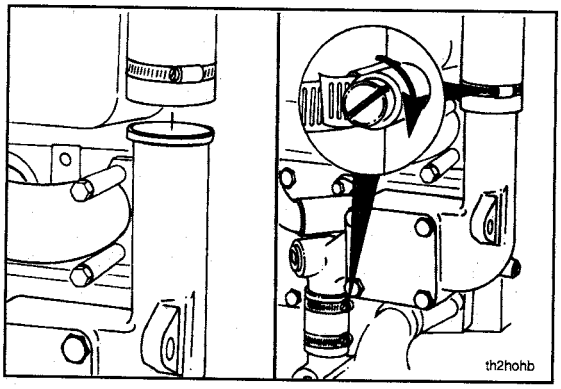


Install the hose on the thermostat housing bypass outlet.

Install the thermostat housing and four mounting capscrews.

Torque Value: 54 N•m [40 ft-lb]

NOTE: If a torque converter cooler disc is used in the coolant bypass hose, refer to Procedure 008-065.



Install the upper radiator hose to the thermostat housing outlet.

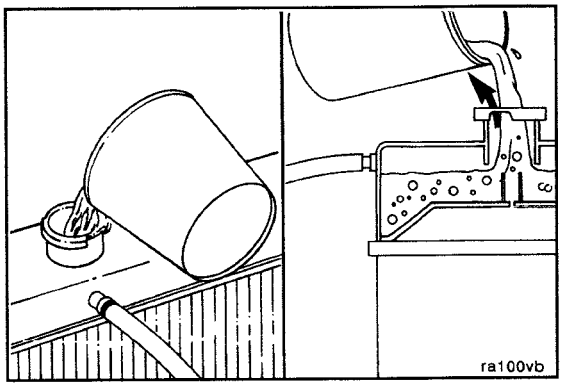
Tighten all hose clamps.

Torque Value: 3 N•m [30 in-lb]

Coolant Vent Lines (008-017)

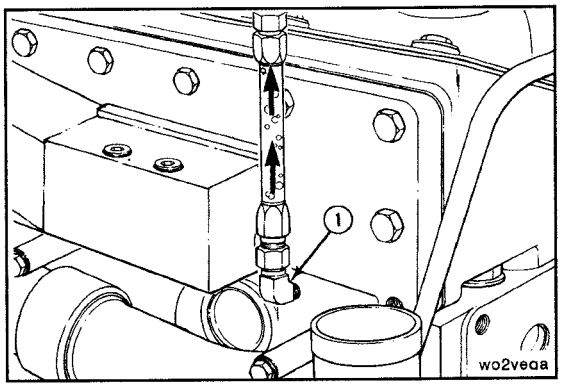
Initial Check (008-017-001)

The system **must** be designed to allow air to escape while filling.

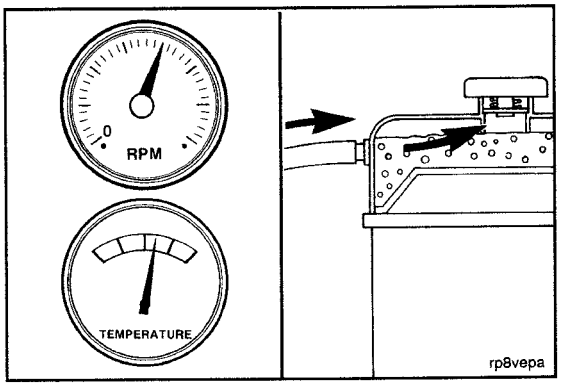


The cooling system vent line is routed from the cylinder head (1) to the radiator fill or auxiliary tank above the coolant level.

Use No. 4 flexible hose.

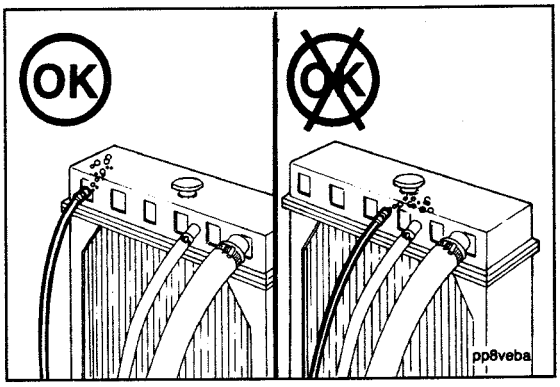


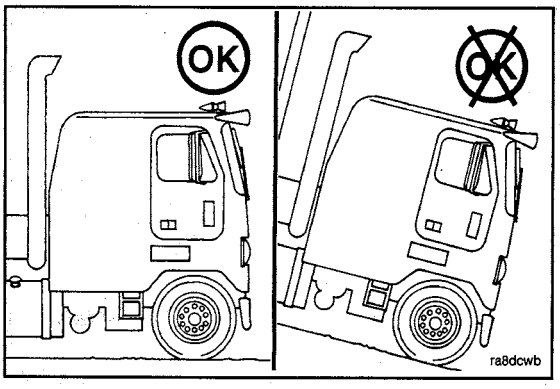
During engine operation, coolant will continue to flow through the engine vent line to remove air from the coolant.



Do **not** route the fill or vent line in a manner that will allow air to be trapped in the system.

Route the vent line away from the fill line as far as possible to prevent turbulence in the fill line.

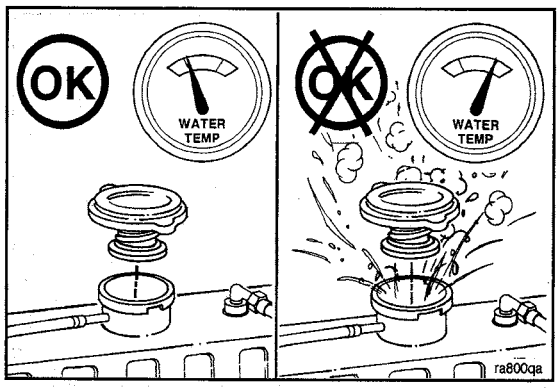




Cooling System (008-018)

Drain (008-018-005)

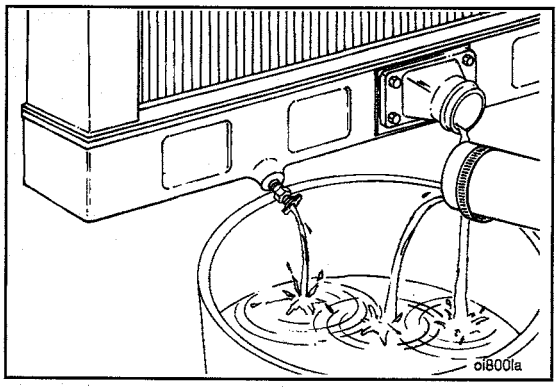
Position the vehicle on level ground.



⚠ WARNING ⚠

Check the coolant level only when the engine is stopped. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.

Remove the radiator cap after the engine is cool.

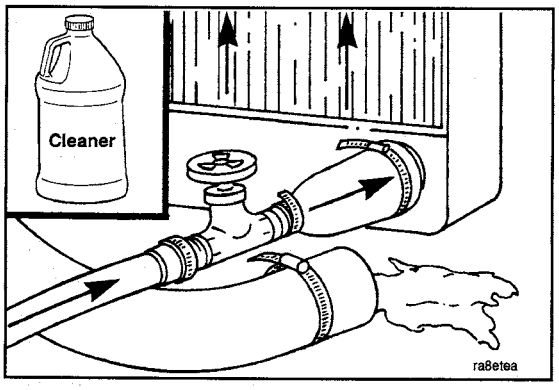


⚠ WARNING ⚠

Coolant is toxic. Keep children and pets away. If the coolant is not going to be reused, dispose of it in accordance with federal, state, and local regulations.

Drain the cooling system as follows:

- Open the radiator draincock.
- Remove the lower radiator hose.



Clean (008-018-006)

△ CAUTION △

Do not use caustic cleaners in the cooling system. Aluminum components will be damaged.

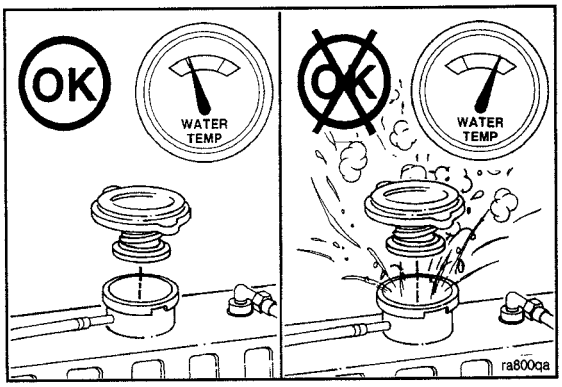
The cooling system **must** be clean to work correctly and to eliminate buildup of harmful chemicals.

Restore™ is a heavy-duty cooling system cleaner that removes corrosion, silica gel, and other deposits. The performance of Restore™ is dependent on time, temperature, and concentration levels. An extremely scaled or flow-restricted system, for example, can require higher concentrations of cleaners, higher temperatures, or longer cleaning times, or the use of Restore Plus™. Up to twice the recommended concentration levels of Restore™ can be used safely. Restore Plus™ **must** be used **only** at its recommended concentration level. Extremely scaled or fouled systems can require more than one cleaning.

⚠ WARNING ⚠

Wait until the temperature is below 50°C [120°F] before removing the coolant system pressure cap. Failure to do so can cause personal injury from heated coolant spray.

Remove the radiator cap.

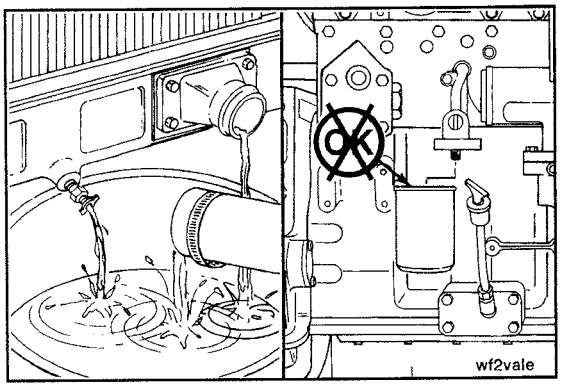


⚠ WARNING ⚠

Coolant is toxic. Keep children and pets away. If the coolant is not going to be reused, dispose of it in accordance with federal, state, and local regulations.

Drain the cooling system. Refer to Procedure 008-018. Do **not** allow the cooling system to dry out.

Do **not** remove the coolant filter.

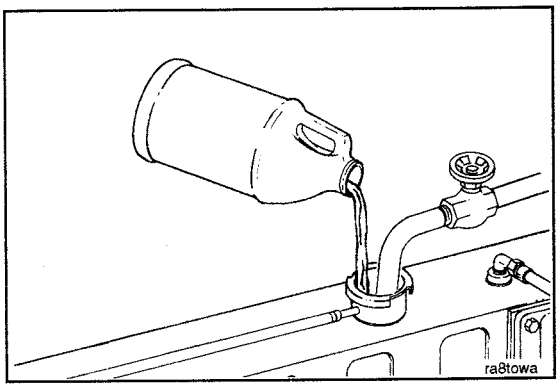


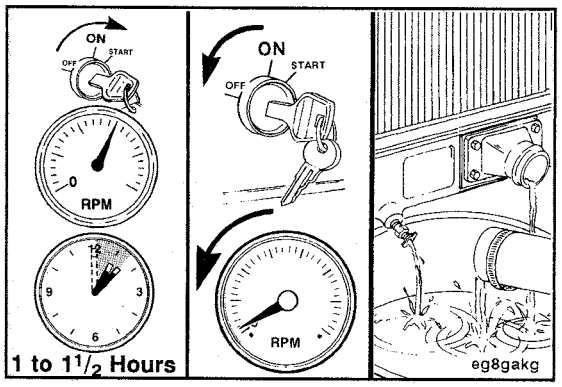
△ CAUTION △

Fleetguard® Restore™ contains no antifreeze. Do not allow the cooling system to freeze during the cleaning operation.

Immediately add 3.8 liters [1 gal] of Fleetguard® Restore™, Restore Plus™, or equivalent, for each 38 to 57 liters [10 to 15 gal] of cooling system capacity, and fill the system with plain water.

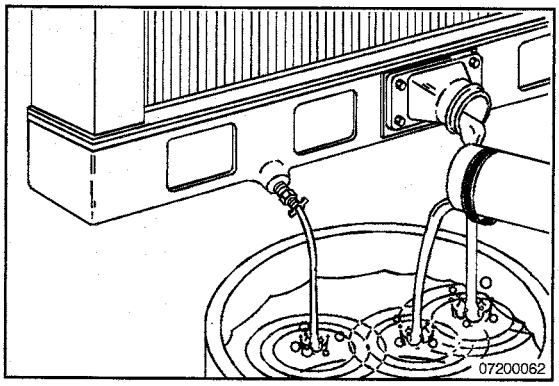
Turn the cab heater temperature switch to high to allow maximum coolant flow through the heater core. The blower does **not** have to be on.





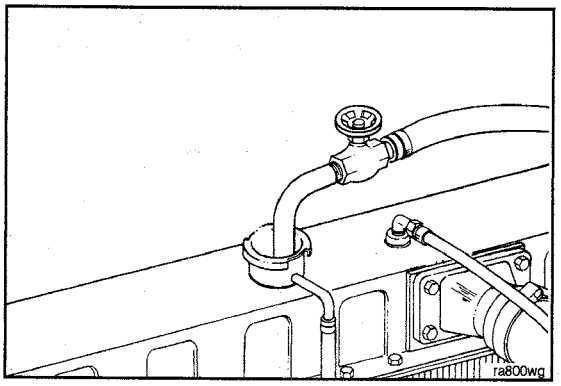
Operate the engine at normal operating temperatures, at least 85°C [185°F], for 1 to 1-1/2 hours.

Shut off the engine, and drain the cooling system.

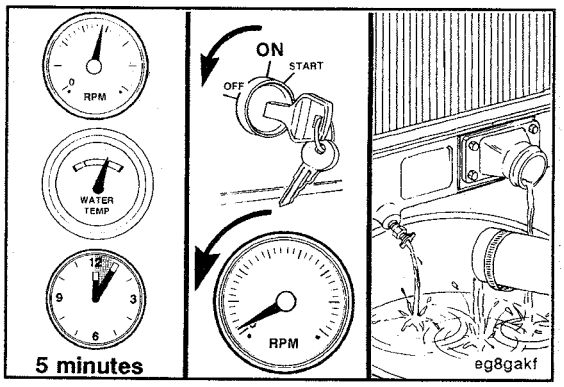


Operate the engine at normal operating temperatures, at least 85°C [185°F], for 1 to 1-1/2 hours.

Shut off the engine, and drain the cooling system. Refer to Procedure 008-018.



Fill the cooling system with clean water.



⚠ WARNING ⚠

Coolant is toxic. Keep children and pets away. If the coolant is not going to be reused, dispose of it in accordance with federal, state, and local regulations.

Operate the engine at high idle for five minutes with the coolant temperature above 85°C [185°F].

Shut off the engine and drain the cooling system. Refer to Procedure 008-018.

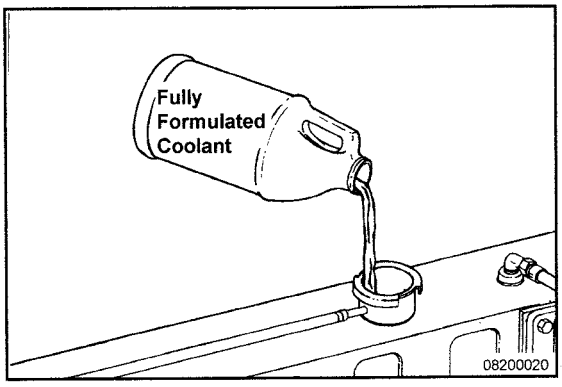
If the water being drained is still dirty, the system **must** be continually flushed until the water is clean.

⚠ WARNING ⚠

Do not add coolant while engine is hot.

Fill the cooling system with fully formulated coolant or a 50/50 mixture of fully formulated antifreeze and good-quality water. Refer to Procedure 008-018. Use a service filter to bring the coolant to the correct SCA concentration level. Refer to Fleetguard® DCA4 Service Filters and Liquid Precharge in the General Information portion of this section for the correct filter to use.

Install the pressure cap. Operate the engine until it reaches a temperature of 80°C [180°F] and check for coolant leaks.



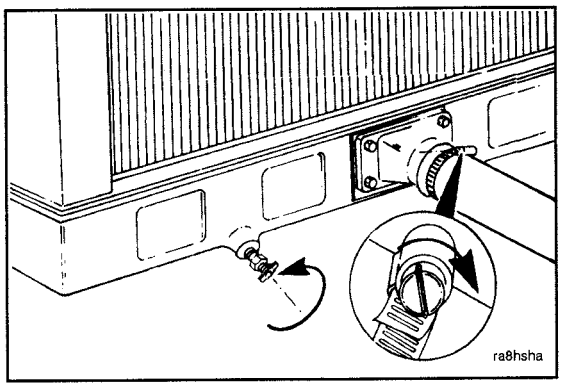
Fill (008-018-028)

Close the radiator draincock.

Install the lower radiator hose.

Tighten the hose clamp.

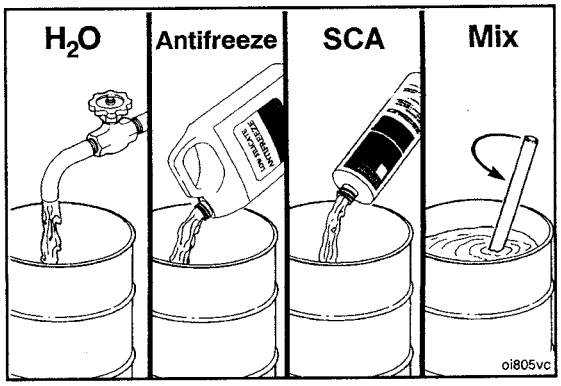
Torque Value: 5 N•m [40 in-lb]



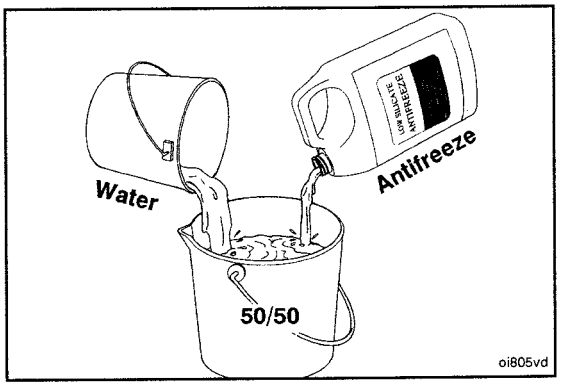
Proper mixing of coolant is required:

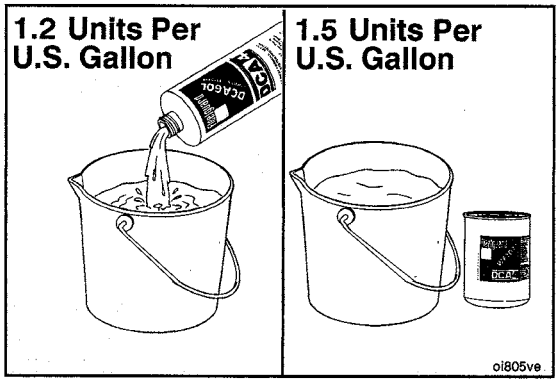
- Pour water into the container.
- Add low-silicate antifreeze.
- Add DCA4 liquid.
- Thoroughly blend the components.

Following the correct order for mixing the coolant will prevent additive dropout during the mixing process.

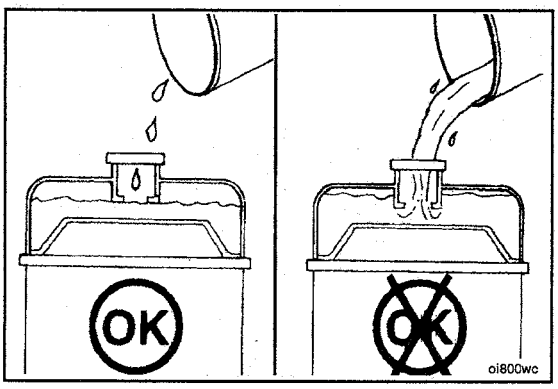


Low-silicate antifreeze **must** be used at a 50:50 ratio to give adequate freezing point and boiling point protection. Also, the use of low-silicate antifreeze minimizes the chance of having a silicate gel problem.

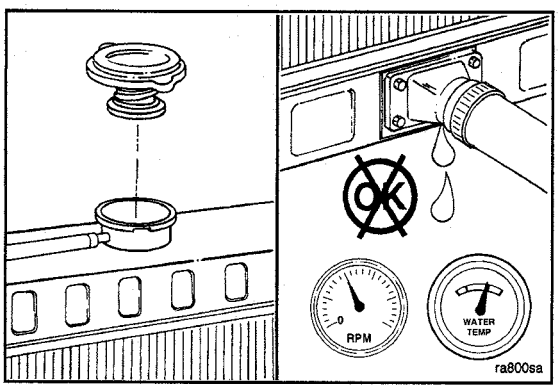




The cooling system **must** be precharged with SCA. Add 1 pint of DCA4 liquid (5 units) for each 4 gallons of coolant (1.2 units per gallon). In addition, a service coolant filter containing 1 unit of DCA4 for each 4 gallons of coolant **must** be installed. This will result in a total precharge of approximately 1.5 DCA4 units per gallon of coolant. Refer to the Coolant Capacity Charts at the beginning of this section for correct filter selection.

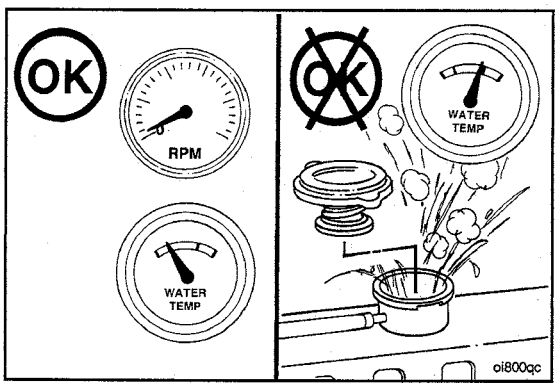


Fill the system with coolant until the level is at the bottom of the radiator fill neck.



Install the radiator fill cap.

Operate the engine until it reaches a temperature of 80°C [180°F] and check for leaks.



⚠ WARNING ⚠

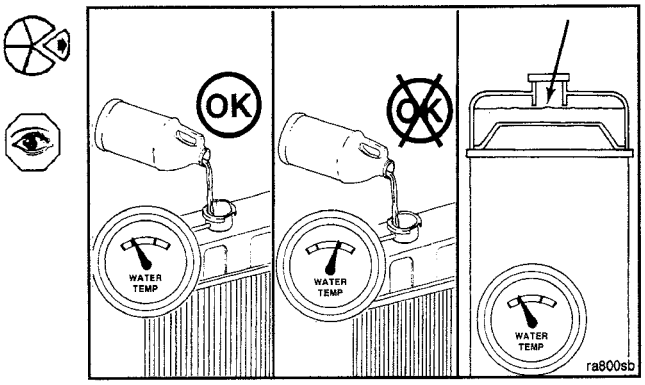
Check the coolant level only when the engine is stopped. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.

Shut off the engine, and allow it to cool.

⚠ CAUTION ⚠

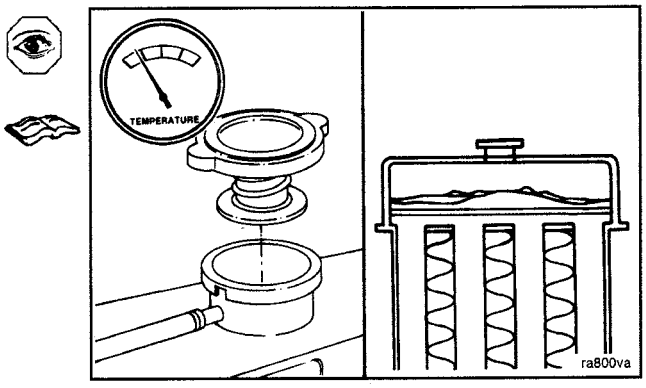
Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool below 50°C [120°F] before adding coolant.

Remove the radiator or fill cap, and check the coolant level. Add coolant, if necessary.



Pressure Test (008-018-013)

Check the coolant level and fill, if necessary. Refer to Procedure 008-018.



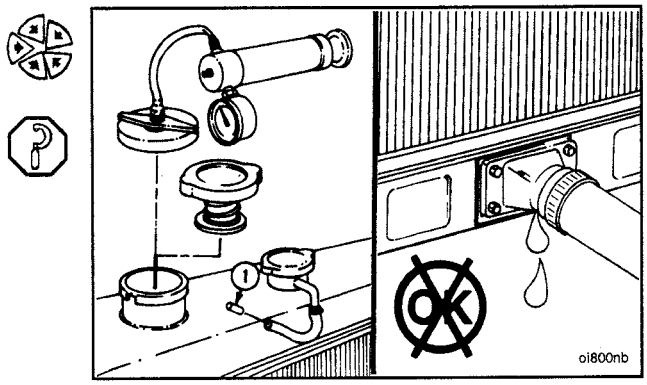
⚠ CAUTION ⚠

Do not apply more than 138-kPa [20-psi] air pressure to the cooling system. The water pump seal can be damaged.

If the radiator is equipped with a pressure relief valve, plug the overflow line (1).

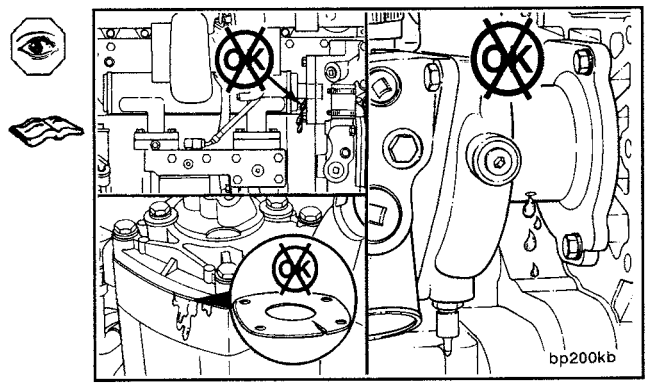
Install the pressure tester on the radiator fill neck or surge tank, if equipped, and apply air pressure.

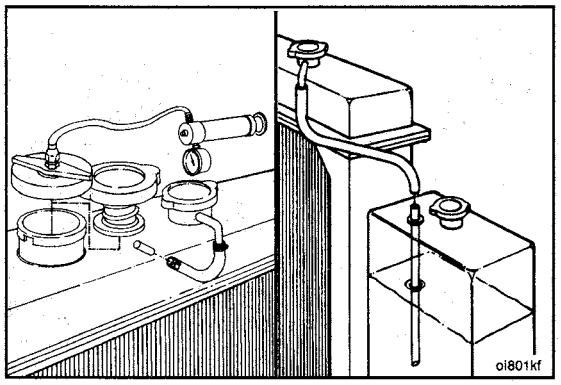
Air Pressure: 138 kPa [20 psi]



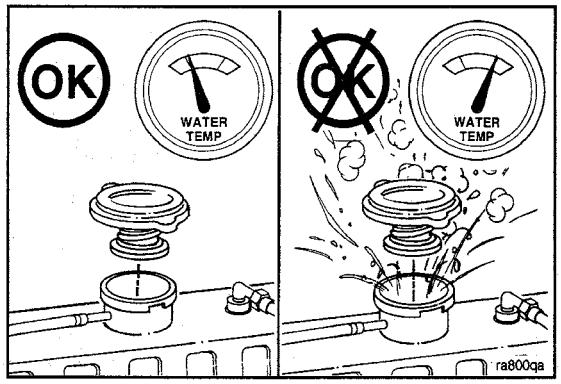
Inspect the following for coolant leaks and repair, if necessary:

- Lubricating oil cooler (refer to Procedure 007-003)
- Water pump (refer to Procedure 008-062)
- Air compressor head gasket (refer to Procedure 012-007).





Remove the pressure-test equipment, and connect the relief valve and surge tank, if equipped.



Cooling System - Air or Combustion Gas Test (008-019)

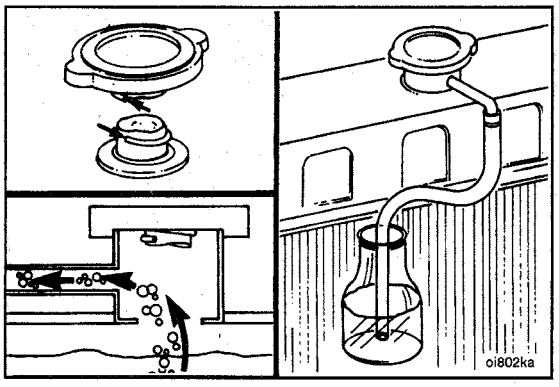
Initial Check (008-019-001)

Air in Cooling System

⚠ WARNING ⚠

Wait until the temperature is below 50°C [120°F] before removing the coolant system pressure cap. Failure to do so can cause personal injury from heated coolant spray.

Allow the engine to cool, and remove the radiator cap.

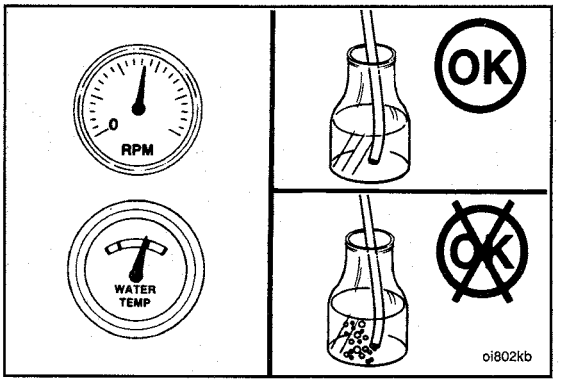


NOTE: The pressure cap **must** make a tight seal.

Install a radiator pressure cap that has had the spring and pressure relief valve removed.

Attach a rubber hose to the radiator overflow connection.

Place the free end of the hose in a container of water.

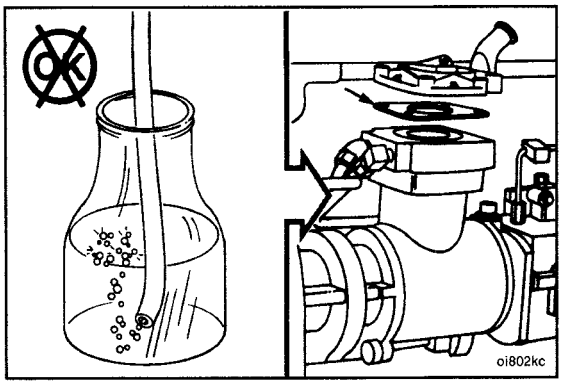


Operate the engine at rated rpm until it reaches a temperature of 80°C [180°F] with the thermostat open.

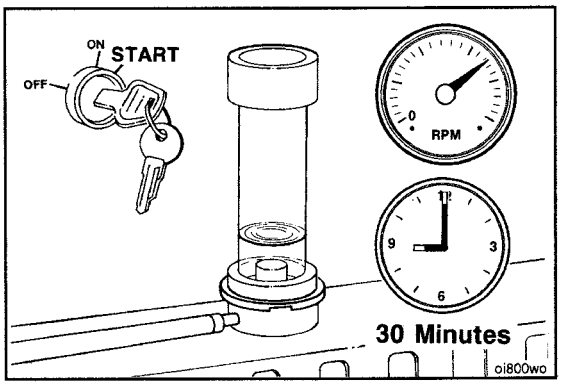
Check for a continuous flow of air bubbles from the hose in the water container.

A continuous flow of air bubbles can be caused by one of the following:

- Fan, shutter, or heater air control thermostat valve leaking air. Refer to the Leak Test for Fan, Shutter, or Heater Air Control Valve, Procedure 008-019.
- An air compressor cylinder head leak. Refer to the Leak Test for Air Compressor in this section.

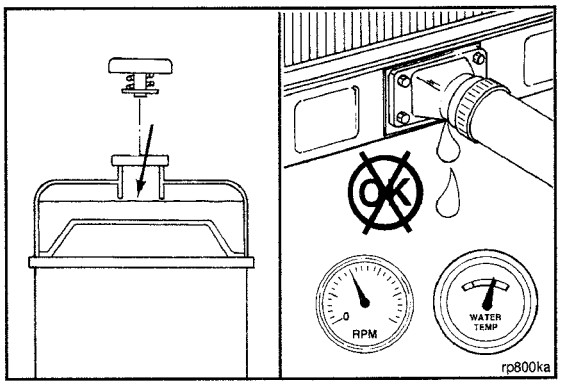


If one of the air control valves or the air compressor was **not** the source of air entering the cooling system, perform the Combustion Gas Leak Test in this section.



If no air is found in the cooling system, do the following:

- Remove the test equipment.
- Check the coolant level and fill, if necessary.
- Install the radiator pressure cap.
- Operate the engine until it reaches a temperature of 80°C [180°F] and check for coolant leaks.

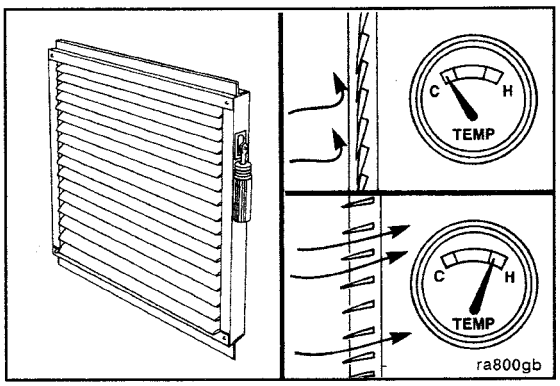


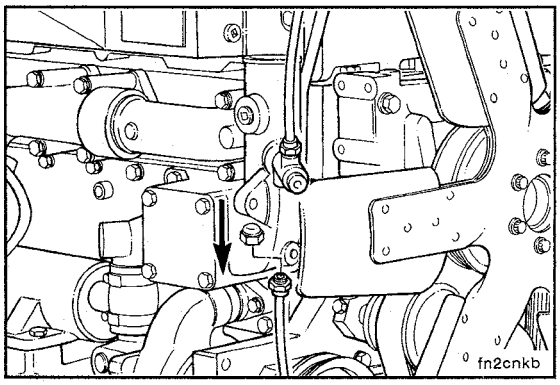
Leak Test (008-019-014)

Fan, Shutter, or Heater Air Control Valve

⚠ CAUTION ⚠

The engine can overheat with the fan control or the shutter air control valve disconnected. Monitor the engine coolant temperature while performing this test. The coolant temperature must not exceed 100°C [212°F].

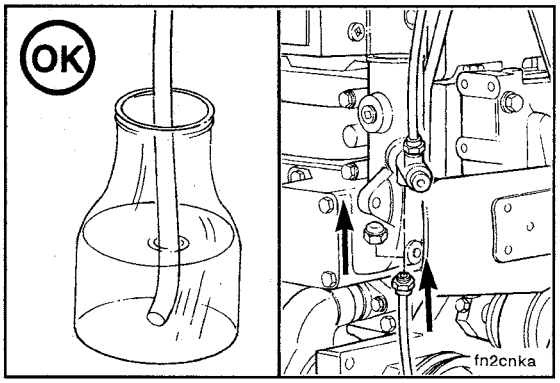




Disconnect the vehicle air supply hose to the fan, the shutter, and the heater air control valve.

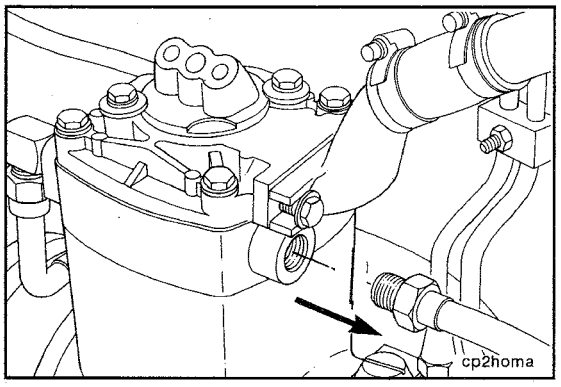
Install a plug in the air supply hose.

If the vehicle is equipped with more than one air control valve, check **only** one valve at a time.



Repeat the test for air in the cooling system as previously described in Procedure 008-019. If no air is found in the cooling system with the air control valve(s) isolated, install a new control valve.

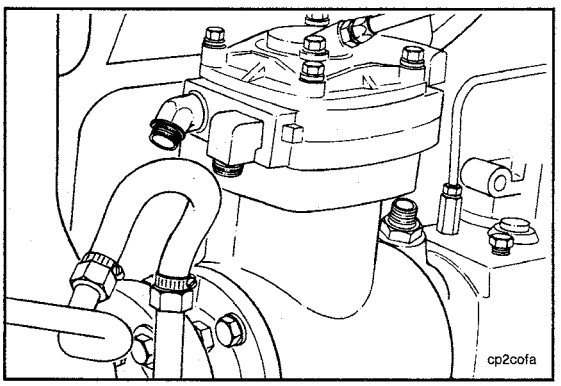
NOTE: Start the engine and run for 5 minutes before testing for air in the coolant. This will purge any trapped air from the system.



Air Compressor

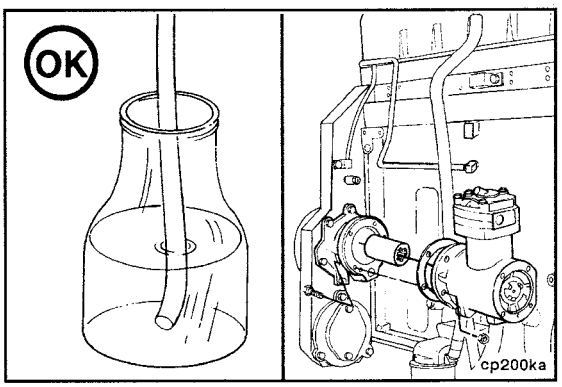
△ CAUTION △

The air compressor discharge line must be disconnected at the compressor to allow the compressor to discharge air to the atmosphere to prevent the compressor from overheating during this next test. Do not run the engine over 5 minutes with components isolated from the cooling system. Component damage can occur.



Disconnect the coolant supply and the return tubes from the air compressor. Use a short piece of hose to connect the tubes together to prevent coolant loss during engine operation.

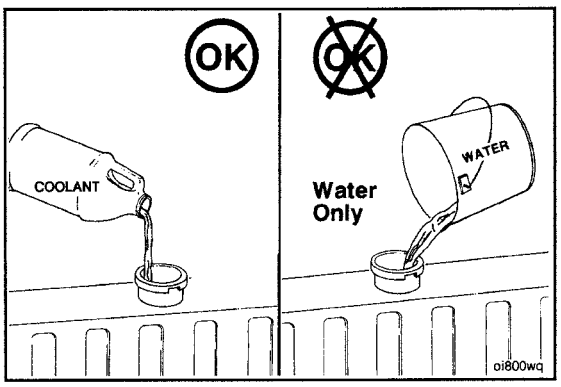
Repeat the test for air in the cooling system as previously described in Procedure 008-019. If no air is found in the cooling system with the air compressor isolated, repair or replace the air compressor. Refer to Section 12.



Combustion Gas Leak

Use combustion gas leak test kit, Part No. 3822985 or equivalent, to test for combustion gases in the cooling system.

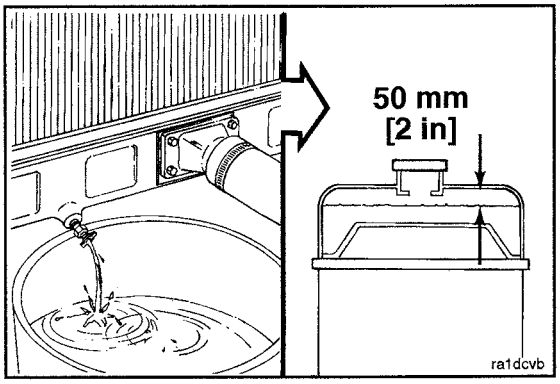
It is recommended that the cooling system contain a mixture of 50-percent antifreeze and 50-percent water during the combustion gas leak test. The use of **only** water can result in a color change in the test fluid from blue to turquoise or light green during the test. This is **not** an indication of a combustion gas leak.



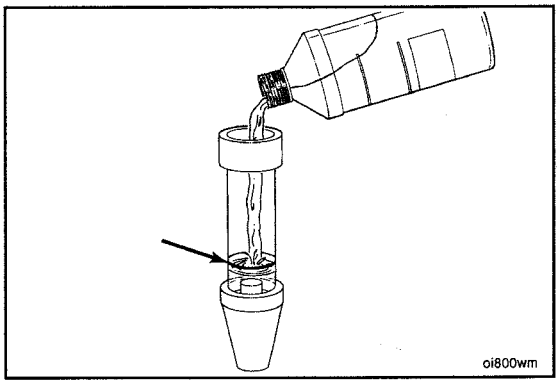
⚠ WARNING ⚠

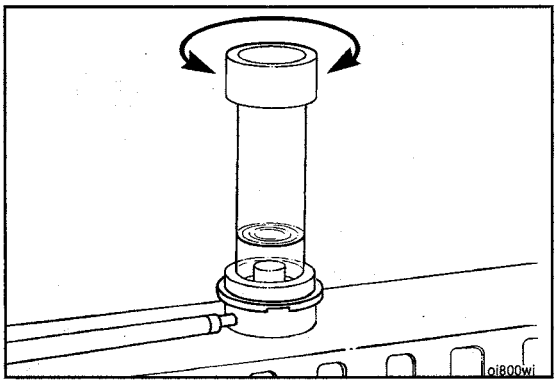
Coolant is toxic. Keep children and pets away. If the coolant is not going to be reused, dispose of it in accordance with federal, state, and local regulations.

Drain the coolant level down approximately 50 mm [2 in] below the radiator cap seal ledge in the radiator fill neck.

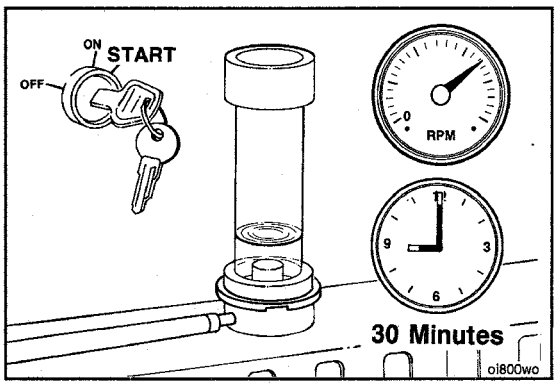


Pour the test fluid into the combustion gas leak test instrument until it is up to the yellow fill line on the instrument.

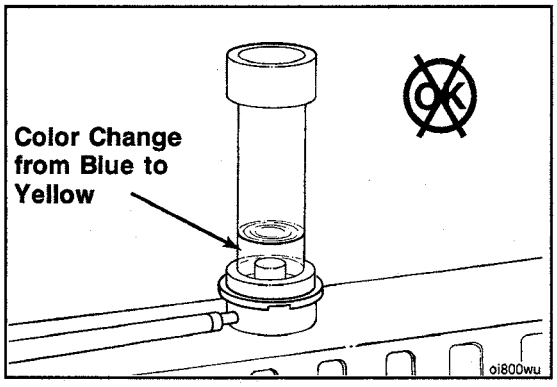




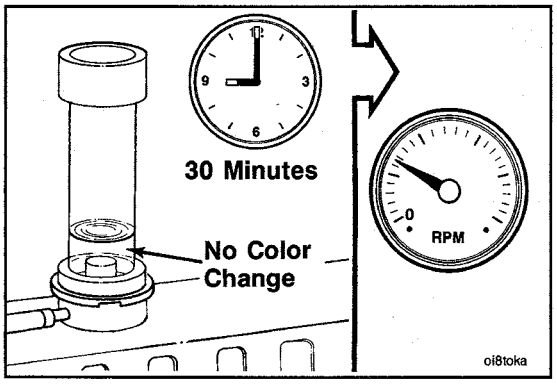
Insert the rubber tip of the combustion gas leak test instrument in the radiator fill neck. Hold the instrument down firmly while turning back and forth to make sure that an airtight seal is formed between the tester and radiator fill neck.



Start the engine and run at high idle for approximately 30 minutes. Monitor the engine temperature and color of the test fluid during engine operation. Do **not** allow the engine temperature to exceed 100°C [212°F] during the test.

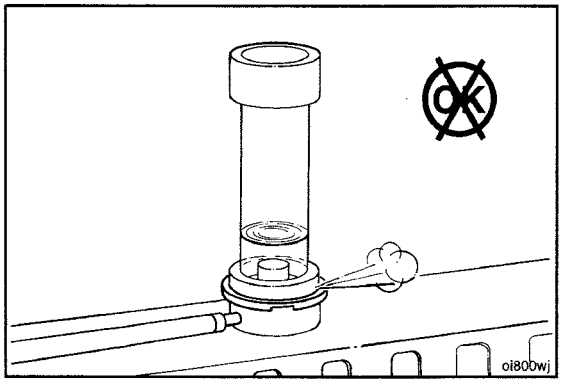


If the color of the test fluid changes from blue to yellow anytime during the test, combustion gases are leaking into the cooling system. Discontinue the test if the color of test fluid changes from blue to yellow.



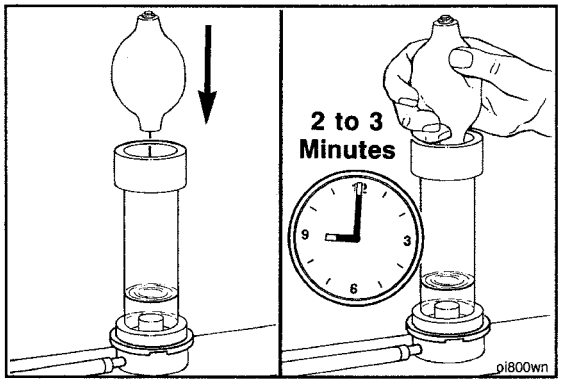
If the color of the test fluid does **not** change from blue to yellow during the 30-minute test period, return the engine to low idle.

Check the test instrument to make sure that it is firmly sealed in the radiator fill neck.

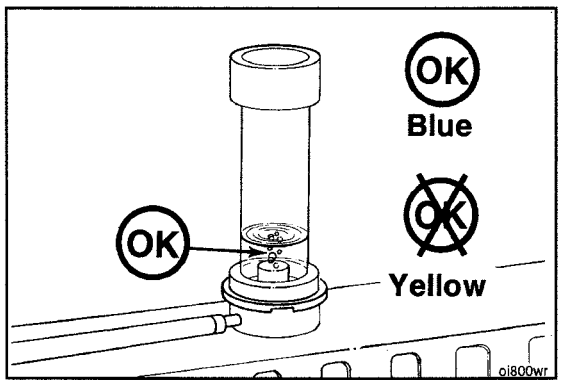


Insert the tip of the rubber ball into the hole in the top of the test instrument. Squeeze the rubber ball 2 to 3 minutes to draw air from the radiator through the test fluid.

If the color of the test fluid remains blue, combustion gases are **not** entering the cooling system. If the color of the test fluid changes from blue to yellow, combustion gases are entering the cooling system. Further investigation is required to determine the source of the combustion leak.



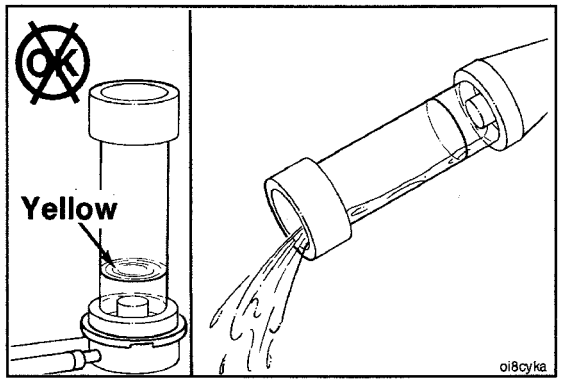
As the cooling system warms up to operating temperature, air will be expelled through the combustion gas tester in the form of bubbles in the test fluid. This is due to normal expansion of the coolant. Do **not** mistake the presence of air bubbles in the tester as combustion gases or air leaks into the cooling system. A change in the color of the test fluid from blue to yellow is the **only** indication of combustion gas in the cooling system.

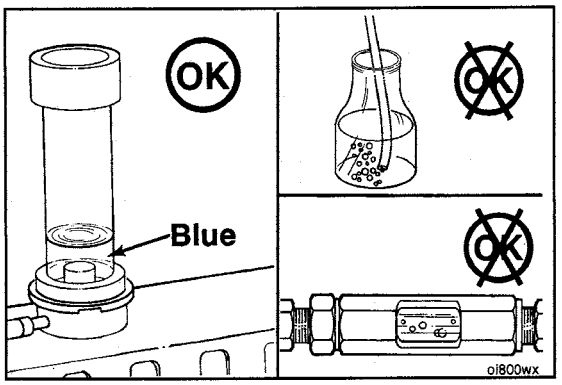


A positive result from the combustion gas leak tester indicates the following:

- Cylinder liner protrusion incorrect. Refer to Procedure 001-064.
- Cylinder head gasket or cylinder head casting leakage. Refer to Procedure 002-004.
- Injector sleeve leakage. Refer to Procedure 002-004.
- Cracked cylinder liner. Refer to Procedure 001-028.

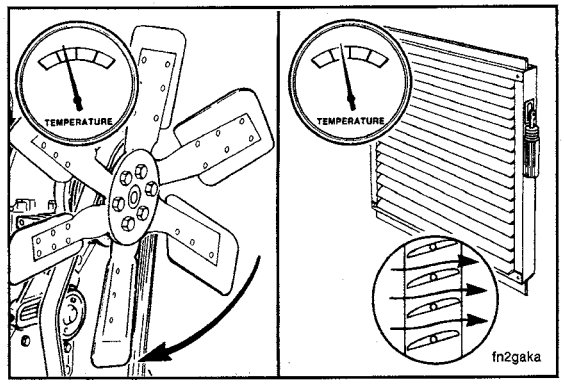
NOTE: Discard the test fluid if it has indicated positive.





A negative result from the combustion gas leak tester coupled with a continuous flow of air bubbles from the previous test indicates the following:

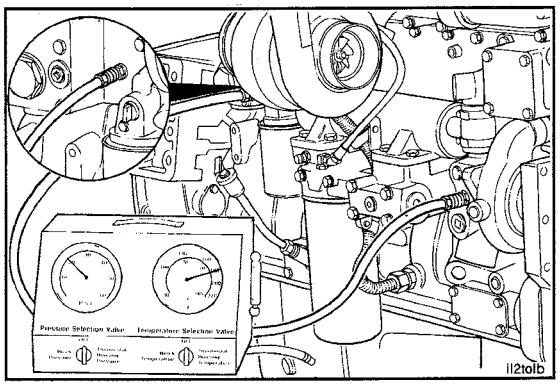
- Defective fan, shutter, or heater air control valve
- Air compressor head or head gasket leakage
- Air entrained due to a bad radiator check valve or incorrect fill.



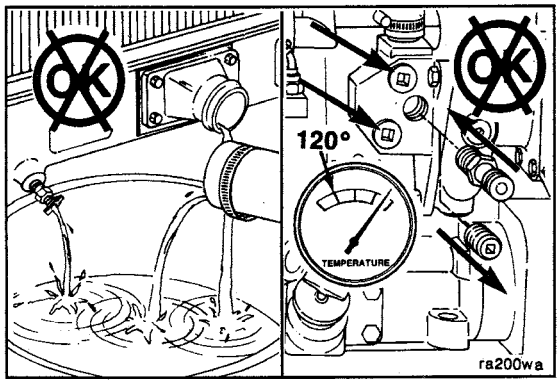
Cooling System Diagnostics (008-020)

General Information

This procedure tests the correct operation of the fan, shutter, coolant temperature gauge, and thermostat. It also checks for combustion leaks into the cooling system, coolant flow through the filter, and entrained air in the system. Carefully read and understand all the following steps before beginning the troubleshooting procedure.



This is a free-running (non-dyno) test. It requires the use of the coolant pressure/temperature/flow analyzer kit, Part No. 3822994, and the proper installation of the cooling system Compuchek® fittings located on the engine.



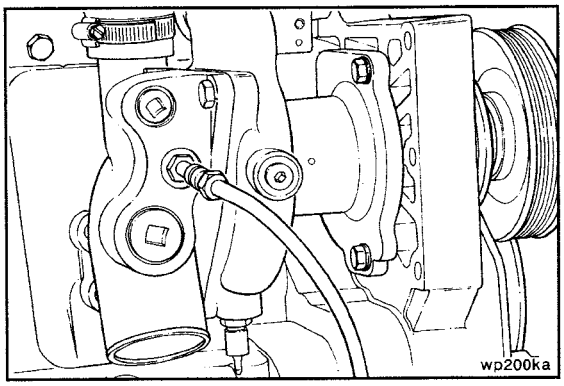
⚠ WARNING ⚠

Do not attempt to install fittings unless the coolant temperature is below 49°C [120°F]. Failure to do so can cause personal injury from heated coolant.

The coolant **must not** be drained to install the fittings. Draining the engine can introduce air into the system and give false results.

Required Engine Sensor Fittings

The water pump inlet pressure line of the analyzer kit **must** be installed on the water pump inlet Compuchek® fitting on the rear cover of the water pump.

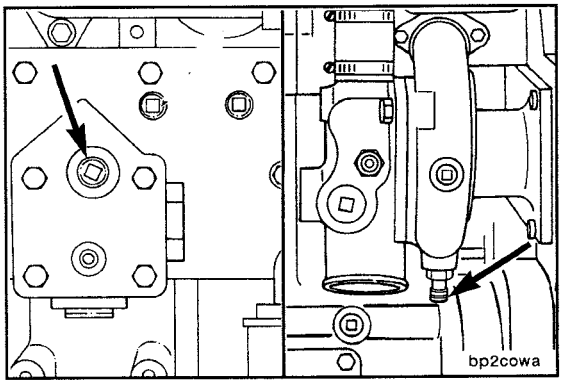


The thermostat housing pressure line of the analyzer kit can be installed in one of the following Compuchek® fitting locations:

- The heater housing on the rear of the water header plate
- The outlet fitting on the water pump.

This connection will enable the operator to record cylinder block pressure.

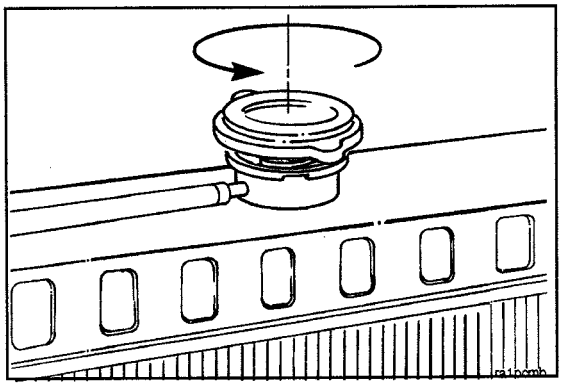
The remaining line of the analyzer kit **must** be plugged.



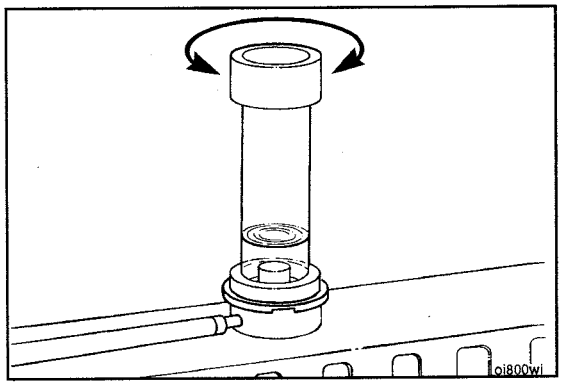
Setup (008-020-011)

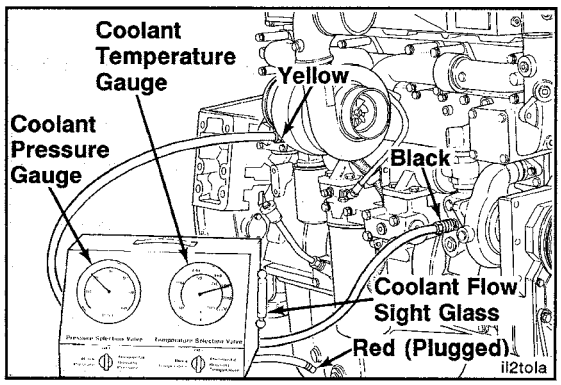
Remove the radiator cap, and leave it off for the following test.

NOTE: All cab heaters and air conditioners **must** be turned off, and the engine fan control **must** be turned to the Automatic position if applicable.



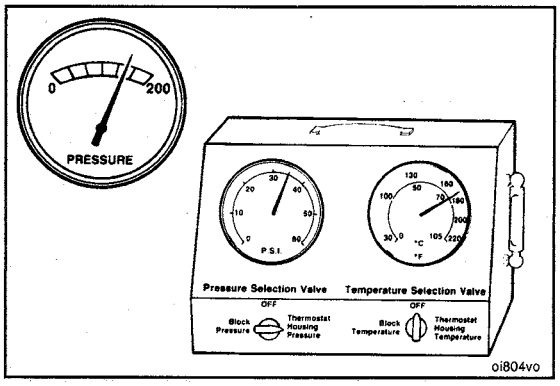
Install the combustion gas leak test instrument, Part No. 3822985. Refer to Procedure 008-019.





Install the analyzer kit, Part No. 3822994.

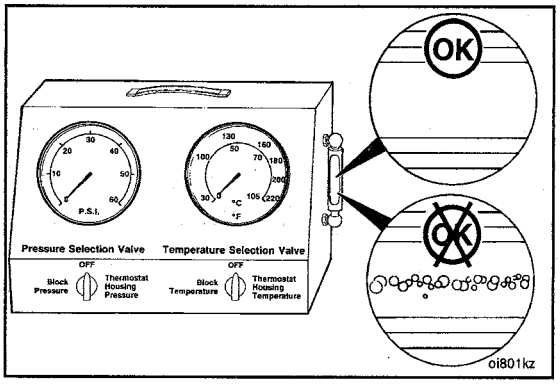
- Red Line - Plugged
- Yellow Line - Cylinder Block Pressure
- Black Line - Water Pump Inlet.



Test (008-020-012)

Pressure Readings - Turn the pressure selection valve to the position corresponding to the desired reading. Turn the temperature selection valve to the OFF position.

NOTE: When the cylinder block pressure reading is taken, the valve **must** be turned to the thermostat housing pressure location. This is due to the different hose connection used on M Series engines.



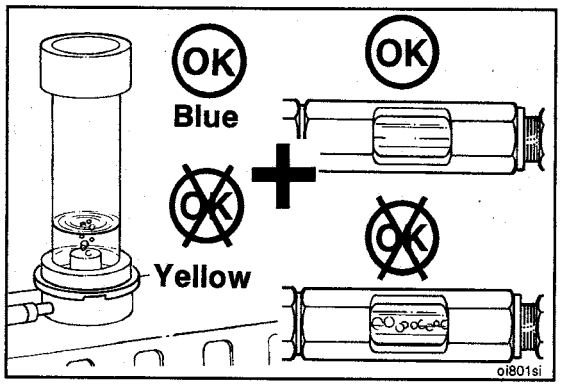
Monitor the sight glass installed on the service tool throughout the test. If air is observed, finish the test, and examine the combustion leak tester. This will determine the origin of the leak. Refer to Procedure 008-019.

Temperature Readings - There will be temperature fluctuations when switching the temperature selection valve. This fluctuation is normal and is caused by temperature loss in the line. The temperature will stabilize after a few seconds.

Operational Worksheet

Fill in the blanks with the test data as the test is being run. Mark when the radiator line gets hot, when the fan starts operating, and when the shutters open.

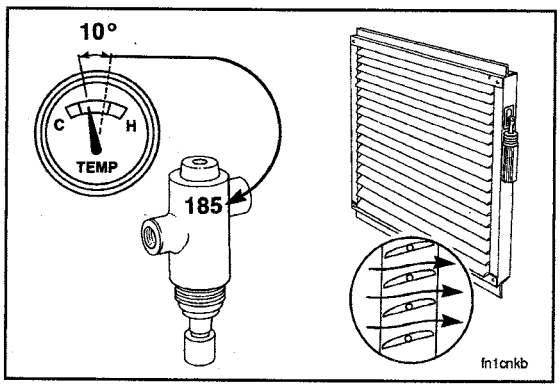
Temperature			Pressure				
Thermostat Housing	**Cylinder Block**	**Cab Gauge**	**Cylinder Block**	**Radiator "In Line" Starts Getting Hot**	**Fan Starts Operating**	**Shutters Open**	**Notes**
140			____	____	____	____	Engine at high idle throughout test
145				____	____	____	Monitor for air throughout test
150			____	____	____	____	
155	____	____		____	____	____	Start monitoring radiator "in line"
160			____	____	____	____	
165				____	____	____	Check water filter
170			____	____	____	____	
175				____	____	____	
180			____	____	____	____	
185	____	____		____	____	____	
190			____	____	____	____	
195			____	____	____	____	
200			____	____	____	____	
205				____	____	____	Cool engine down



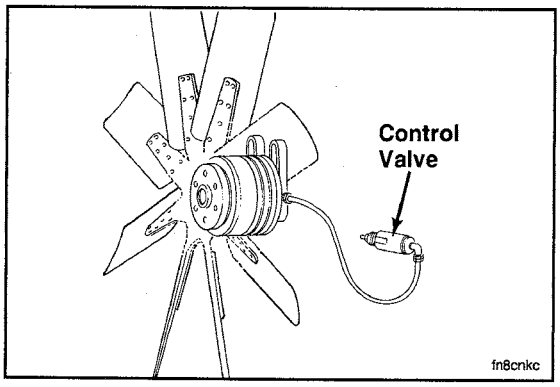
Analyzing the Data (008-020-055)

Check the color of fluid in the combustion gas leak tester. This information, along with the sight glass observations, will help isolate the source of air in the cooling system, if any. Refer to Procedure 008-019.

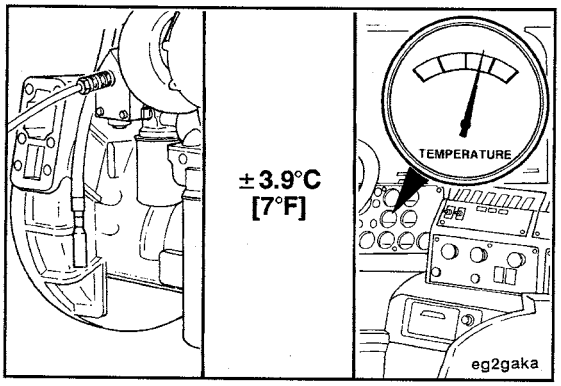
Do **not** rule out combustion gas leaks if the combustion gas leak test does **not** indicate a combustion gas leak. The test kit is **not** sensitive enough to detect very small combustion gas leaks.



Check the recorded coolant temperature when the shutters are opened. Compare this value to that which is stamped on the shutter control. Cummins Engine Company, Inc. recommends that the shutters open at 85°C [185°F].



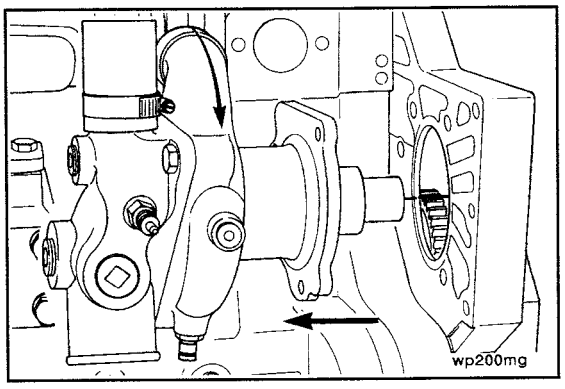
Check the recorded coolant temperature when the fan is engaged. Compare this value to that which is stamped on the fan control. Cummins Engine Company, Inc. recommends that the fan engage at 96°C [205°F].



Compare the cab temperature gauge reading with the block temperature. Replace the cab temperature gauge if it is **not** within the manufacturer's specifications of the correct reading. If no manufacturer's specifications are available, replace the gauge if it is **not** ±3.9°C [7°F] of the correct reading.

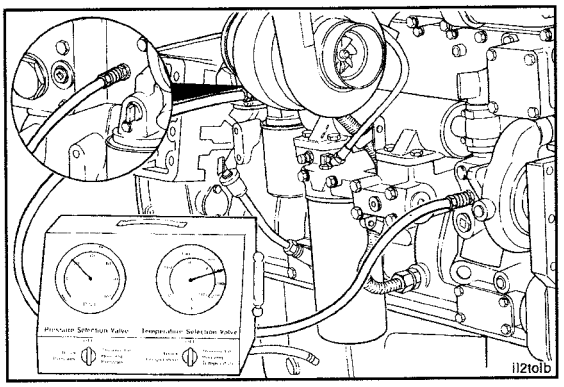
Read the recorded block pressure at 60°C [140°F]. If the block pressure is less than 138 kPa [20 psi] at high idle and without a pressure cap, check the following:

- Remove the water pump, and inspect the impeller's integrity and for slippage on the shaft.



If there is a drop in block pressure of more than 34 kPa [5 psi] during the test, check the following:

- Air in the system. Refer to Procedure 008-019.
- Incorrect initial cooling system fill.
- Less than 50/50 antifreeze mixture, or the engine is at high altitude.

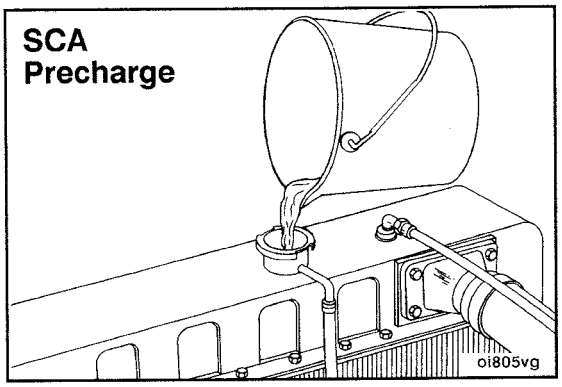


Cooling System Precharge (008-021)

General Information

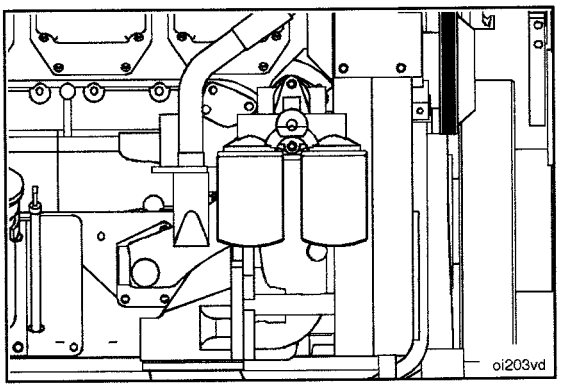
Correct use of SCAs in conjunction with proper maintenance practices are needed to protect engines from cooling system problems. The system **must** be precharged with the correct number of units of SCA.

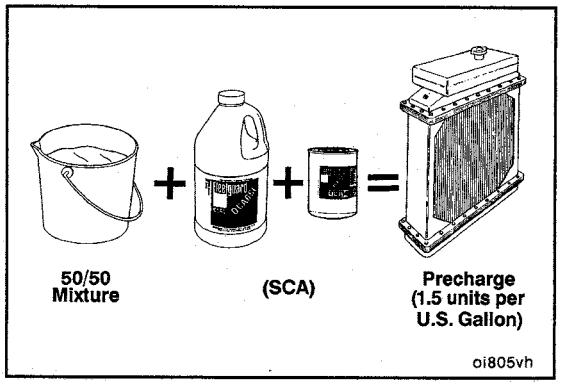
Cummins/Fleetguard® uses the SCA unit to define the required concentration level to protect against liner pitting.



Factory Precharge Method (008-021-271)

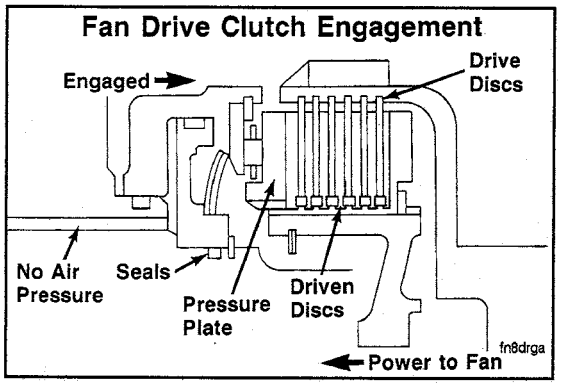
New engines have a DCA4 coolant filter installed at the factory that will precharge the cooling system to the correct SCA concentration of approximately 1.5 units per gallon.





Customer Precharge Method (008-021-272)

When coolant is replaced in the field, it **must** be replaced with **fully formulated coolant** or a 50/50 mixture of good-quality water and **fully formulated antifreeze** and the correct service coolant filter. Refer to Specifications at the front of this section for correct requirements.



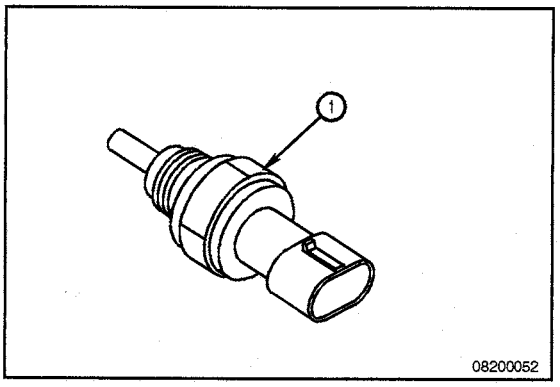
Fan Clutch, Air-Disengaged (008-024)

Maintenance Check (008-024-008)

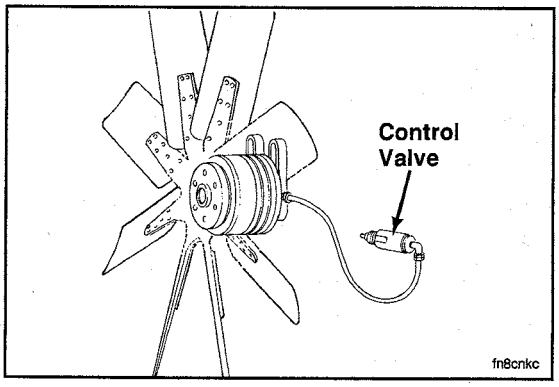
This type of fan clutch is engaged by spring tension and is disengaged by air pressure.

This type of fan clutch requires air pressure for free rotation. In the event of air pressure loss, the fan will be engaged.

Air pressure of 480 to 830 kPa [70 to 120 psi] is required to override the clutch spring tension to disengage the fan.



If the fan does **not** operate within the temperature range indicated on the coolant temperature sensor (1), the fan clutch and the controls **must** be checked. Refer to the fan clutch manufacturer's service manual.



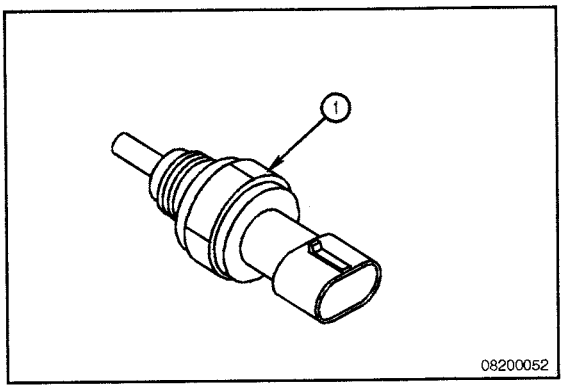
Fan Clutch, Air-Engaged (008-025)

Maintenance Check (008-025-008)

This type of fan clutch is engaged by air pressure and is disengaged by spring tension.

Air pressure of 620 to 830 kPa [90 to 120 psi] is required to override the clutch spring tension to engage the fan.

If the fan does **not** operate within the temperature range indicated on the coolant temperature sensor (1), the fan clutch and the controls **must** be checked. Refer to the fan clutch manufacturer's service manual.



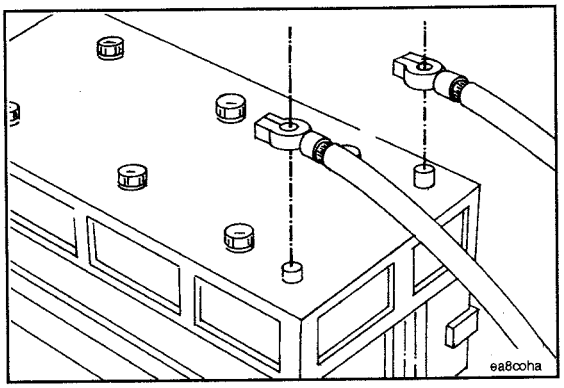
Fan Clutch, Electric (008-026)

Remove (008-026-002)

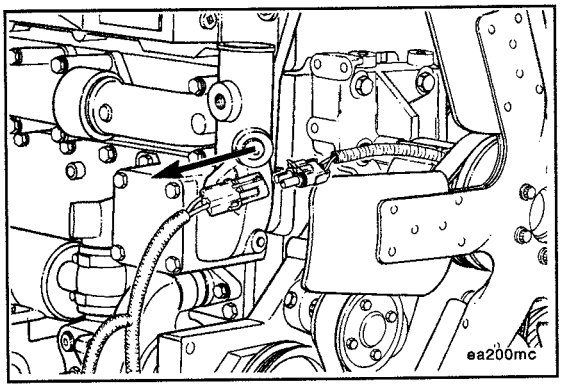
⚠ WARNING ⚠

Batteries can emit explosive gases. To avoid personal injury, always ventilate the compartment before servicing the batteries. To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

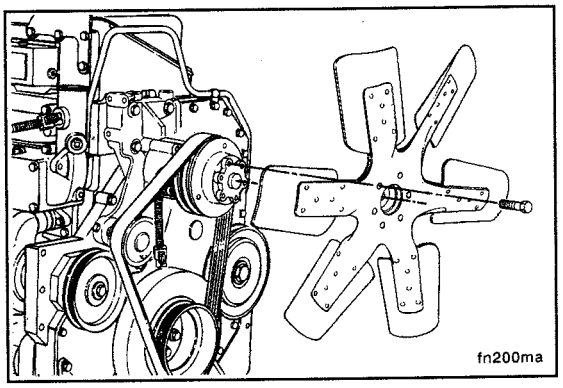
Disconnect the electrical connections, negative (-) cable first, from the batteries.

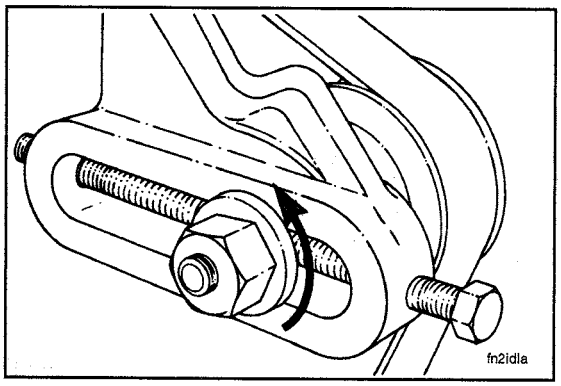


Disconnect the fan clutch connector on the base harness from the fan clutch.



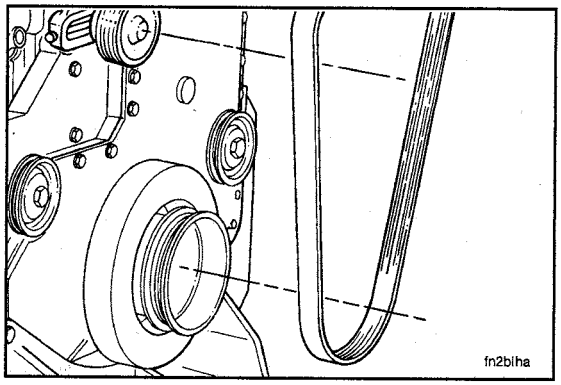
Remove the fan from the engine.



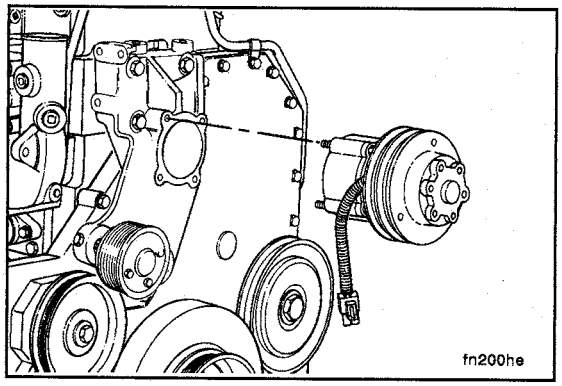


Loosen the fan idler pulley shaft locknut.

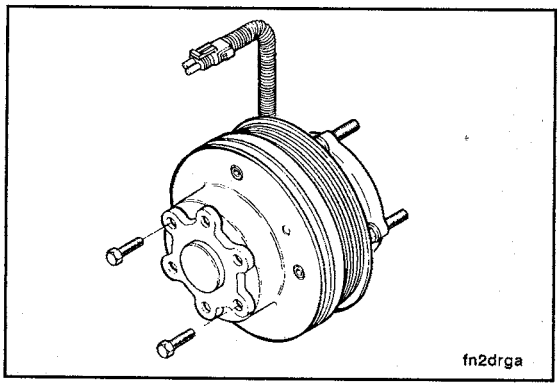
Turn the adjusting screw **counterclockwise** to release the fan belt tension.



Remove the fan drive belt.



Remove the fan hub, clutch and capscrews from the engine.

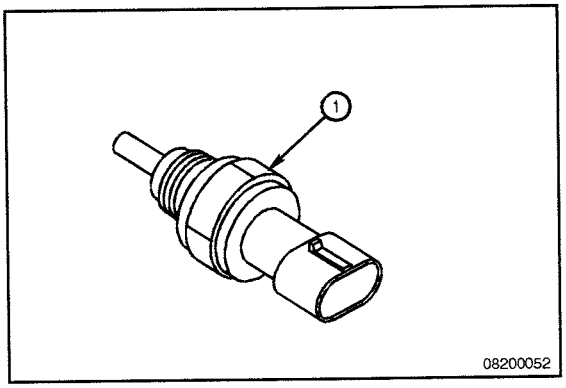


Inspect for Reuse (008-026-007)

This type of fan clutch is activated when 12 VDC from the vehicle electrical system is applied.

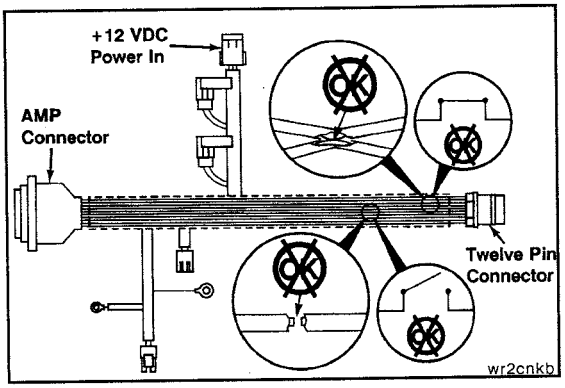
The clutch will disengage when 0 VDC is applied.

If the fan does **not** operate within the temperature range on the coolant temperature sensor (1), the fan clutch and the controls **must** be checked.



Electrical Connections

Inspect wires and harnesses to make sure none are broken or shorted. Replace harnesses or wires that are broken. Refer to Procedure 008-069.

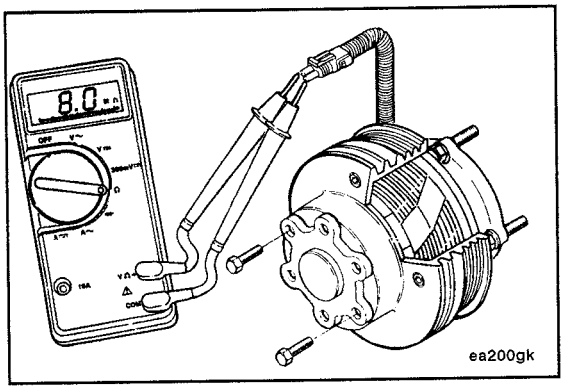


Electromagnetic Coil

The Cummins electric fan clutch contains an electromagnetic coil. If the fan is **not** operating and all electrical circuits are OK, the coil possibly has an open circuit.

Measure the continuity across the isolated coil. Connect one multimeter lead to pin A in the fan clutch connector. Connect the other lead to pin B.

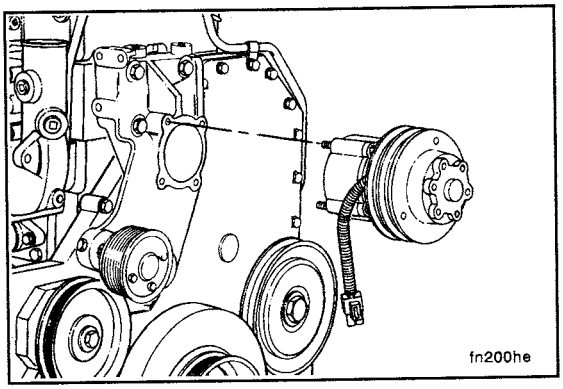
The resistance **must** be within 6-10 ohms. If the resistance is **not** within this range, replace the fan clutch.

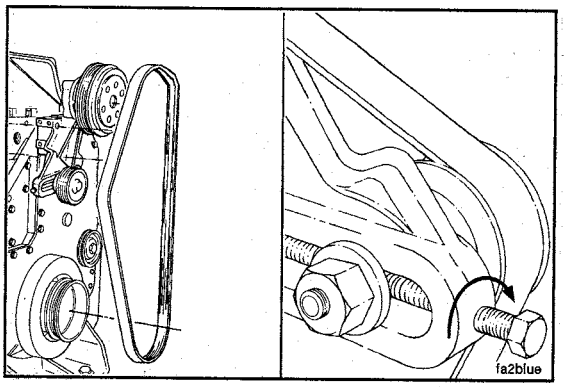


Install (008-026-026)

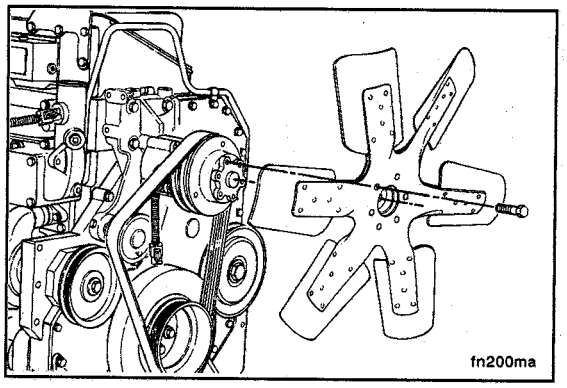
Install the fan hub, clutch, and capscrews. Tighten the capscrews alternately and evenly.

Torque Value: 47 N•m [35 ft-lb]

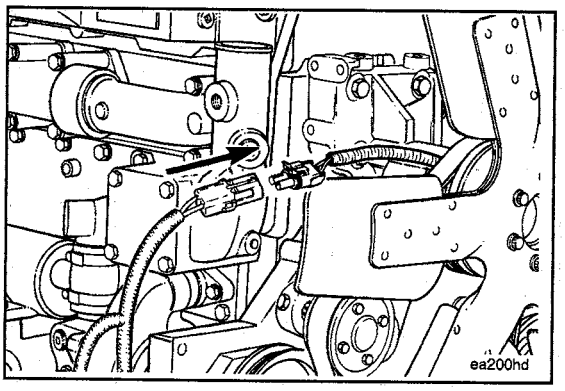




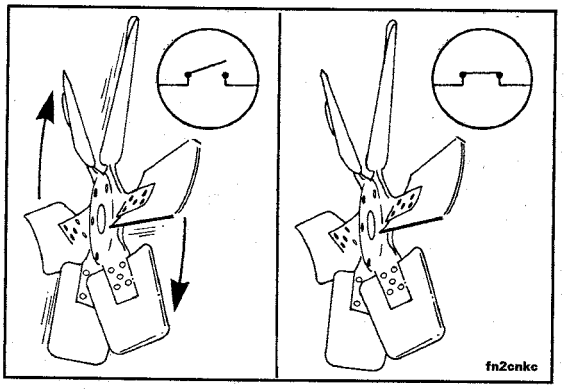
Install the fan belt on the engine. Refer to Procedure 008-002.



Install the fan and capscrews. Tighten the capscrews to the fan manufacturer's specifications.



Connect the fan clutch connector on the base harness to the fan clutch.



Fan Clutch, On-Off (008-027)

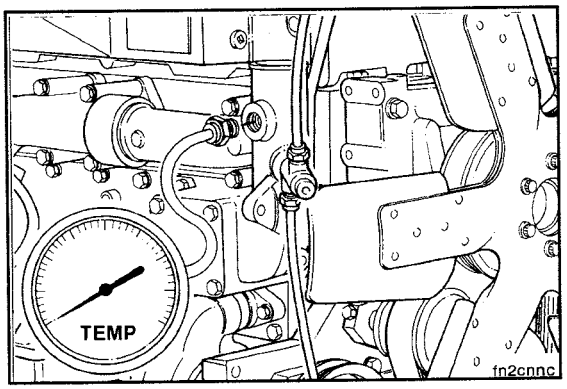
General Information

The fan clutches can be controlled by the electronic control module (ECM). The ECM is programmed to turn the fan on when 0 VDC (normally open switch) is applied to the fan clutch relay, and turn the fan off when 12 VDC (normally closed switch) is applied to the fan clutch relay.

The following fan clutch checks are for fan clutches wired to the electronically controlled fuel system. Refer to the vehicle manufacturer's specifications to determine the installation of the fan clutch.

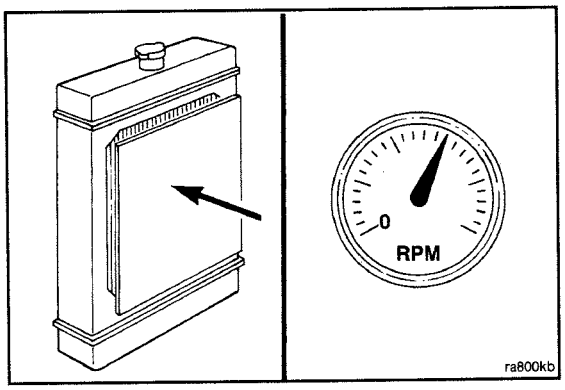
Initial Check (008-027-001)

Remove the shutter stat from the thermostat housing, if equipped, and install a master temperature gauge that is known to be accurate. A thermocouple can be used.



Restrict the radiator's airflow.

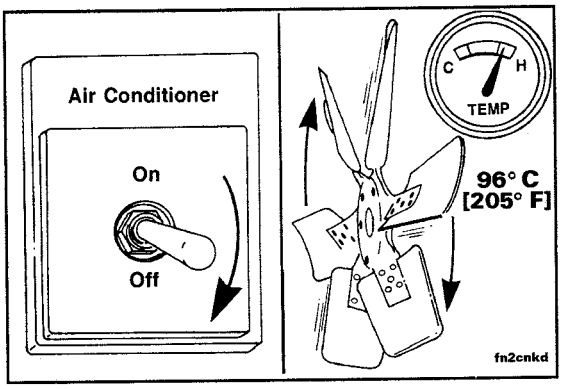
Operate the engine at rated rpm.



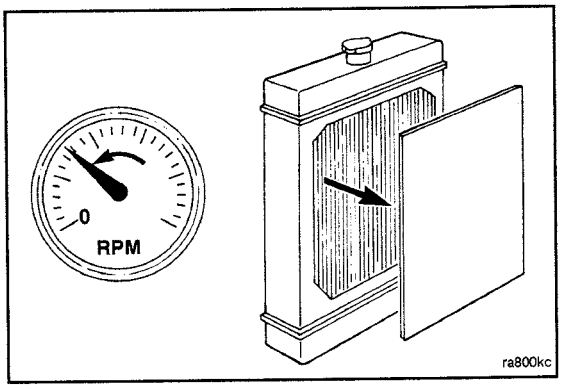
If the vehicle is air-onditioned, make sure the air-conditioning is turned off to prevent continuous operation of the fan. When the coolant temperature reaches 96°C [205°F], check for fan engagement.

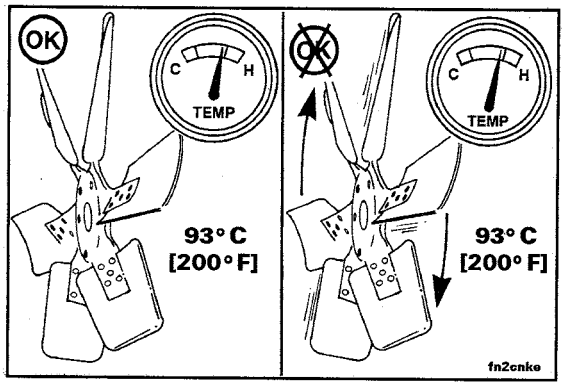
NOTE: The temperature given for fan engagement is for fans controlled by the ECM.

NOTE: Fan noise and airflow increase when the fan clutch engages.



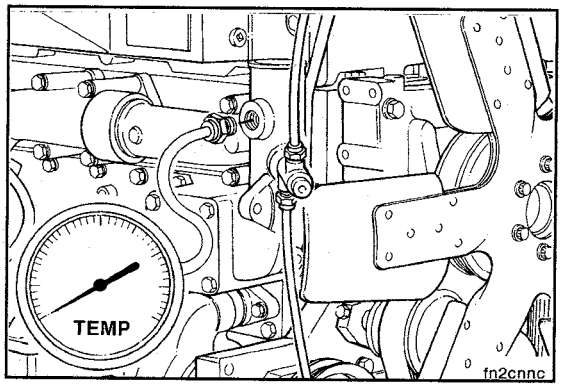
Return the engine to idle, and remove the radiator air restriction.



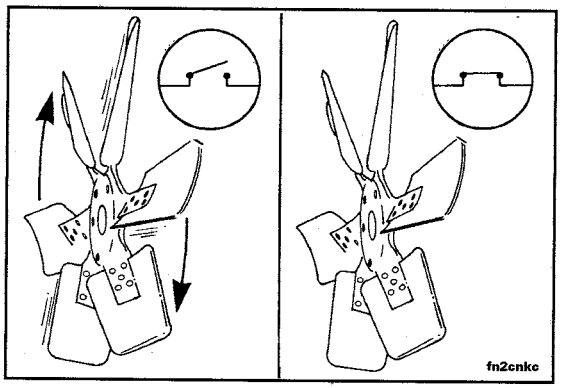


The fan clutch **must** disengage before the coolant temperature drops to 93°C [200°F]. Cummins Engine Company, Inc. recommends the fan disengage at 3°C [6°F] below the temperature stamped on the fan temperature sensor.

NOTE: The temperature given for fan disengagement is for fans controlled by the ECM.



Remove the temperature gauge or thermocouple, and install the shutter stat, if used.

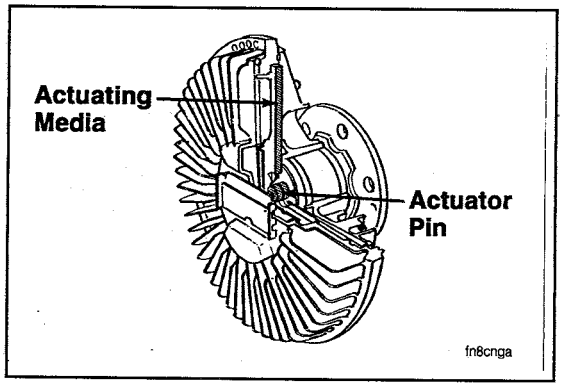


Fan Clutch, Viscous (008-028)

General Information

The fan clutches can be controlled by the electronic control module (ECM). The ECM is programmed to turn the fan on when 0 VDC (normally open switch) is applied to the fan clutch relay, and turn the fan off when 12 VDC (normally closed switch) is applied to the fan clutch relay.

The following fan clutch checks are for fan clutches wired to the electronically controlled fuel system. Refer to the vehicle manufacturer's specifications to determine the installation of the fan clutch.

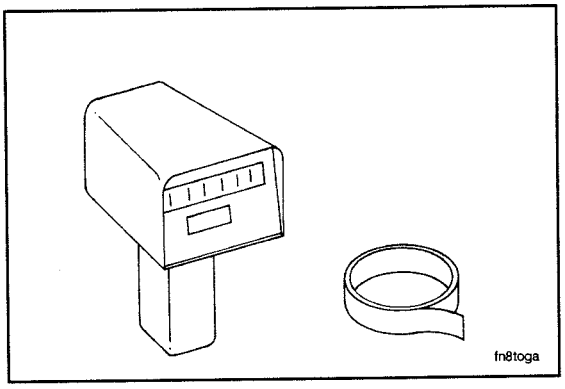


Initial Check (008-028-001)

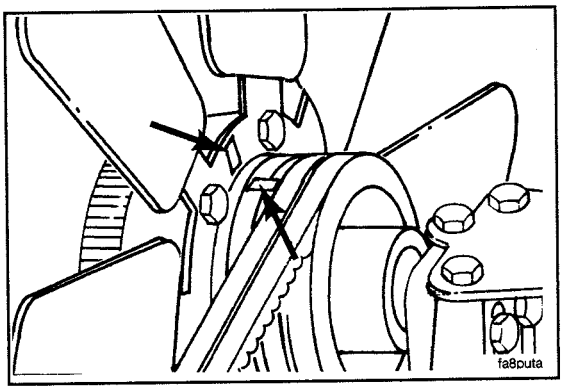
Viscous fan drives are used as a power-saving device activated by a built-in sensor behind the radiator used to monitor air temperature.

When the air temperature reaches a specific level, depending on the temperature setting of the sensor used, the temperature-sensing control moves an actuator that allows viscous fluid to engage the fan drive and increase the fan speed.

Use a fan rpm-measuring device to check the operation of the viscous fan hub. A strobe or digital optical tachometer, Part No. 3377462, can be used.

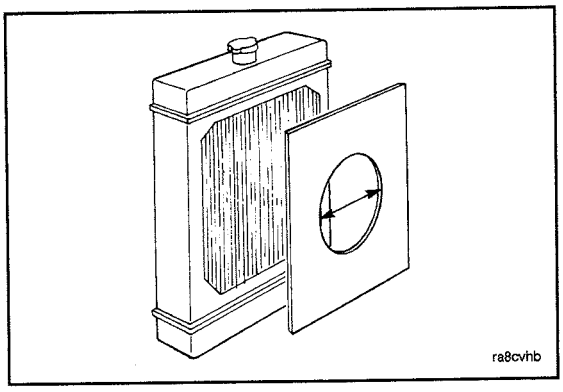


Mark a spot on the fan hub pulley and one fan blade so the measuring device can determine the pulley and the fan speed. Reflective tape, Part No. 3377464, in digital optical tachometer, Part No. 3377462, can be used to mark the fan blade and the pulley. (Refer to Service Tools Instruction, Bulletin No. 3377544, for more information.)



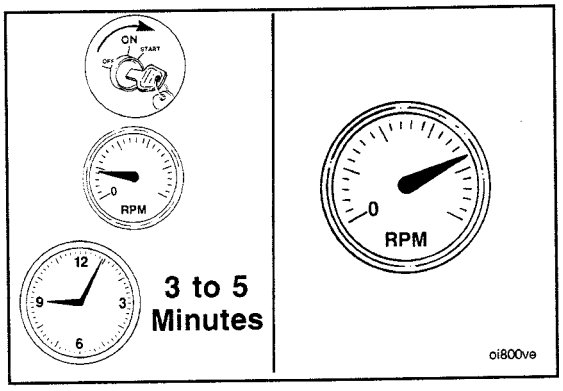
While the engine is still warm and the vehicle is shut off, cover the radiator grill.

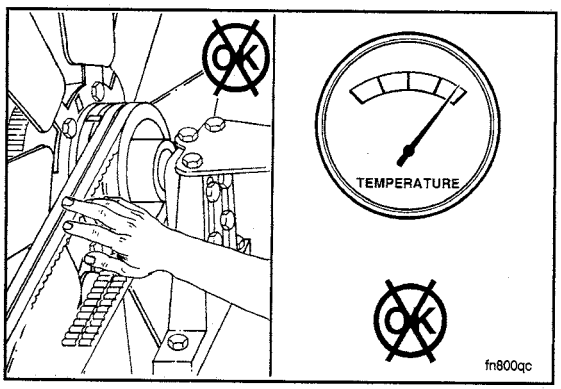
Leave a hole approximately 0.3 m [1-ft] in diameter in the cardboard to allow some air to flow to the viscous fan hub.



Start the engine. Idle the engine for 3 to 5 minutes. Lock the throttle in a HIGH IDLE position.

Use the PTO option to operate the engine at maximum PTO engine rpm.



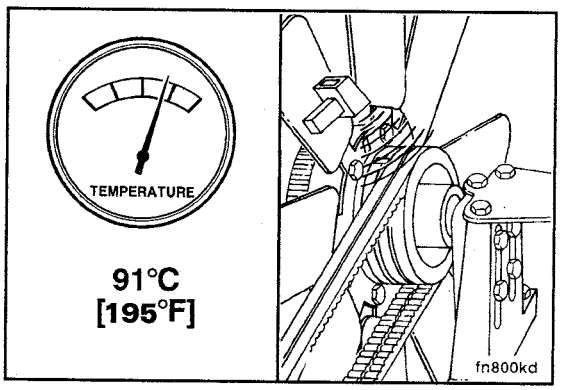


⚠ WARNING ⚠

The fan will engage when the engine is started. To avoid personal injury, do not put your hands in the path of the rotating fan. Do not wear jewelry or loose or torn clothing.

△ CAUTION △

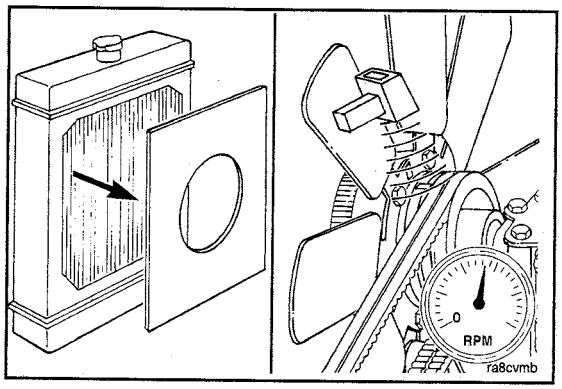
Do not exceed 100°C [212°F] coolant temperature. Higher coolant temperatures can damage the engine.



When the coolant temperature reaches 91°C [195°F], measured fan speed **must** reach a minimum of 85 percent of the pulley speed.

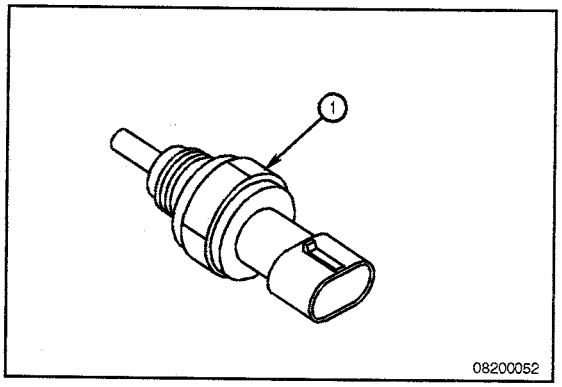
Measure the fan speed divided by the fan hub (pulley) speed. The dividend **must** be greater than or equal to 0.85.

Measured Fan Speed	**0.85**
Fan Hub (Pulley Speed)	



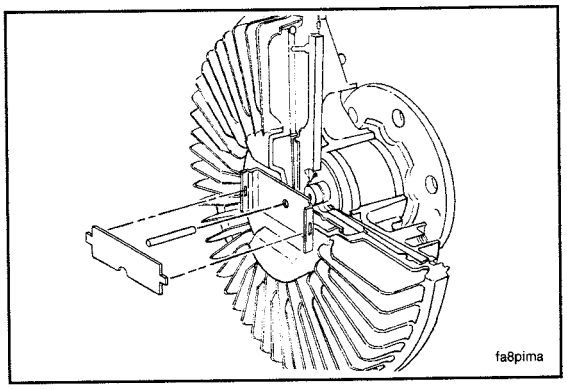
While the engine is still at high idle, remove the radiator grill cover. The fan speed **must** begin to decrease after 1 minute and eventually drop to a maximum of 50 percent of the input pulley speed.

If the viscous fan hub fails this test, have it checked by an authorized fan hub dealer for repair or replacement.

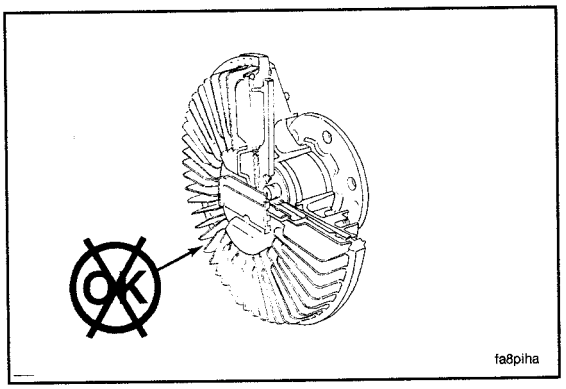


If the fan does **not** operate within the temperature range indicated on the coolant temperature sensor (1), the fan clutch and the controls **must** be checked. Refer to the fan clutch manufacturer's service manual.

If a fan speed measuring device is **not** available and the complaint concerns overheating, remove the viscous fan hub bimetal strip and the control pin. This will cause the fan hub to operate all the time.



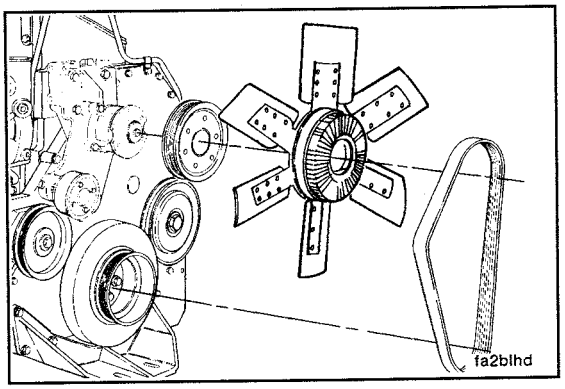
If the overheating complaint does **not** occur with the control pin removed, install the control pin, and take the fan hub to an authorized fan hub dealer for repair or replacement.



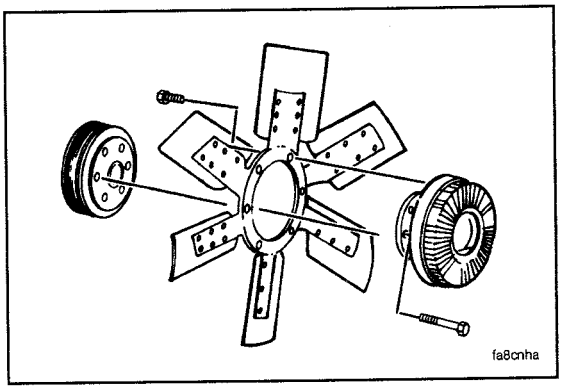
Remove (008-028-002)

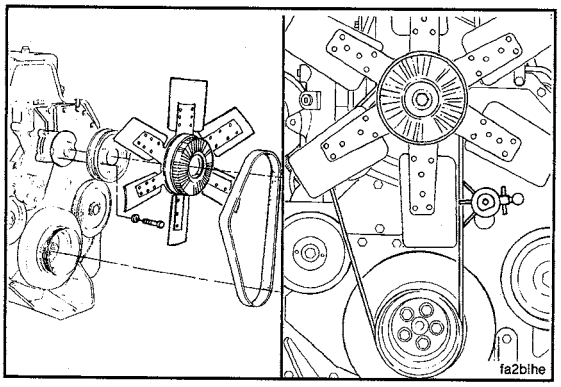
Remove the fan drive belt. Refer to Procedure 008-002.

Remove the fan and fan clutch assembly.



Remove the nuts, washers, and fan.





Install (008-028-026)

Install the fan on the fan clutch assembly.

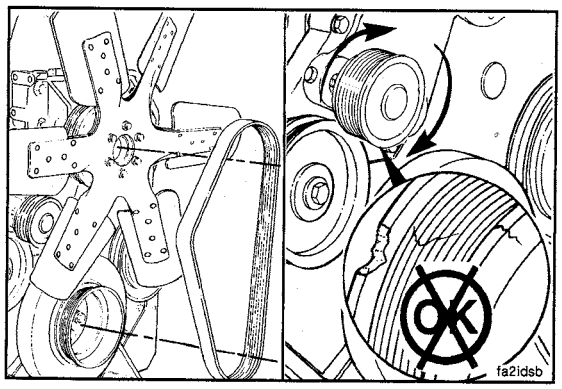
Tighten the mounting nuts to the manufacturer's torque specifications.

Install the fan clutch and fan assembly on the engine.

Tighten the capscrews.

Torque Value: 68 N•m [50 ft-lb]

Install, adjust, and tighten the fan drive belt. Refer to Procedure 008-002.



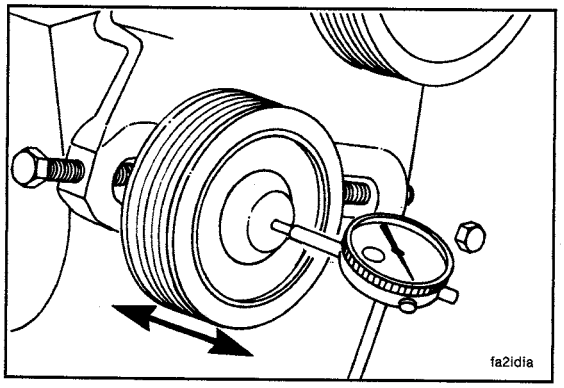
Fan Drive Idler Pulley Assembly (008-030)

Initial Check (008-030-001)

Remove the fan drive belt. Refer to Procedure 008-002.

Inspect the idler pulley for:

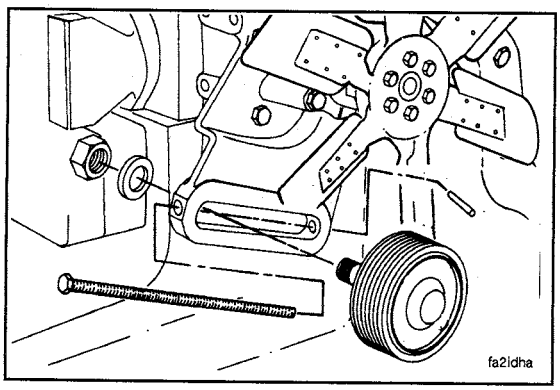
- Freedom of rotation
- Cracked, chipped, or broken pulley grooves.



Measure the idler pulley end clearance.

Idler Pulley End Clearance		
mm		in
0.025	MIN	0.0010
0.250	MAX	0.0100

Replace or rebuild the idler pulley if the end clearance is **not** within these specifications. Refer to the Shop Manual listed in Section L for rebuilding procedures, or contact your local Cummins Authorized Repair Location.



Remove (008-030-002)

Remove the roll pin and washer from the idler pulley adjusting screw.

Remove the locknut and washer from the back of the idler pulley shaft.

Remove the adjusting screw.

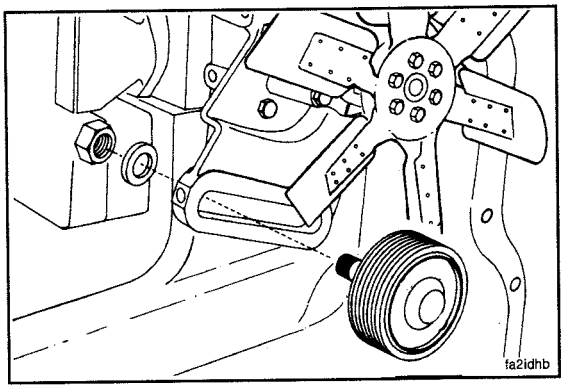
Remove the fan idler pulley from the fan hub support bracket.

Install (008-030-026)

NOTE: Do **not** tighten the locknut until the fan drive belt has been installed and adjusted.

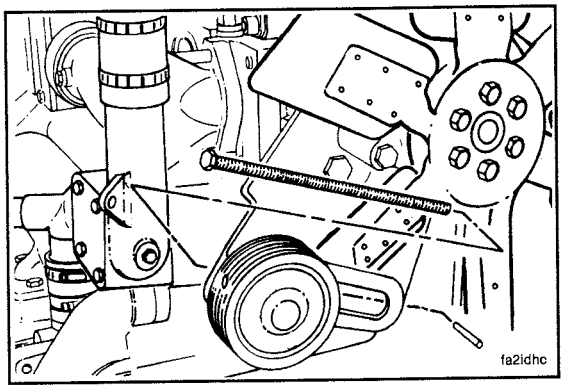
Install the idler pulley in the fan hub support bracket.

Install the washer and locknut on the idler pulley shaft.



Install the adjusting screw in the idler pulley shaft.

Turn the adjusting screw in far enough to install the washer and roll pin in the shaft at the bottom of the fan hub support bracket.

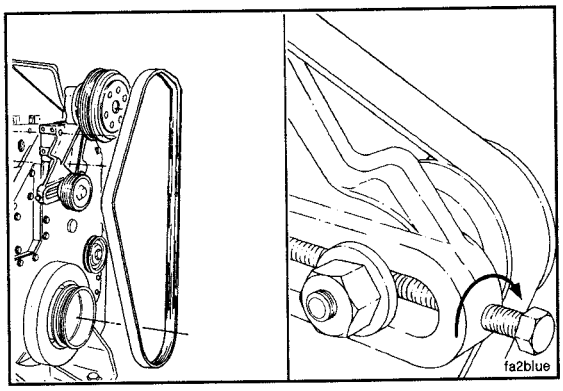


Install and adjust the fan drive belt.

Tighten the idler pulley shaft locknut.

Torque Value: 190 N•m [140 ft-lb]

Check the belt tension again after the locknut is tightened.

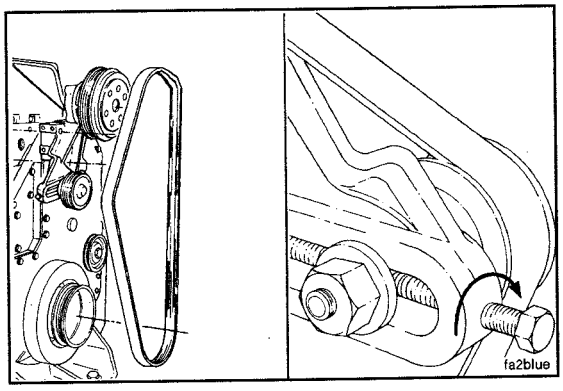


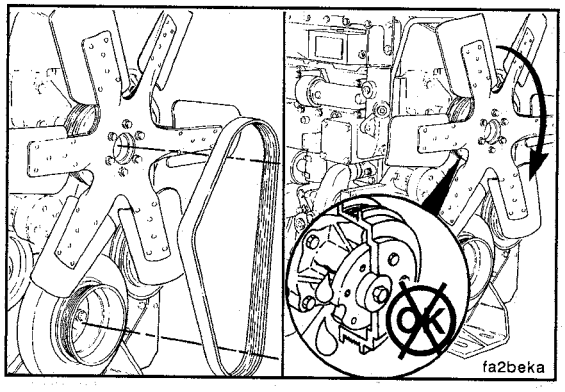
Install and adjust the fan drive belt. Refer to Procedure 008-002.

Tighten the idler pulley shaft locknut.

Torque Value: 190 N•m [140 ft-lb]

Check the belt tension again after the locknut is tightened.





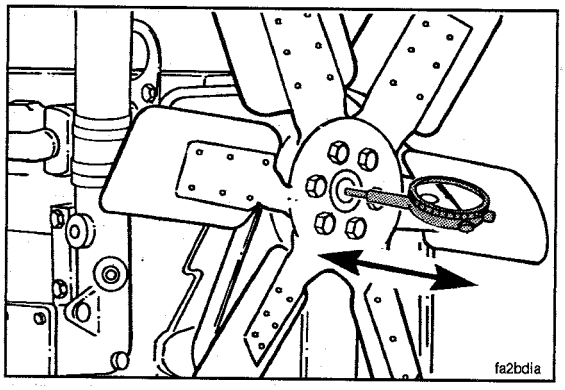
Fan Hub, Belt Driven (008-036)

Initial Check (008-036-001)

Remove the fan drive belt. Refer to Procedure 008-002.

Inspect the fan hub for:

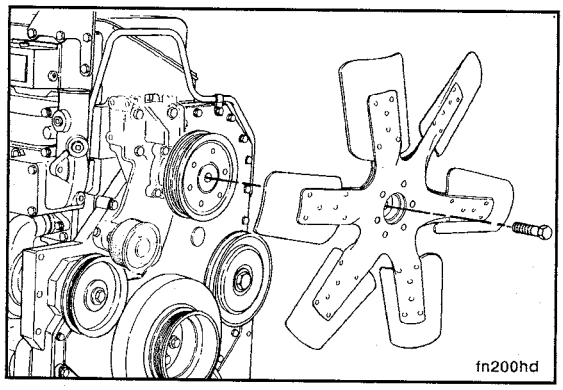
- Freedom of rotation
- Cracks
- Grease seal leakage.



Measure the fan hub end clearance.

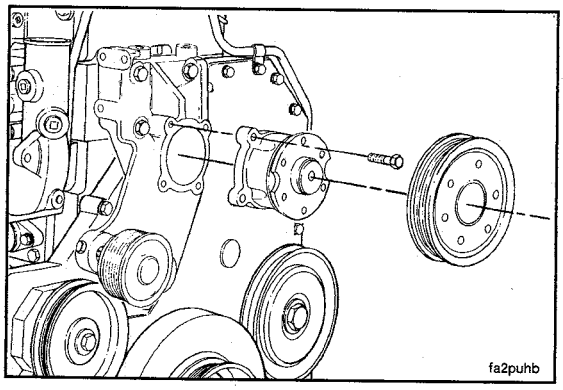
Fan Hub End Clearance		
mm		in
0.08	MIN	0.003
0.41	MAX	0.016

Replace or rebuild the fan hub if the end clearance does **not** meet these specifications. Refer to the Shop Manual listed in Section L for rebuilding procedures, or contact your local Cummins Authorized Repair Location for rebuilding the fan hub.



Remove (008-036-002)

Remove the fan and clutch assembly. Refer to Procedure 008-040.



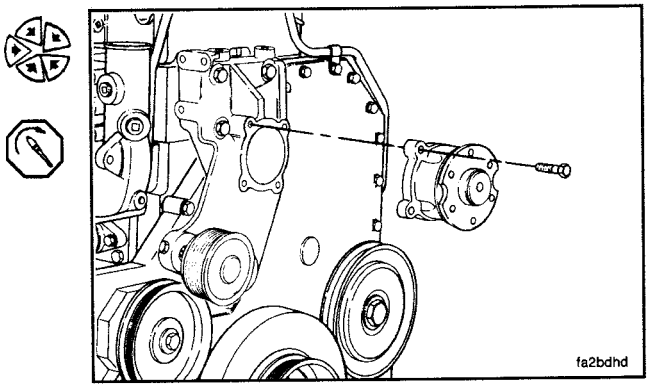
Remove the fan drive pulley.

Remove the four capscrews and the fan hub.

Install (008-036-026)

Install the new fan hub and four capscrews.

Torque Value: 47 N•m [35 ft-lb]



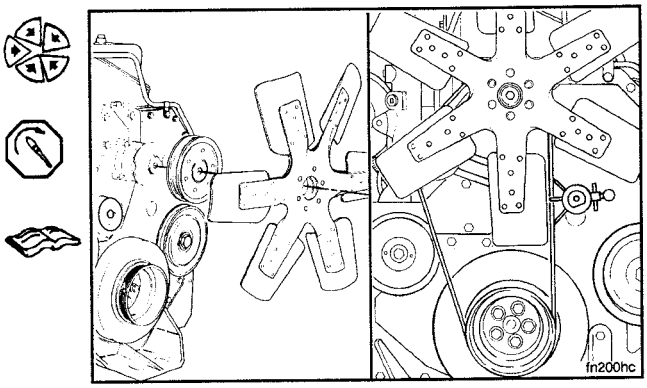
Install the fan drive pulley.

Install the fan and clutch assembly. Refer to Procedure 008-040.

Install and tighten the mounting capscrews.

Torque Value: 68 N•m [50 ft-lb]

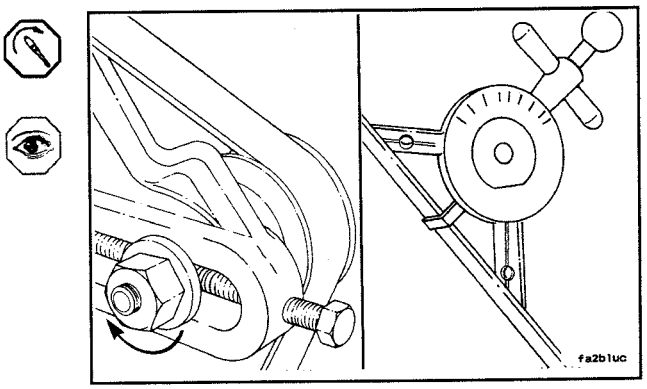
Install, adjust, and tighten the fan drive belt. Refer to Procedure 008-002.



Tighten the fan idler pulley shaft locknut.

Torque Value: 190 N•m [140 ft-lb]

Check the belt tension again after the locknut is tightened.



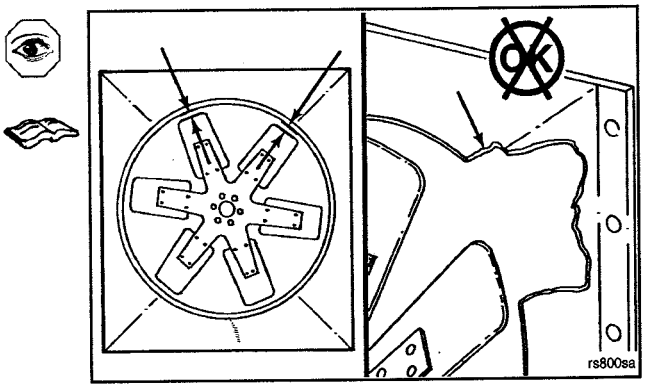
Fan Shroud Assembly (008-038)

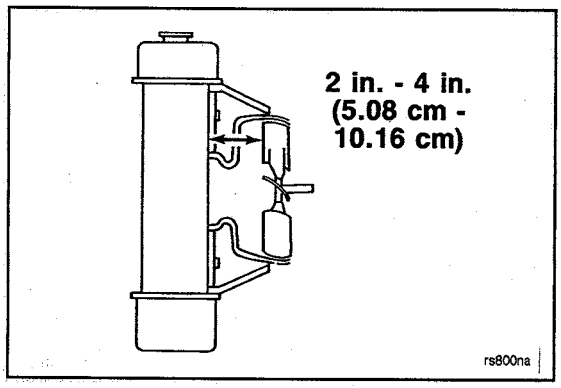
Initial Check (008-038-001)

△ CAUTION △

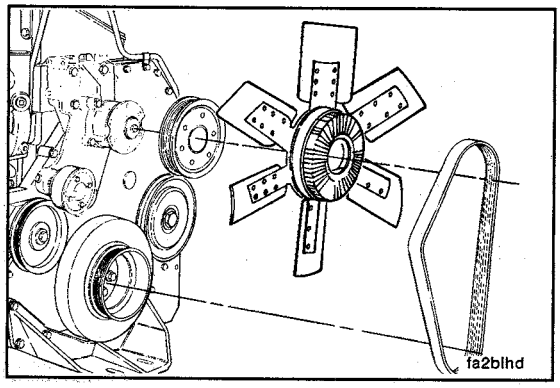
The fan shroud must be installed correctly, be in good condition, and the shroud-to-fan clearance must be within the manufacturer's specifications to make sure proper air flow through the radiator exists to provide adequate engine cooling.

Inspect the fan shroud for proper fan clearance, cracks, air leaks, or damage. Replace if necessary. Refer to the manufacturer's instructions.





Cummins Engine Company, Inc. recommends fan clearance be 5.08 to 10.16 cm [2 to 4 in] from the radiator core. Refer to the equipment manufacturer for alternative positions.

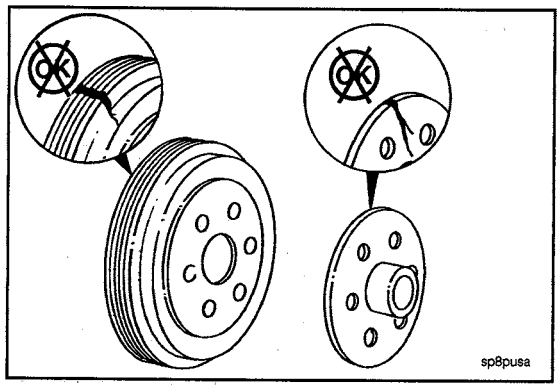


Fan Spacer and Pulley (008-039)

Remove (008-039-002)

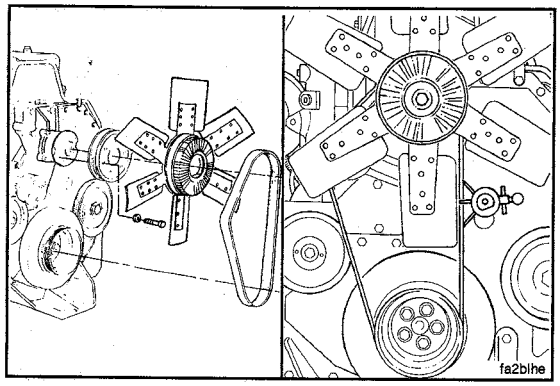
Remove the fan drive belt. Refer to Procedure 008–002.

Remove the fan and fan clutch assembly.



Inspect for Reuse (008-039-007)

Inspect the fan spacer and pulley, if used, for cracks or damage. Replace if necessary.



Install (008-039-026)

Install the fan on the fan clutch assembly.

Tighten the mounting nuts to the manufacturer's specifications.

Install the fan clutch and fan assembly on the engine.

Tighten the capscrews.

Torque Value: 68 N•m [50 ft-lb]

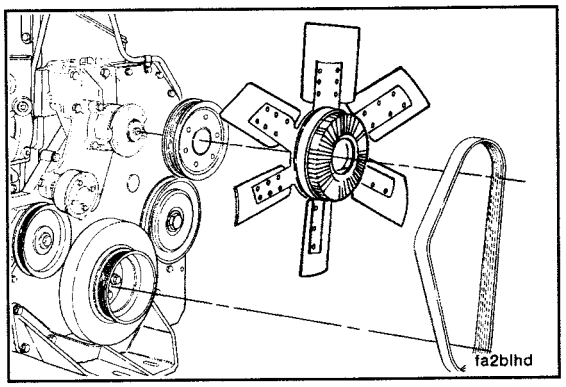
Install, adjust, and tighten the fan drive belt. Refer to Procedure No.008-002.

Fan, Cooling (008-040)

Remove (008-040-002)

Remove the fan drive belt. Refer to Procedure 008-002.

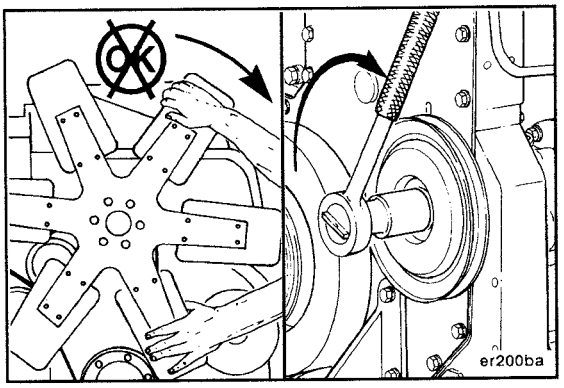
Remove the fan and fan clutch assembly.



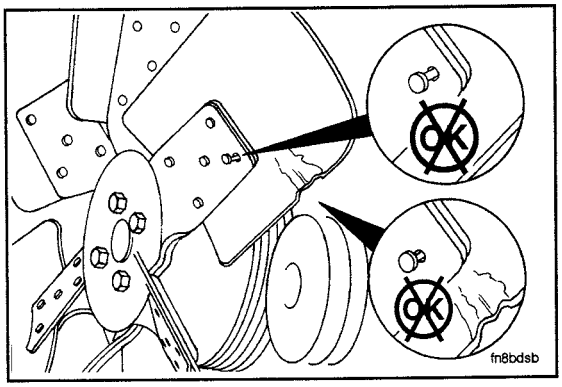
Inspect for Reuse (008-040-007)

⚠ WARNING ⚠

Do not rotate the engine by pulling or prying the fan. The fan blade(s) can be damaged, causing the fan to fail and cause serious personal injury or property damage. Use the accessory driveshaft to rotate the crankshaft.

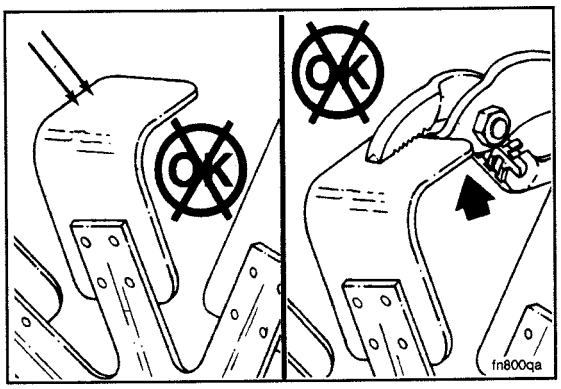


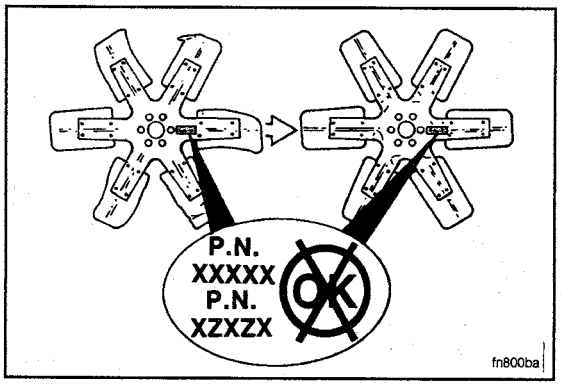
An inspection of the cooling fan is required daily. Check for cracks, loose rivets, and bent or loose blades. Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.



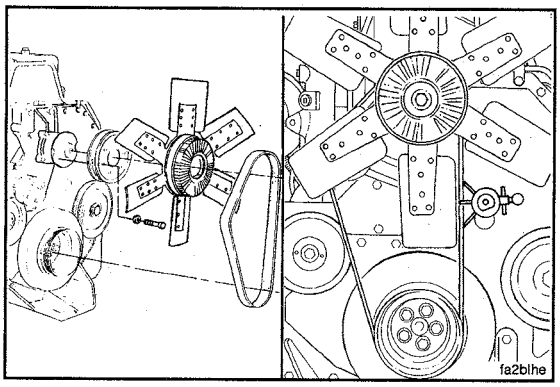
⚠ WARNING ⚠

Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause serious personal injury or property damage.





Replace any original equipment fan that is damaged with a fan of the identical part number. Cummins Engine Company, Inc. **must** approve any other fan changes.



Install (008-040-026)

Install the fan on the fan clutch assembly.

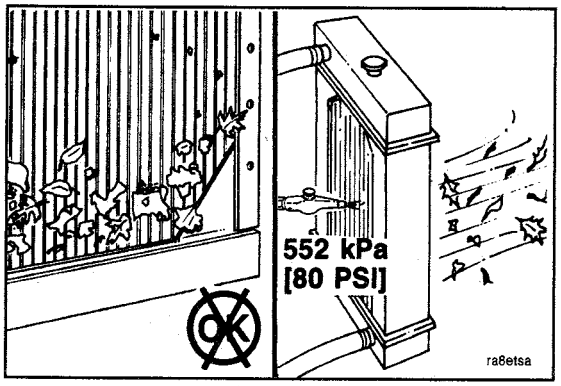
Tighten the mounting nuts to the manufacturer's specifications.

Install the fan clutch and fan assembly on the engine.

Tighten the capscrews.

Torque Value: 68 N•m [50 ft-lb]

Install, adjust, and tighten the fan drive belt. Refer to Procedure 008-002.



Radiator (008-042)

Initial Check (008-042-001)

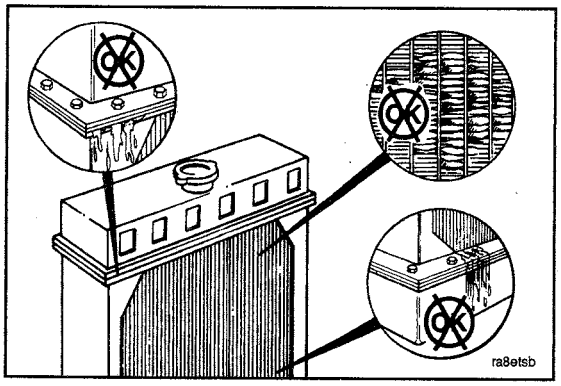
⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Improper use can cause bodily injury from flying debris and dirt.

Inspect for plugged radiator fins.

Use compressed air to blow out the dirt and debris.

Air Pressure: 552 kPa [80 psi]



Inspect for bent or broken fins.

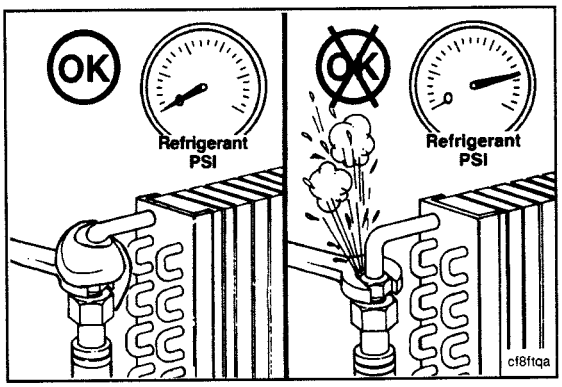
Inspect for radiator core and gasket leaks.

If the radiator **must** be replaced, refer to the manufacturer's replacement procedures.

⚠ WARNING ⚠

If a liquid refrigerant system must be removed before removing the radiator, wear eye and face protection. Wrap a cloth around the fittings before removing. Liquid refrigerant can cause serious eye and skin injury.

For environmental protection, federal regulations require that Freon be recycled and **not** vented into the atmosphere.

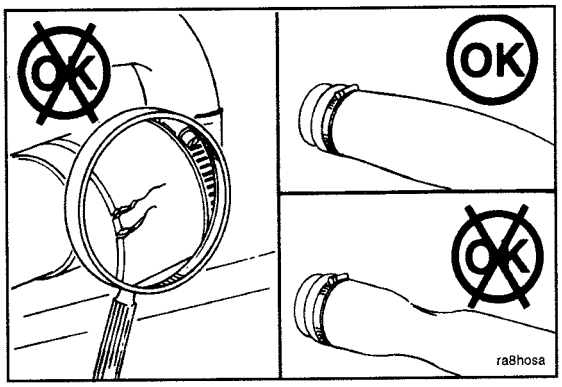


Radiator Hoses (008-045)

Inspect for Reuse (008-045-007)

Inspect all hoses for cracks, cuts, or collapsing.

NOTE: The silicone engine coolant hose will exhibit swelling due to the elasticity of the hose.



Radiator Pressure Cap (008-047)

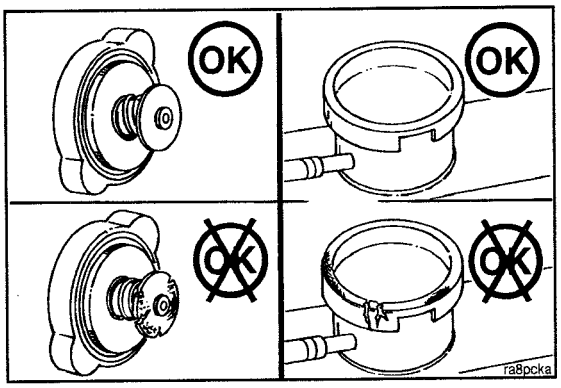
Inspect for Reuse (008-047-007)

Be sure the correct radiator cap is being used. Refer to "Cooling System Specifications."

Inspect the rubber seal of the pressure cap for damage.

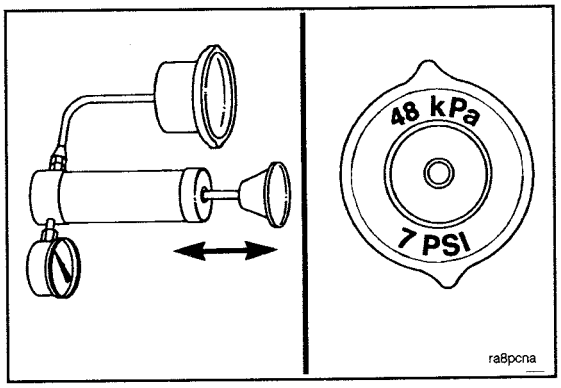
Inspect the radiator fill neck for cracks or other damage.

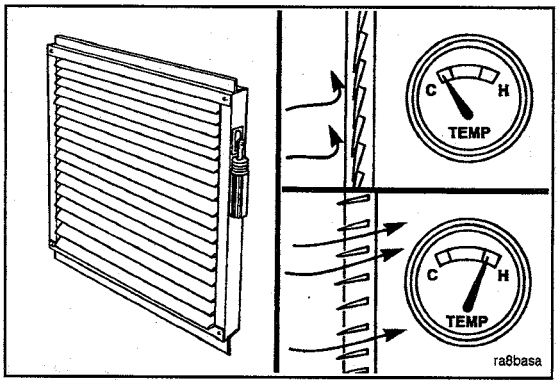
Refer to the radiator manufacturer for instructions if the fill neck is damaged.



Pressure-test the radiator cap.

The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.





Radiator Shutter Assembly (008-049)

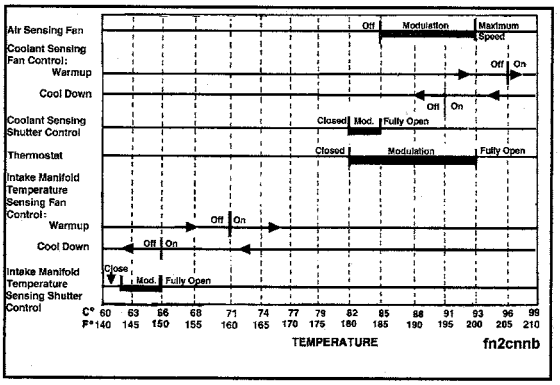
Initial Check (008-049-001)

Check the shutters in the closed position to be sure they are completely closed.

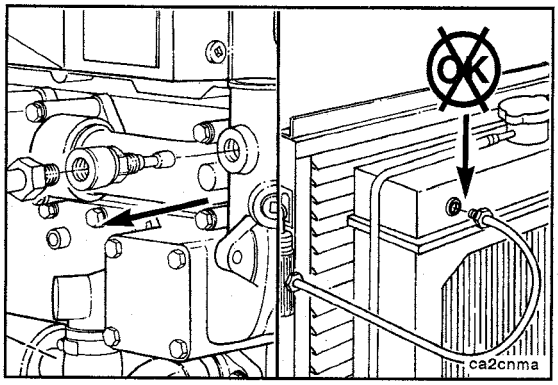
NOTE: If the shutters are **not** closed, refer to the manufacturer's instructions.

Be sure the shutters open completely at the desired temperature setting.

NOTE: If the shutters are **not** open, refer to the manufacturer's instructions.

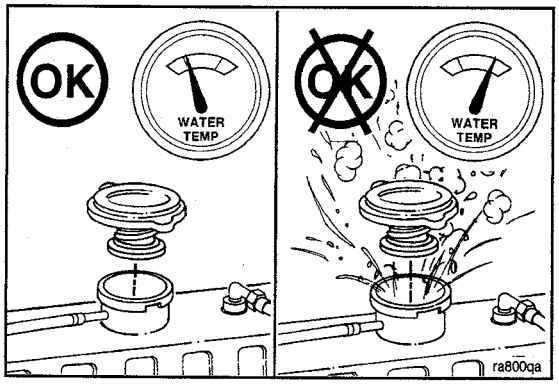


Shutters and thermatic fans **must** be set to operate in the same temperature range as the thermostat with which they are used. Refer to the Thermal Control Settings chart at the front of this section.



Install the shutter temperature sensor in the thermostat housing.

Do **not** install the shutter temperature sensing unit in the radiator top (expansion) tank.



Water Pump (008-062)

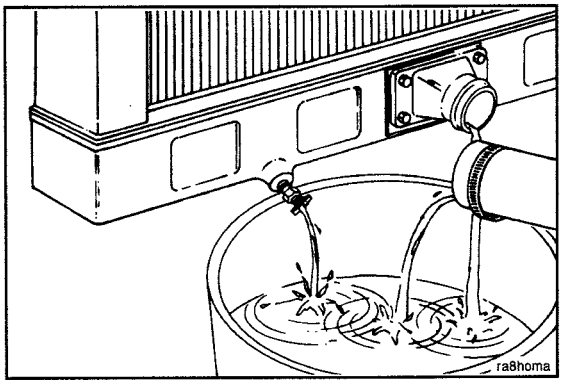
Remove (008-062-002)

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Remove the pressure cap when the engine is cool.

Drain the cooling system. Refer to Procedure 008-018.

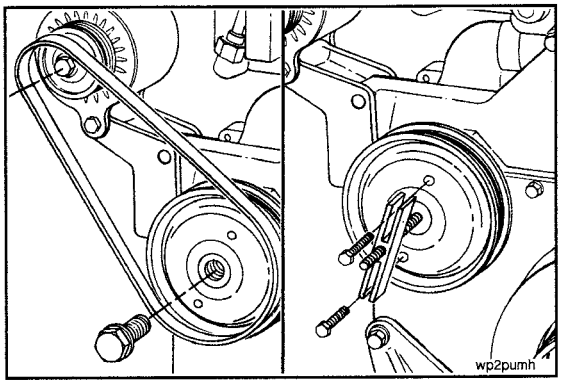


Remove the alternator drive belt. Refer to Procedure 013-005.

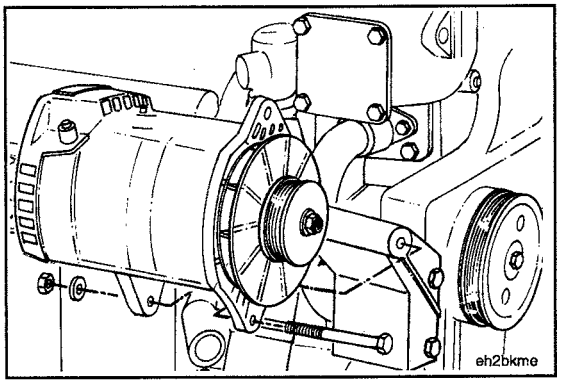
Remove the water pump pulley retaining capscrew.

Use the standard pulley puller, Part No. ST-647, and two 5/16 x 18-2 capscrews to remove the pulley.

NOTE: Make sure the puller capscrews are threaded all the way through the puller before applying pressure to the puller screw.



Remove the alternator. Refer to Procedure 013-001.

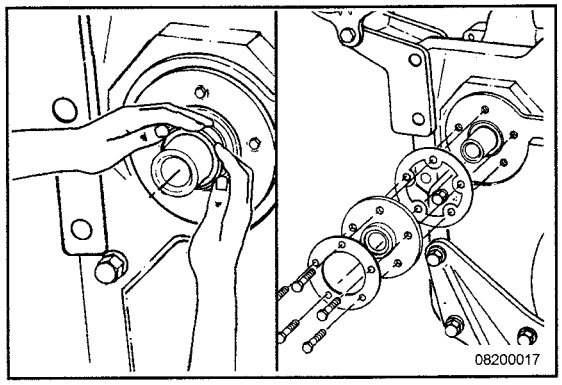


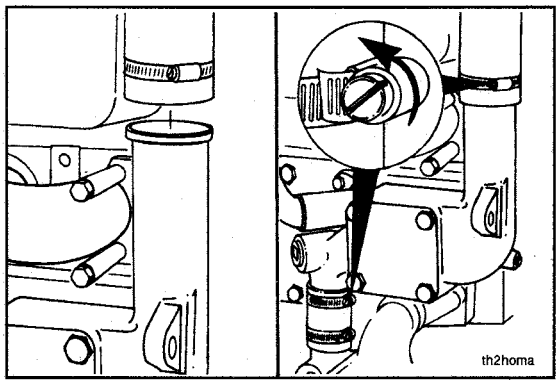
Remove the dust seal.

Remove the five water pump oil seal capscrews, clamping ring, oil seal, and gasket.

NOTE: Remove the dust seal as the seal carrier is removed; or use a heel bar, or similar tool, to pry the dust seal away from the seal case. Then remove the dust seal by hand.

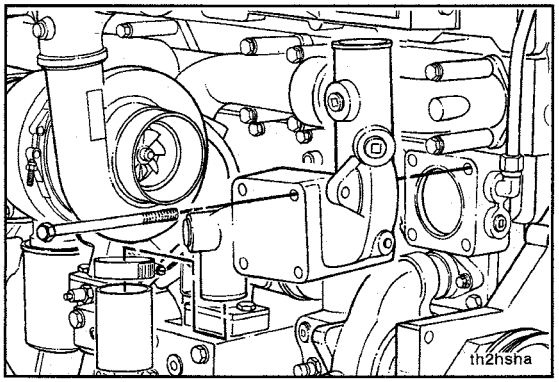
Discard the oil seal and dust seal.



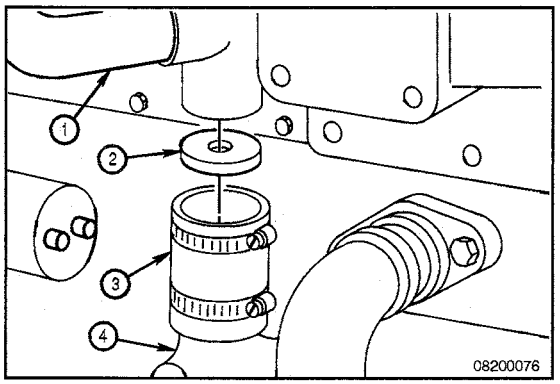


Loosen the coolant bypass hose clamps on both the upper and lower hoses.

Remove the upper coolant hose from the thermostat housing.



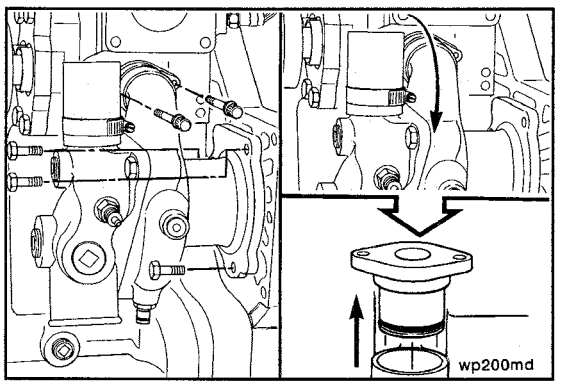
Remove the four thermostat housing mounting capscrews and the thermostat housing.



The coolant flow that provides cooling to the torque converter (if equipped) is achieved in different manners.

M Series engines use a torque converter cooler disc inside the coolant bypass hose to direct engine coolant to the inlet side of the torque converter cooler.

1. Torque Converter Coolant Supply
2. Torque Converter Disc (Orifice)
3. Bypass Hose
4. Water Pump.



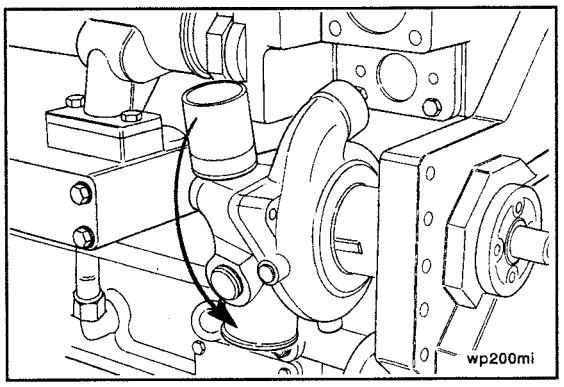
Remove the two water pump water transfer connection capscrews.

Remove the three water pump mounting capscrews.

Rotate the water pump outward so the water transfer connection can be removed from the water pump.

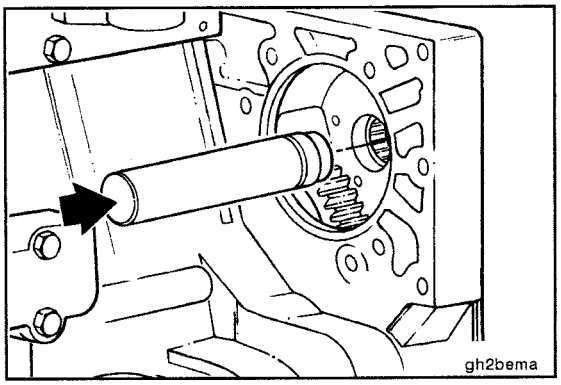
Remove the water transfer connection from the water pump.

Remove the water pump. Twist the pump outward from the top, and angle the rear of the pump downward as it is being removed to allow the pump to pass the thermostat housing support.



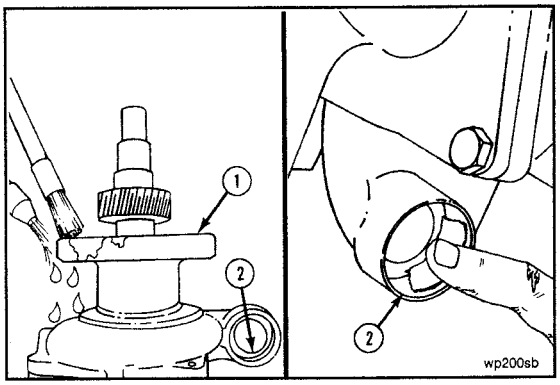
Check the needle bearing for damage and freedom of needle rotation. Replace the bearing if it is damaged or if it does **not** turn freely.

If the bearing is replaced, use bearing installation tool, Part No. 3824117, along with a cup plug driver to remove the needle bearing from the gear housing. Gently tap the bearing out from the rear side of the housing.



Clean (008-062-006)

Clean surfaces (1and 2).



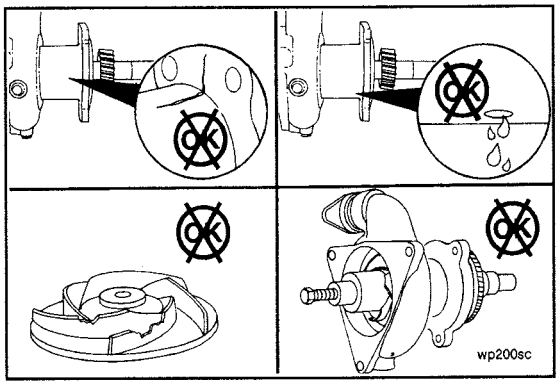
Inspect for Reuse (008-062-007)

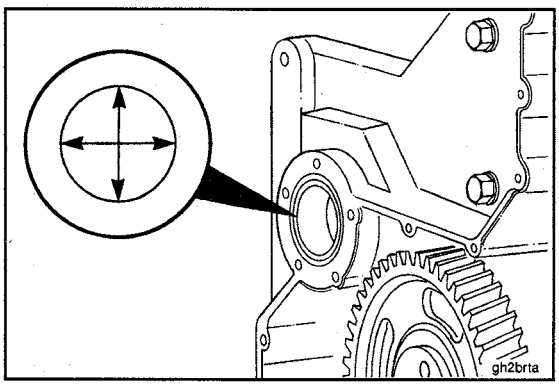
Inspect the water pump housing for cracks.

Inspect the water pump weep hole for indication of leaks.

NOTE: A streak or chemical buildup at the weep hole is **not** justification for water pump replacement. If a steady flow of coolant or oil is observed, replace the water pump with a new or rebuilt unit.

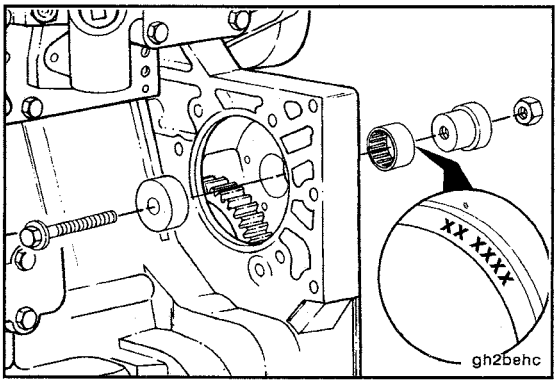
Remove the water pump cover, and inspect the water pump impeller for cracks or damage.





If the needle bearing was removed, measure the inside diameter of the gear housing needle bearing bore.

Needle Bearing Bore Inside Diameter (Gear Housing)		
mm		in
36.967	MIN	1.4553
36.992	MAX	1.4564

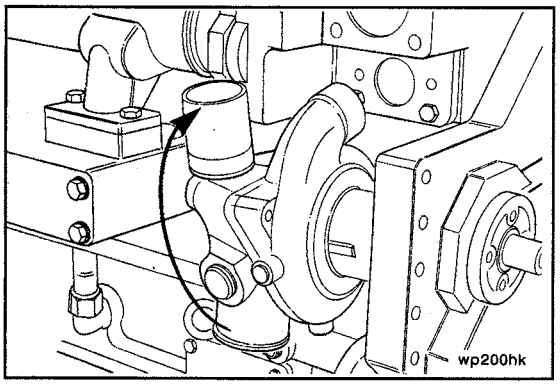


Install (008-062-026)

If the needle bearing was removed, use bearing installation tool, Part No. 3824117, to install a new needle bearing in the gear housing.

NOTE: The bearing **must** be installed with the part number side of the bearing against the installation tool to prevent damage to the bearing during the installation.

Install the bearing from the front side of the gear housing until the bearing is flush with the front edge of the housing bore.



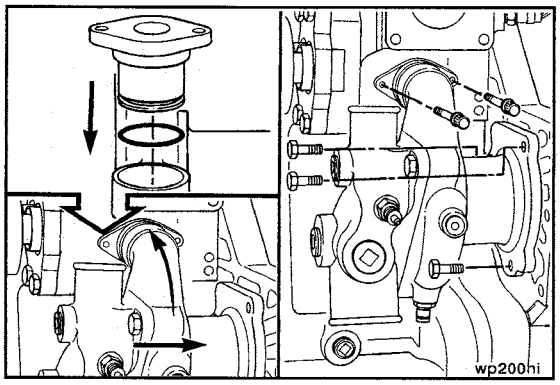
Install the water pump cover. Use a new o-ring seal.

Torque Value: 47 N•m [35 ft-lb]

Install a new o-ring on the water pump mounting flange.

NOTE: The water pump **must** be twisted outward from the top until the transfer outlet clears the thermostat housing support during installation.

Install the water pump.



Install a new o-ring on the water pump water transfer tube.

Install the connection into the water pump.

Twist the water pump inward, and install the three water pump mounting capscrews.

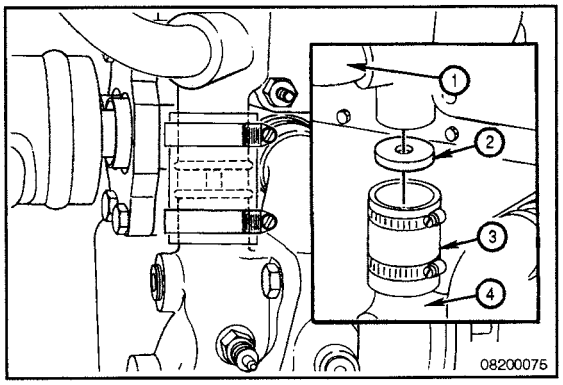
Torque Value: 47 N•m [35 ft-lb]

Install a new gasket on the water pump water transfer connection. Install and tighten the water transfer connection capscrews.

Torque Value: 25 N•m [18 ft-lb]

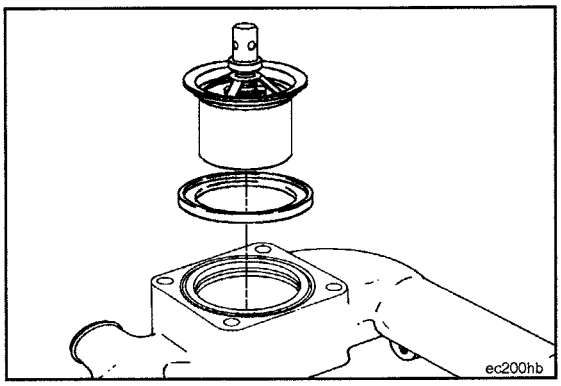
If the engine is equipped with a torque convertor cooler, install the disc in the bypass hose before installing the thermostat housing.

1. Torque Convertor Cooler Coolant Supply
2. Torque Convertor Cooler Disc (orifice)
3. Bypass Hose
4. Water Pump.



Install the thermostat in the housing.

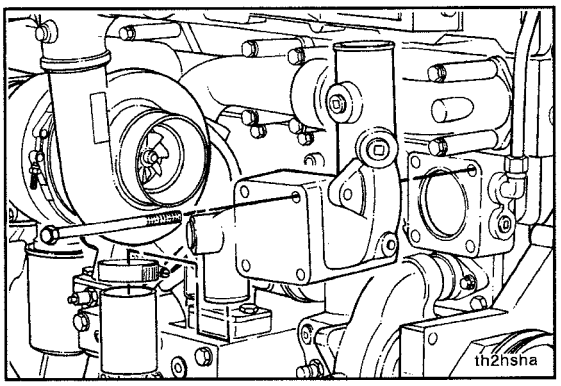
Install a new seal in the groove on the thermostat housing mounting surface.



Install the hose on the thermostat housing bypass outlet.

Install the thermostat housing and four mounting capscrews.

Torque Value: 54 N•m [40 ft-lb]

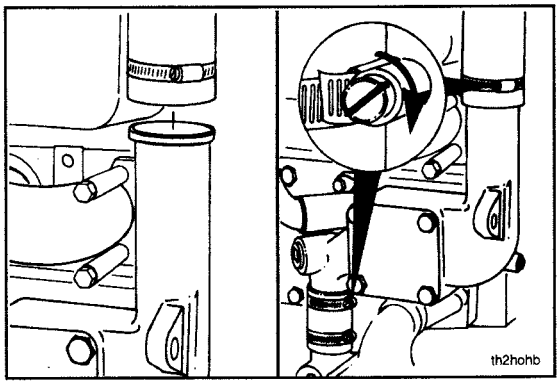


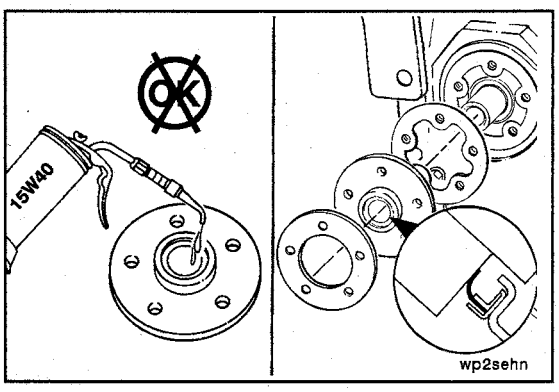
Equally space the bypass hose over the water pump connection and thermostat housing connection, and tighten the bypass hose clamps.

Torque Value: 3 N•m [30 in-lb]

Install the **upper** coolant hose. Refer to the OEM's specifications for the correct torque value.

Install the **lower** coolant hose. Refer to the OEM's specifications for the correct torque value.



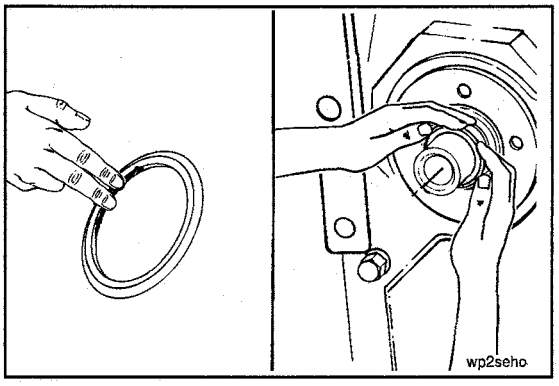


The oil seal **must** be installed with the lip of the seal and the shaft clean and dry. Do **not** lubricate. The yellow dust lip **must** be facing out.

Install the new gasket and oil seal. Use the installation sleeve provided with the new seal to install the seal.

The capscrew threads **must** be coated with thread sealant, Part No. 3823494, to prevent oil leakage.

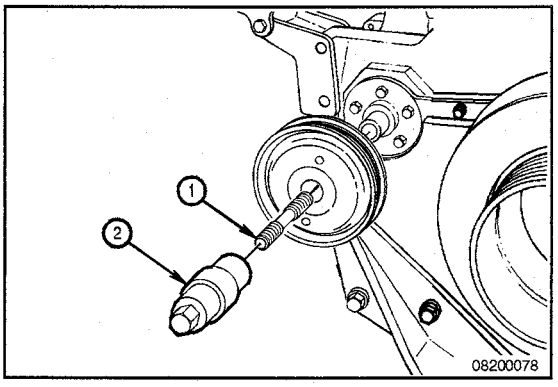
Torque Value: Step 1 7 N•m [60 in-lb]
2 20 N•m [180 in-lb]



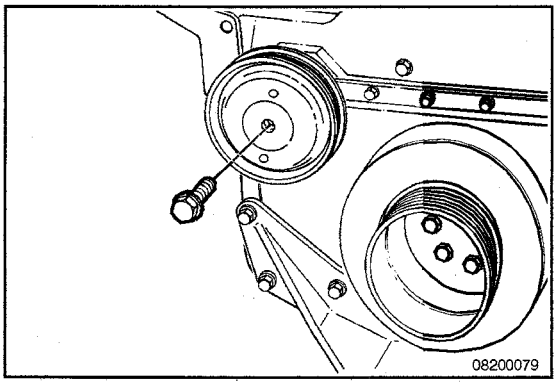
Place a light film of oil or antifreeze on the inside of the oil seal dust seal.

Install the dust seal onto the shaft with the larger outside surface facing the engine.

Push the dust seal back by hand on the shaft until the entire dust seal contacts the oil seal case.



Use the pulley pusher adapter (1), Part No. 3377401, and the pulley pusher (2), Part No. 3376326, to install the pulley.

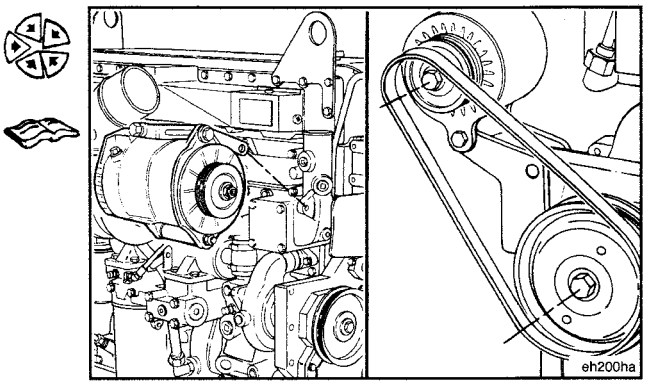


Install the capscrew in the shaft.

Torque Value: 75 N•m [55 ft-lb]

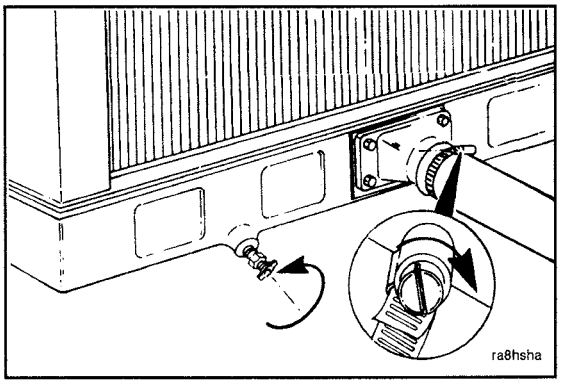
Install the alternator. Refer to Procedure 013-001.

Install and adjust the alternator drive belt. Refer to Procedure 013-005.



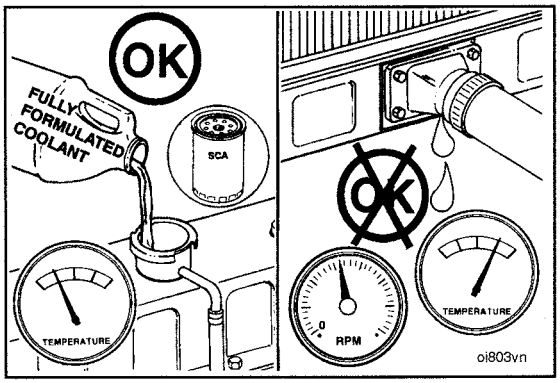
Close the cooling system draincock, and install the lower coolant hose.

Tighten the hose clamps(s). Refer to the manufacturer's specifications for the correct torque value.



Fill the cooling system. Refer to Procedure 008-018.

Operate the engine until it reaches a temperature of 160°F and check for coolant leaks.



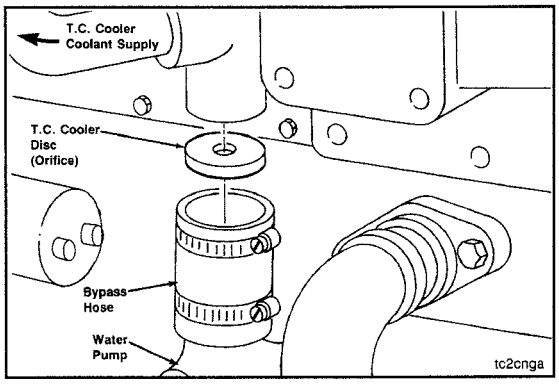
Torque Converter Cooler (008-065)

General Information

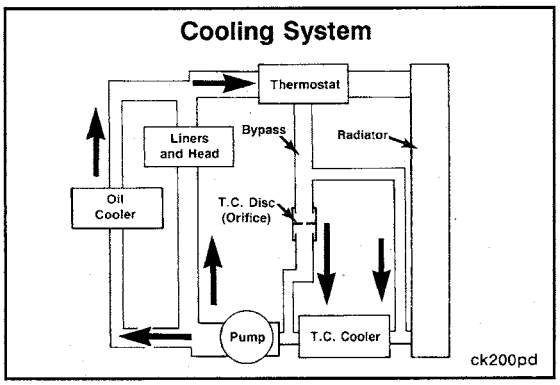
The coolant flow that provides torque converter cooling is achieved in different manners.

M Series engines use a torque converter cooler disc inside the coolant bypass hose to direct engine coolant to the inlet side of the torque converter cooler.

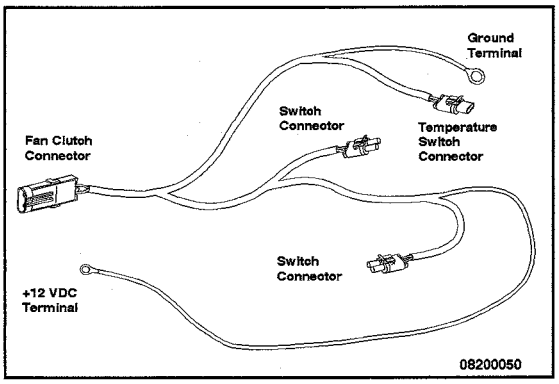
1. Torque Converter Coolant Supply
2. Torque Converter Disc (orifice)
3. Bypass Hose
4. Water Pump.



The disc functions as follows:



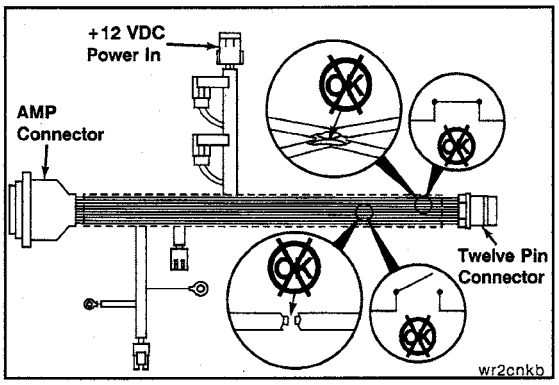
- Closed Thermostat: Coolant flows from the engine through the thermostat housing and down the by-pass hose. The disc directs coolant to the inlet side of the torque converter cooler.
- Open Thermostat: Coolant flows from the engine through the thermostat to the radiator out from the radiator to the torque converter cooler to the water pump inlet. The disc prevents reverse flow around the torque converter cooler to the bypass hose and then to the water pump.



Wiring Harness, Cummins Electric Fan Clutch (008-069)

General Information

This procedure applies to engines using an electric fan clutch controlled by the ECM and utilizing a Cummins electric fan clutch wiring harness. If the wiring harness is **not** a Cummins electric fan clutch wiring harness, refer to the OEM for the correct troubleshooting procedure.

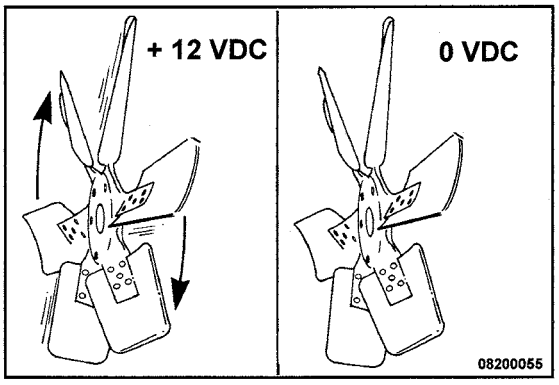


Initial Check (008-069-001)

Electrical Connections

For the fan to operate, the Cummins electromagnetic fan clutch relay **must** receive 0 VDC from the ECM to engage and 12 VDC from the ECM to disengage the fan clutch. To be sure correct electrical connections have been made, refer to the Troubleshooting and Repair Manual, ISM Fuel System, ISM Engines, Bulletin No. 3666266.

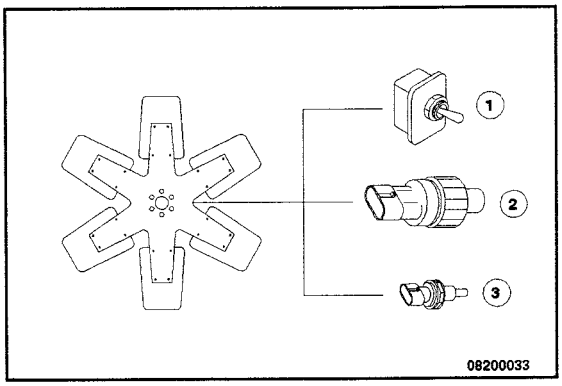
Inspect the wires and harness to be sure none are broken or shorted. Replace the harness or wires that are broken.



The fan clutch will engage when it receives 12 VDC from the fan clutch relay and disengage when it receives 0 VDC from the fan clutch relay.

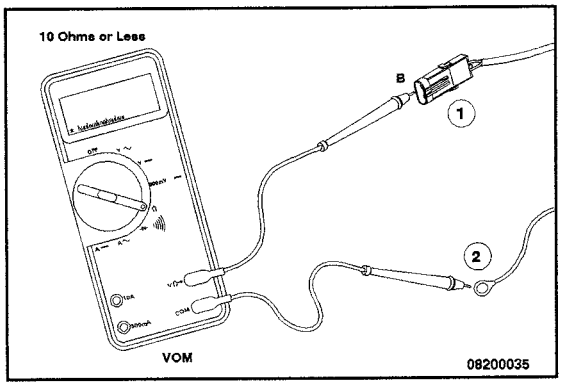
The 12 VDC is supplied from the vehicle's electrical system to the fan by one of three possible controls:

- The manual fan on/off switch (1) in the cab
- The freon compressor pressure switch (2)
- The temperature switch (3) in the thermostat housing.

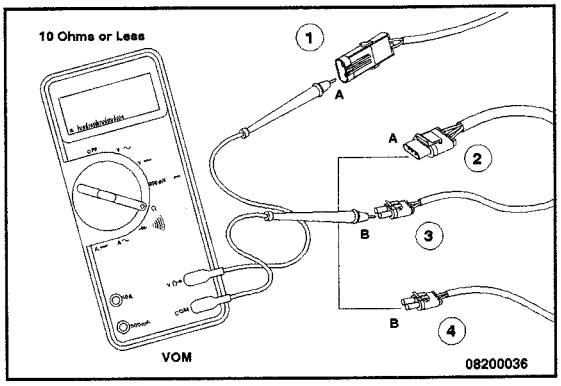


To check to be sure there are no open circuits, the continuity **must** be checked between the following pins of the wiring harness:

- Pin B of the fan clutch connector (1) and the ground terminal (2)

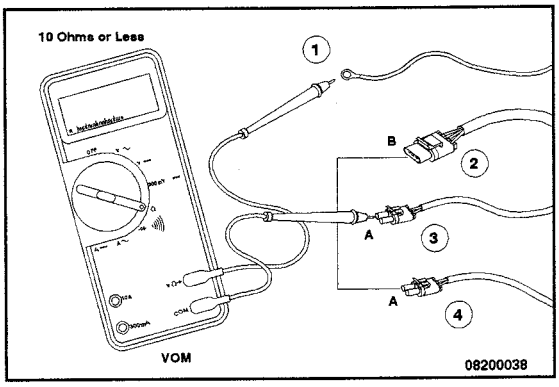


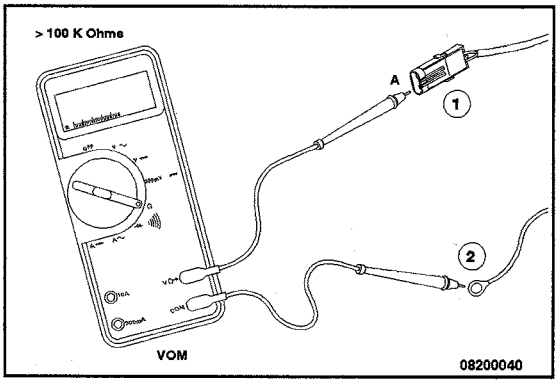
- Pin A of the fan clutch connector (1) and the following fan harness connectors:
  - — Pin A of the temperature switch connector (2)
  - — Pin B of the freon compressor pressure switch connector (3)
  - — Pin B of the manual on/off cab switch connector (4).



- The +12-VDC terminal (1) and the following fan harness connectors:
  - — Pin B of the temperature switch connector (2)
  - — Pin A of the freon compressor pressure switch connector (3)
  - — Pin A of the manual on/off cab switch connector (4).

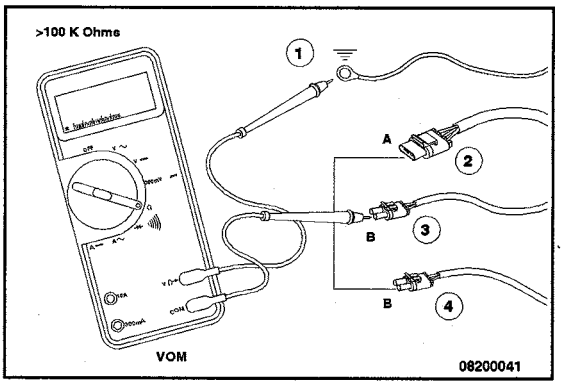
The multimeter **must** read a closed circuit (10 ohms or less). Repair or replace the harness if more than 10 ohms is detected on any of the above checks.



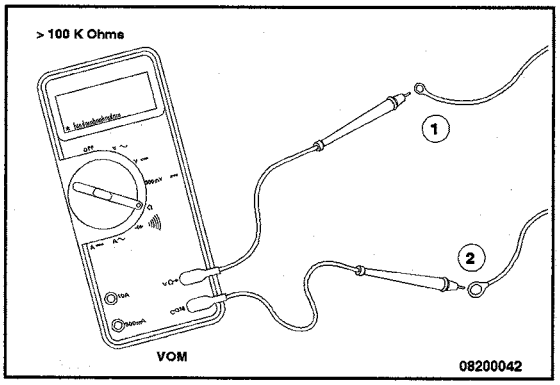


Check for short circuits in the harness. The resistance **must** be greater than 100K ohms for the following:

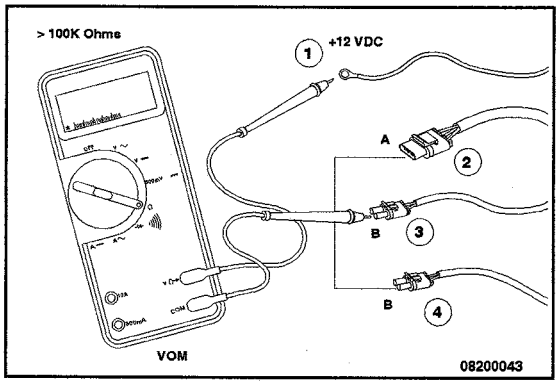
- Pin A of the fan clutch connector (1) to the ground terminal (2)



- The ground terminal (1) and the following fan harness connectors:
  - — Pin A of the temperature switch connector (2)
  - — Pin B of the freon compressor pressure switch connector (3)
  - — Pin B of the manual on/off cab switch connector (4).



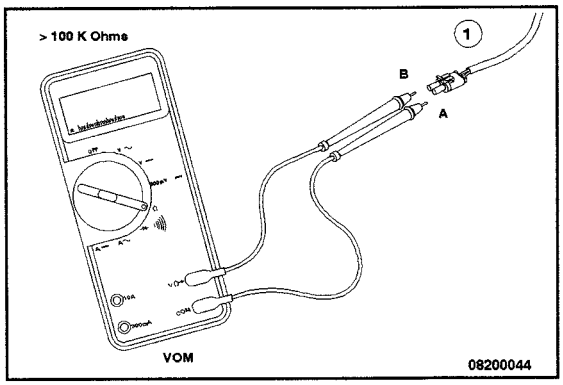
- The + 12-VDC terminal (1) to the ground terminal (2)



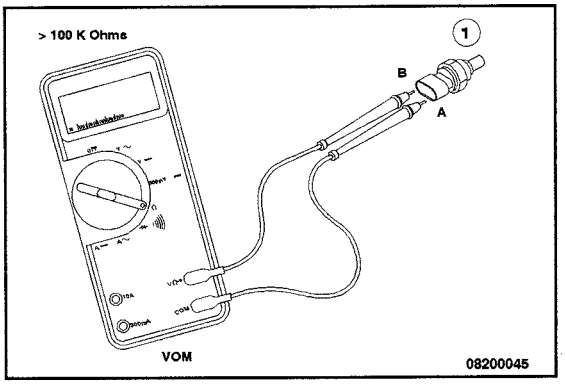
- The + 12-VDC supply (1) and the following fan harness connectors:
  - — Pin A of the temperature switch connector (2)
  - — Pin B of the freon compressor pressure switch connector (3)
  - — Pin B of the manual on/off cab switch connector (4).

- Pin A of each of the three switch connectors (1) to pin B of each of the three switch connectors (1).

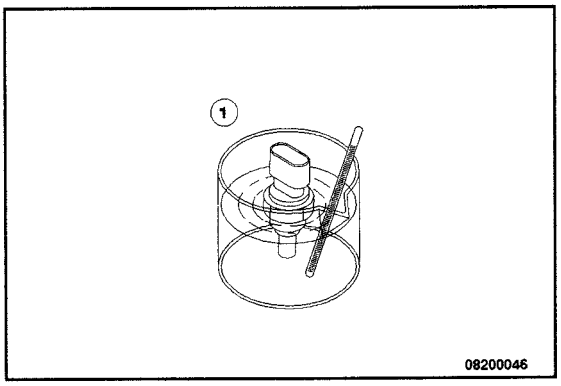
The harness **must** be repaired or replaced if any of the above resistances are less than 100 ohms.



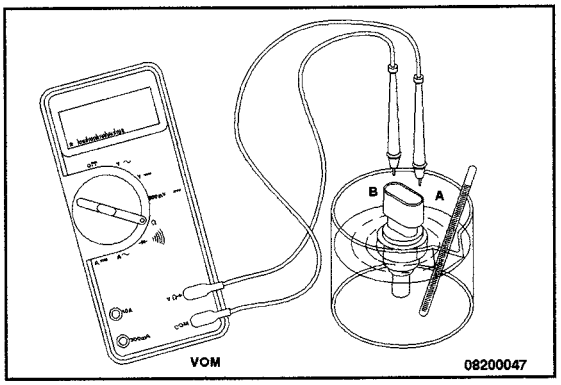
To check the temperature switch (1) for proper operation, check the continuity from pin A to pin B at room temperature (**must** be greater than 100 ohms). Replace the switch if the resistance is less than 100K ohms.

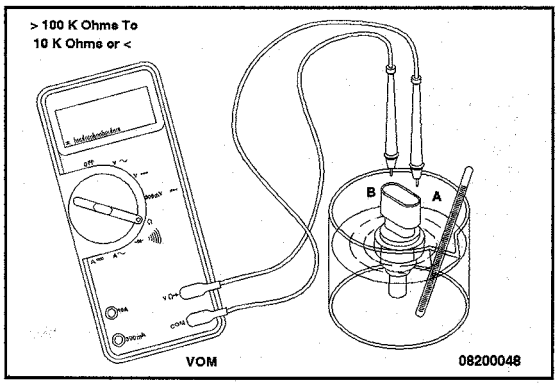


To check the temperature switch for operation at the Fan ON temperature, place the probe (1) in a container of water, along with a thermometer.



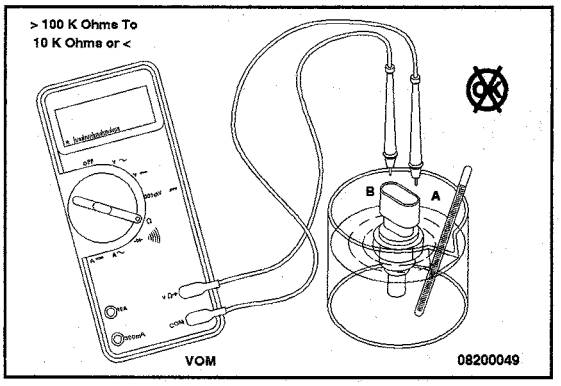
Place the multimeter probes in pin A and pin B.



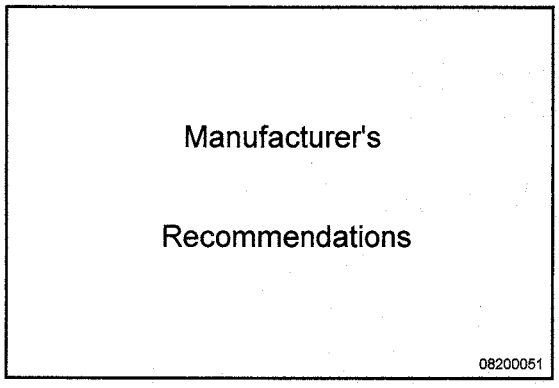


Heat the water.

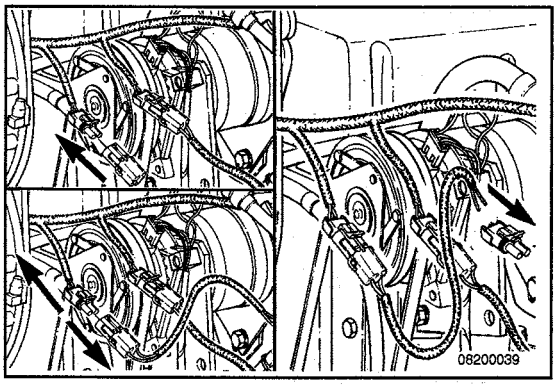
Note the temperature at which the resistance changes from 100 or greater ohms to 10 ohms or less.



If the switch does **not** close at the temperature required according to the switch manufacturer, the switch **must** be replaced.



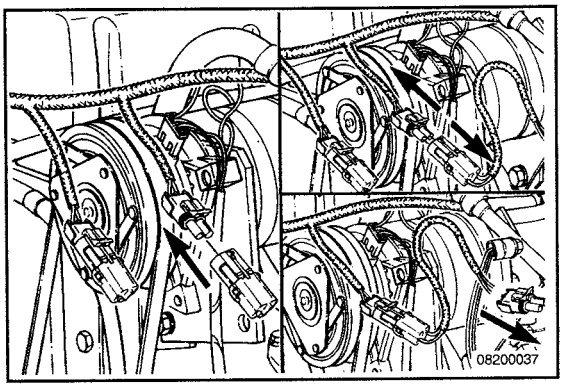
To check the freon compressor pressure switch and the manual fan on/off cab switch, refer to the manufacturer's recommendations.



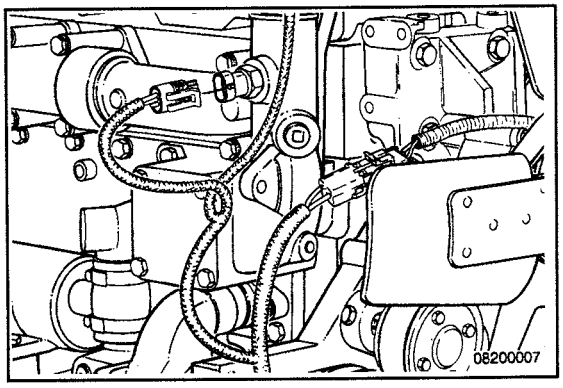
Remove (008-069-002)

Disconnect the operator-controlled manual switch harness, if used, from the base harness.

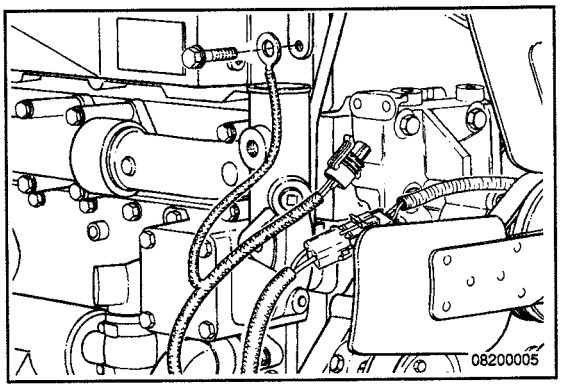
Remove the refrigerant pressure switch harness from the base harness.



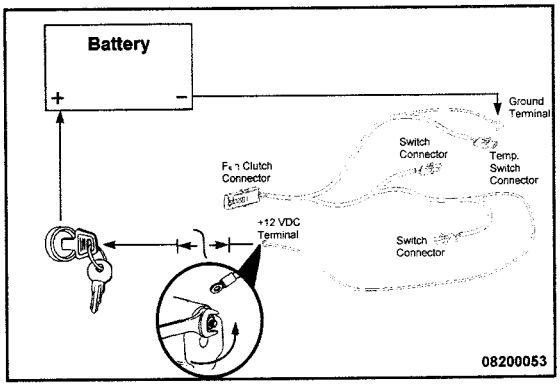
Disconnect the gray harness connector from the temperature switch in the thermostat housing.

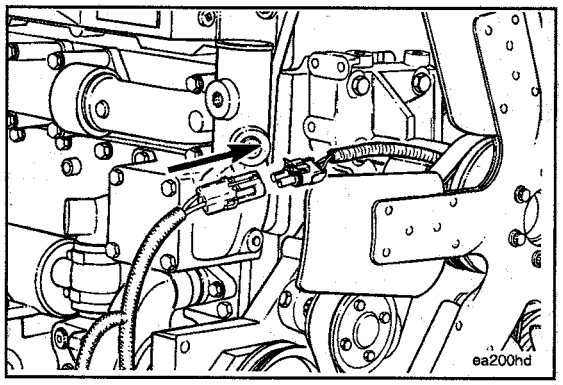


Disconnect the large ring terminal with the black wire from the chassis ground.

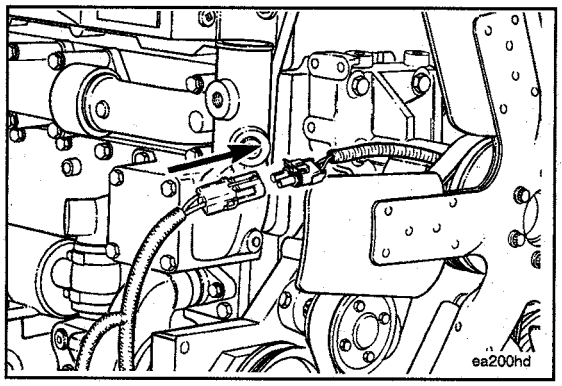


Disconnect the small ring terminal from the power source.



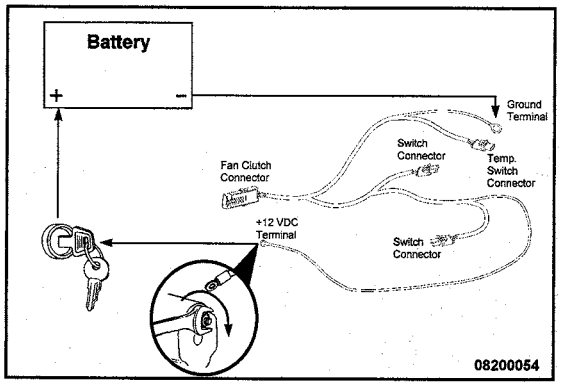


Disconnect the fan clutch connector on the base harness from the fan clutch.

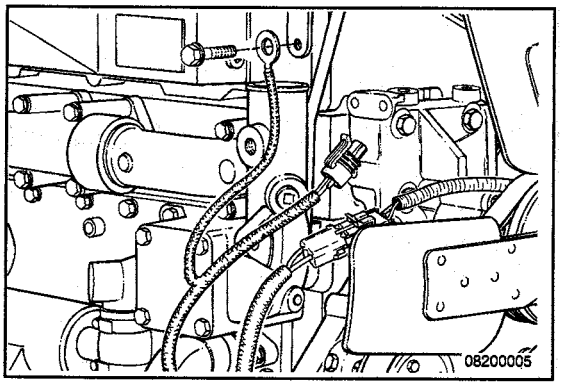


Install (008-069-026)

Connect the fan clutch connector on the base harness to the fan clutch.

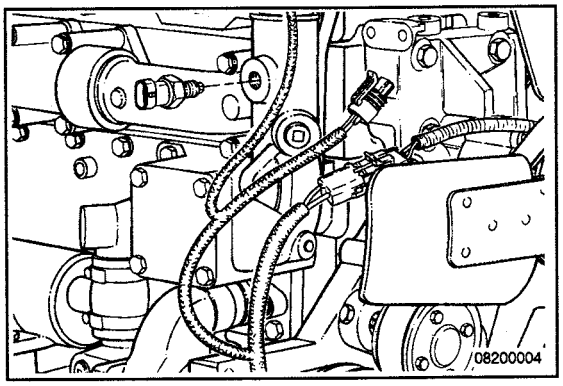


Connect the small ring terminal with the red wire to an ignition switch-controlled fused power source.

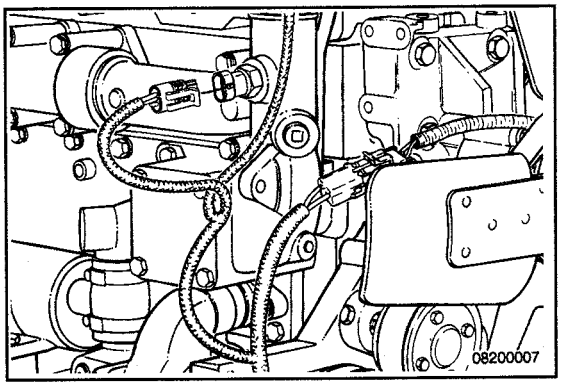


Connect the large ring terminal with the black wire to the chassis ground.

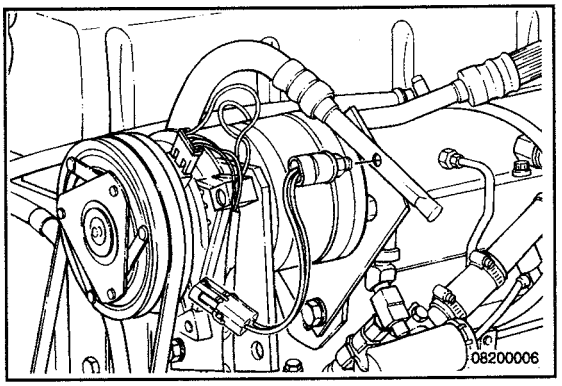
Install the coolant temperature switch in the thermostat housing, if it was removed.



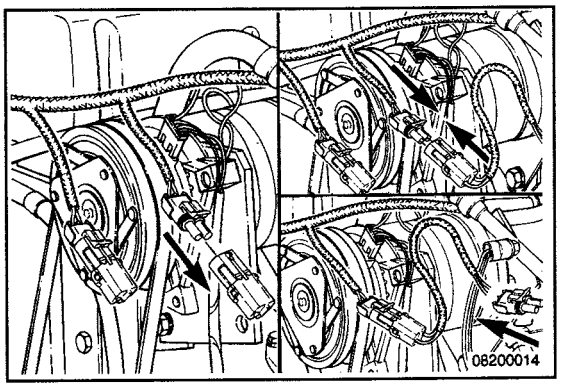
Connect the gray harness connector to the temperature switch in the thermostat housing.

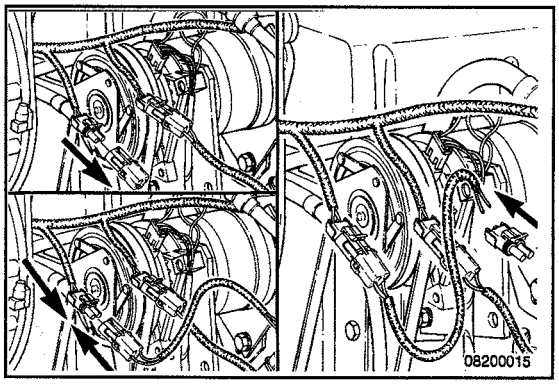


On air-conditioned vehicles, install the appropriate refrigerant pressure switch into the compressor outlet side of the refrigerant circuit, if it was removed.

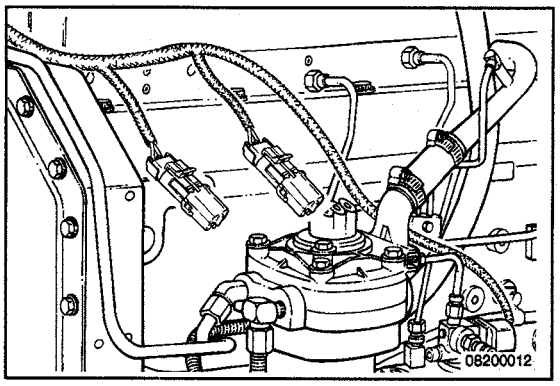


Connect the switch harness to the base harness and to the refrigerant pressure switch.





Connect the operator-controlled manual switch harness to the base harness.



Leave the base harness switch connector sealing cap(s) in place if a refrigerant pressure switch or an operator-controlled manual switch is **not** used.

Section 9 - Drive Units - Group 09

Section Contents

Page

Accessory Drive 9-2
Clean 9-3
Install 9-3
Remove 9-2

Accessory Drive Pulley 9-5
Inspect for Reuse 9-5
Install 9-6
Remove 9-5

Alternator Drive Pulley 9-6
Inspect for Reuse 9-7
Install 9-7
Remove 9-6

Hydraulic Pump Drive 9-7
Clean 9-8
Inspect for Reuse 9-9
Install 9-10
Remove 9-7

Service Tools 9-1
Drive Units 9-1

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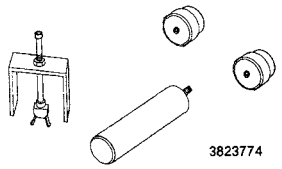
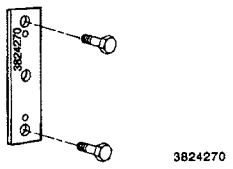
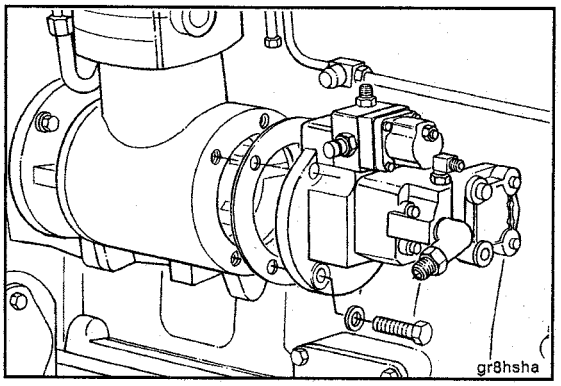
Service Tools

Drive Units

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3823774	**Needle Bearing Kit** Used to remove and install needle bearings in the hydraulic pump adapter. Use mandrel, Part No. 3823776, to install hydraulic pump needle bearings.	
3824270	**Engine Baring Tool** Used to fasten a slide hammer to the hydraulic drive adapter for removal.	

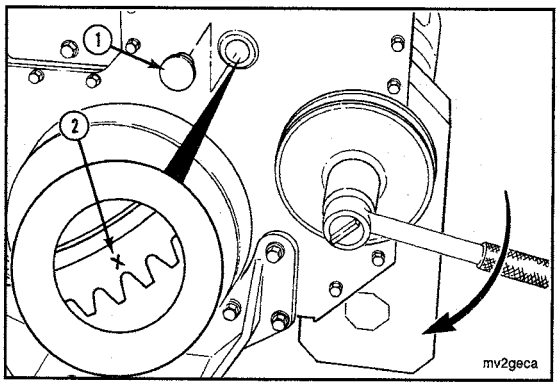


Accessory Drive (009-001)

Remove (009-001-002)

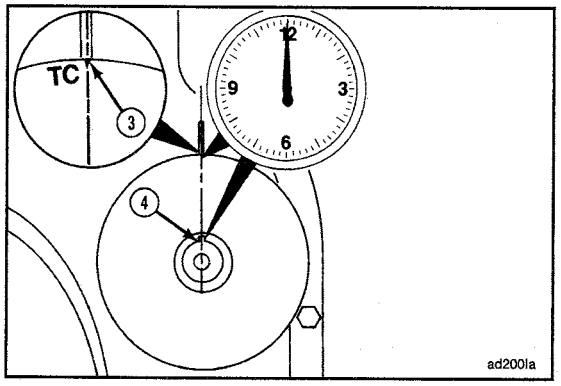
Remove the fuel pump. Refer to Procedure 005-016.

Remove the air compressor, if equipped. Refer to Procedure 012-014.

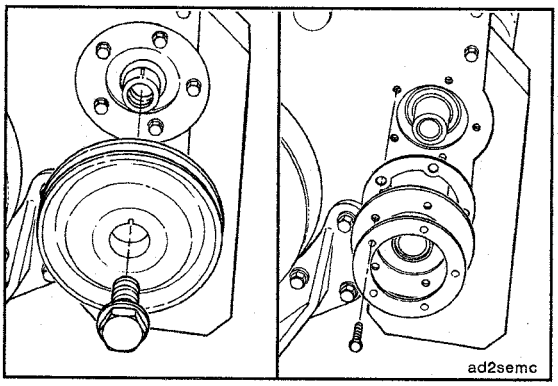


To mark the accessory drive pulley position:

- Remove the inspection hole plug (1) in the gear cover.
- Use the accessory driveshaft to rotate the engine until the camshaft gear timing mark (2) is visible through the inspection hole.



When the timing mark is visible through the inspection hole, cylinders No. one and six are at top dead center. The accessory drive pulley T-C mark (3) and keyway (4) are at the 12-o'clock location.



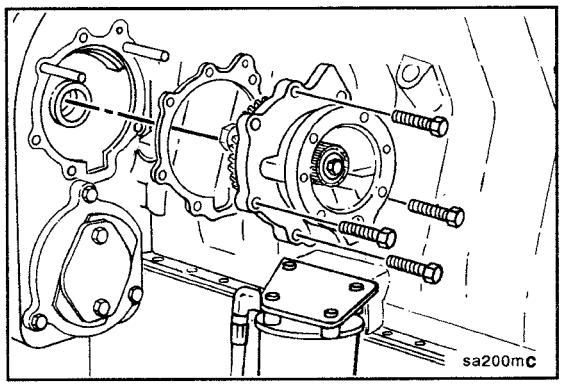
Remove the pulley retainer capscrew.

Remove the accessory drive pulley.

NOTE: This is a slip-fit pulley and does **not** require the use of a puller.

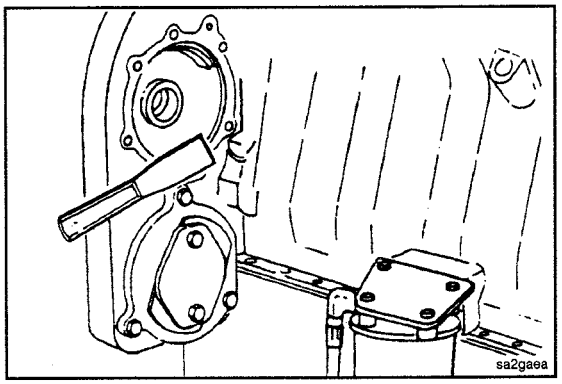
Remove the five seal retaining capscrews, clamping ring, and accessory oil drive seal. Refer to Procedure 001-003.

Remove the six capscrews and the accessory drive assembly.

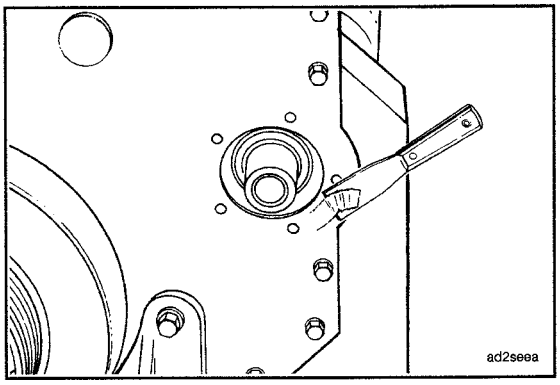


Clean (009-001-006)

Clean the accessory drive to gear housing gasket surface.



Clean the accessory drive oil seal surface on the front of the gear cover.

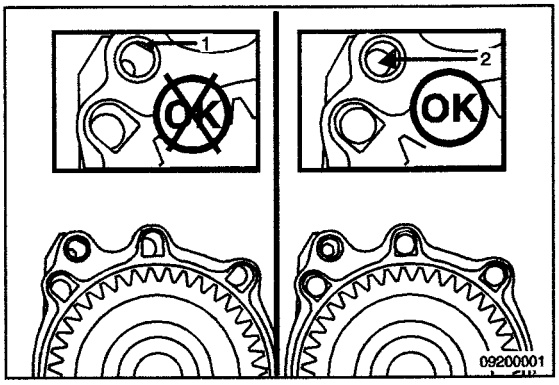


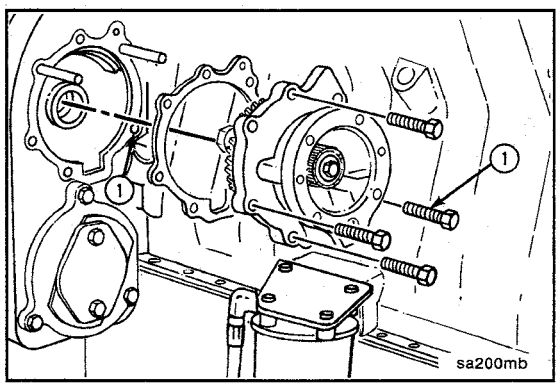
Install (009-001-026)

△ CAUTION △

Care must be used when installing the accessory drive gasket. If the gasket is twisted during the installation of the accessory drive, a leak path (1) will exist between the gasket and the oil passage port at point (2).

Use a small amount of grease or sealant to hold the gasket in place during installation. Use care **not** to block the oil passage.





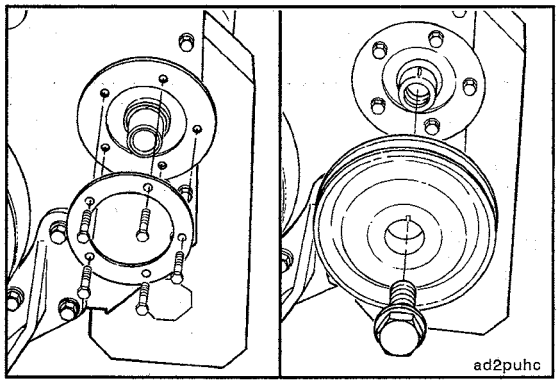
The accessory drive shaft dowel pin **must** be at the 12 o'clock location when the accessory drive is installed. Make sure the camshaft gear timing mark "X" is visible through the inspection hole in the front of the gear cover.

Use a new gasket to install the accessory drive assembly.

Install the six capscrews and tighten.

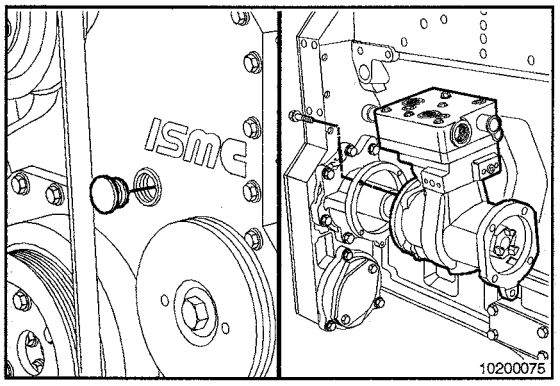
Torque Value: 47 N•m [35 ft-lb]

NOTE: The capscrew (1) located in the lower corner nearest the cylinder block **must** be installed with a new copper sealing washer, Part No. 3882885, and thread sealant, Part No. 3823494, applied to the threads.



Install the accessory drive oil seal. Refer to Procedure 001-003.

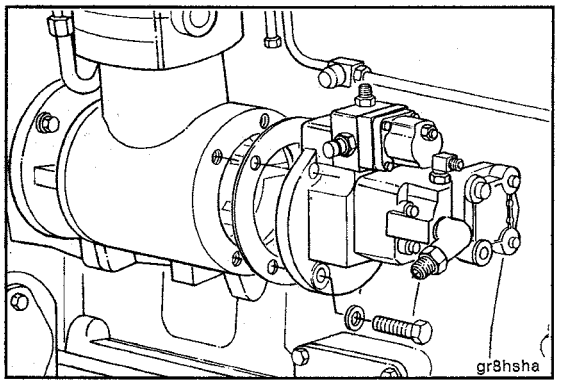
Install the accessory drive pulley. Refer to Procedure 009-004.



Install the inspection hole plug in the gear cover.

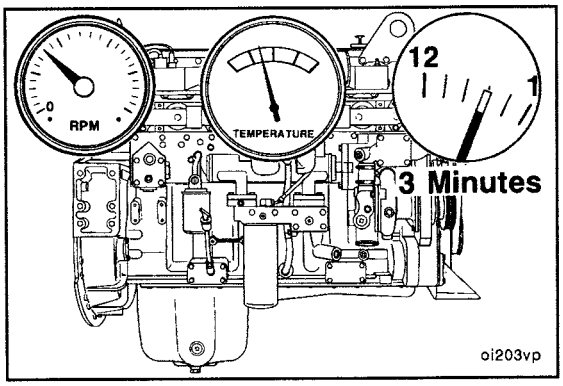
NOTE: The air compressor **must** be timed to the accessory drive.

Install the air compressor, if equipped. Refer to Procedure 012-014.



Install the fuel pump. Refer to Procedure 005-016.

Operate the engine to normal operating temperature and check for leaks.

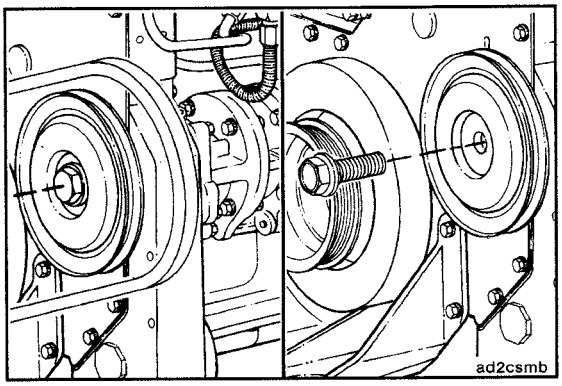


Accessory Drive Pulley (009-004)

Remove (009-004-002)

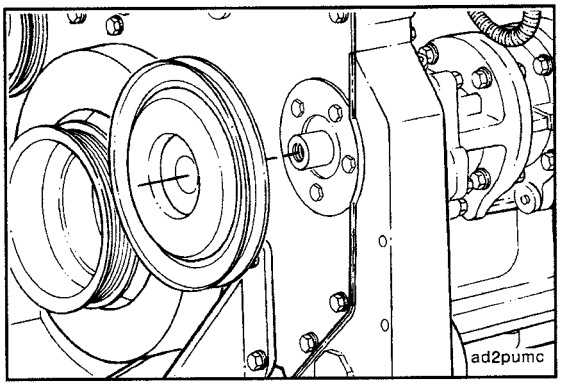
Remove the Freon compressor drive belt, if equipped. Refer to the manufacturer's instructions.

Remove the accessory drive pulley retaining capscrew.



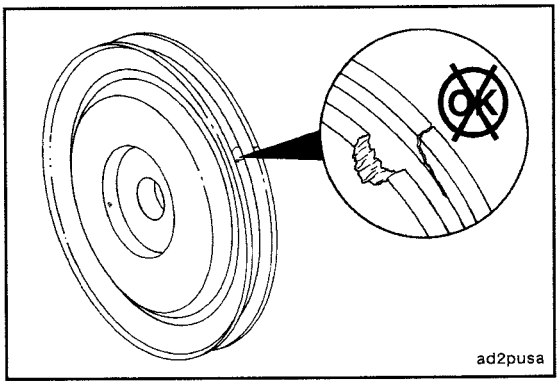
NOTE: The accessory drive pulley is slip fit, and does **not** require a puller to be removed from the engine.

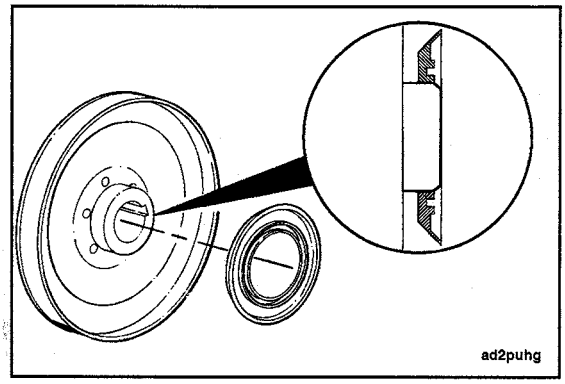
Remove the accessory drive pulley.



Inspect for Reuse (009-004-007)

Inspect the pulley for nicks, cracks or other damage.



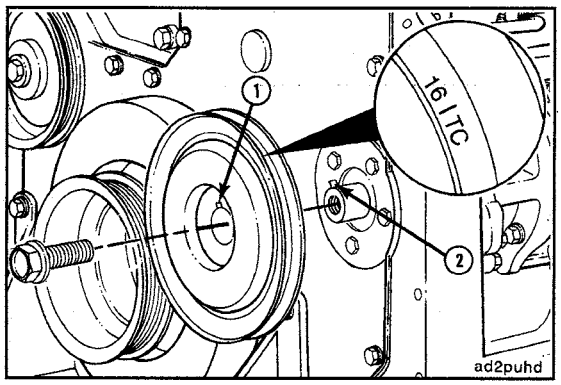


Install (009-004-026)

NOTE: Accessory drive seal dust seals are currently only to be installed on single v-groove stamped steel accessory drive pulleys. The dust seal is **not** compatible with other pulleys.

Place a light film of oil or antifreeze on the inside diameter of the accessory drive oil seal dust seal.

Install the dust seal onto the accessory drive pulley hub so that the larger outside diameter of the dust seal is facing away from the pulley. Push the dust seal onto the hub until the inside diameter of the dust seal is flush with the pulley hub end.



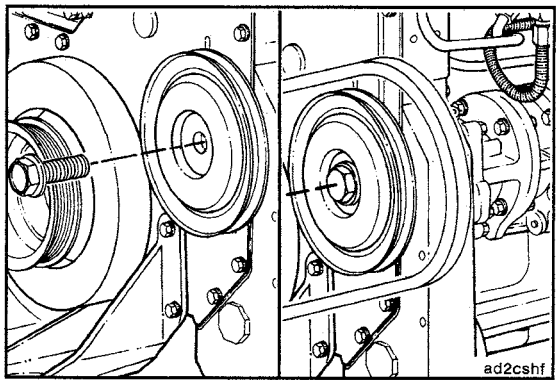
⚠ CAUTION ⚠

To prevent dowel pin damage, the slot (1) in the pulley must align with the dowel pin (2) in the shaft.

The timing marks on the pulley **must** be facing away from the engine.

This is a slip fit pulley and does **not** require the use of an installation tool.

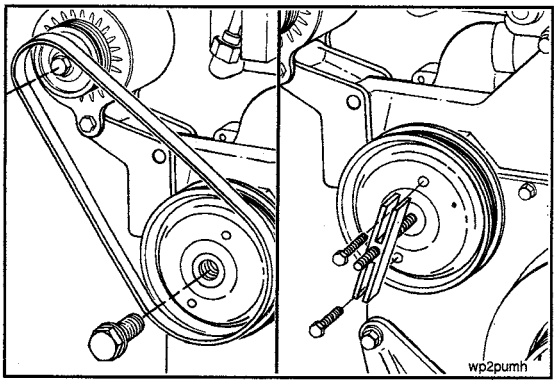
Install the pulley on the shaft by hand.



Install the M20-2.50 x 45 pulley retaining capscrew.

Torque Value: 542 N•m [400 ft-lb]

Install and adjust the freon compressor drive belt, if equipped. Refer to the manufacturer's specifications.



Alternator Drive Pulley (009-010)

Remove (009-010-002)

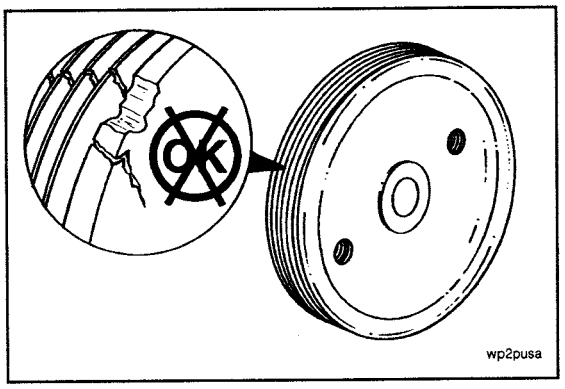
Remove the alternator drive belt. Refer to Procedure 013-005.

Remove the pulley retainer capscrew.

Use pulley puller, Part No. ST-647, and two 5/16 x 18 x 2 capscrews to remove the pulley.

Inspect for Reuse (009-010-007)

Inspect the pulley for nicks, cracks, excessive wear in the belt grooves or other damage.



Install (009-010-026)

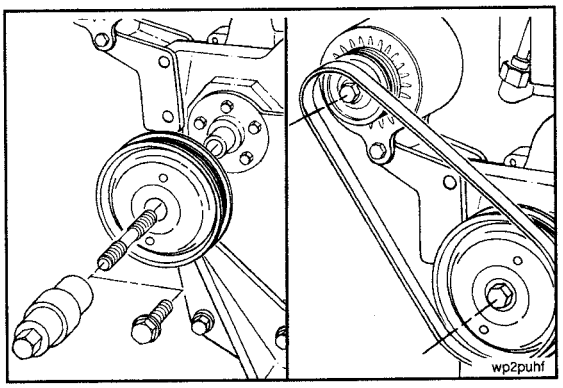
The pulley **must** be installed with the deep dished side of the pulley facing away from the engine.

Use pulley installation tool, Part No. 3376326, and pulley pusher adapter, Part No. 3377401, to install the alternator drive pulley.

Install and tighten the retaining capscrew.

Torque Value: 75 N•m [55 ft-lb]

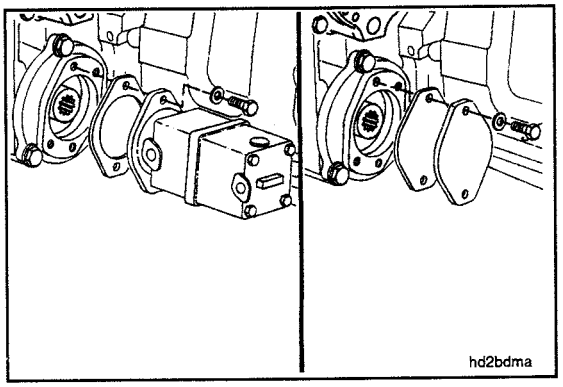
Install and adjust the alternator drive belt. Refer to Procedure 013-005.



Hydraulic Pump Drive (009-016)

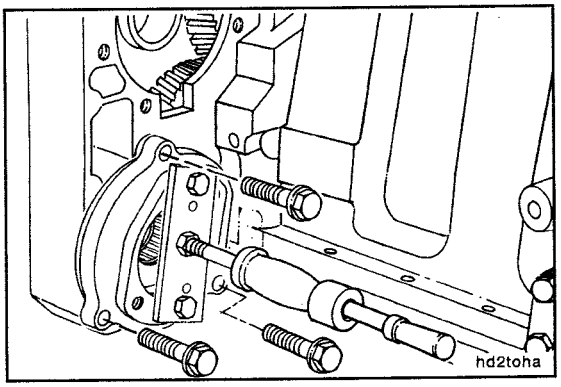
Remove (009-016-002)

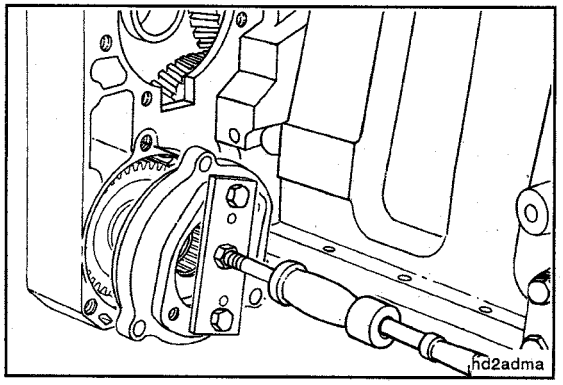
Remove the two mounting capscrews and the hydraulic pump, if equipped, or the cover plate.



Remove the three pump drive mounting capscrews.

Install a slide hammer and the engine baring tool, Part No. 3824270, to the hydraulic drive adapter. Use two M10-1.50 x 30 capscrews, Part No. 3335003, for SAE 'A' drives, or two M12-1.75 x 40 capscrews, Part No. 3018671, for SAE 'B' drives.

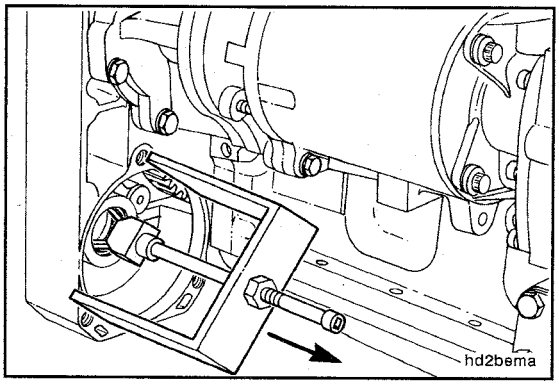




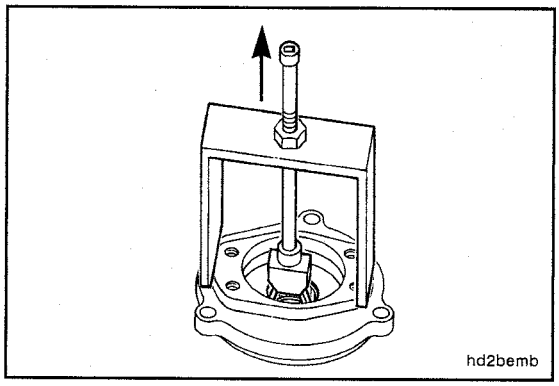
⚠ CAUTION ⚠

Do not allow the hydraulic drive gear to slide out of the adapter or the gear housing during removal. Damage to the gear will result.

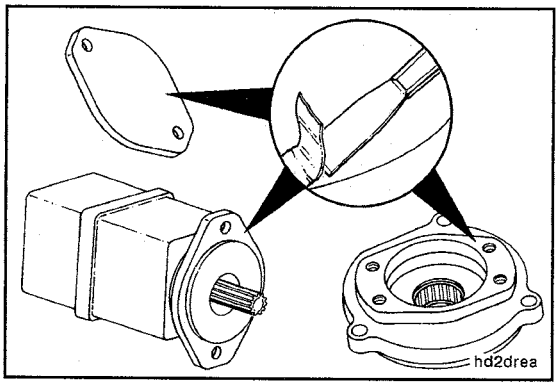
Remove the hydraulic drive adapter, o-ring, and hydraulic drive gear.



Use bearing puller kit, Part No. 3823774, to remove the needle bearing from the gear housing.



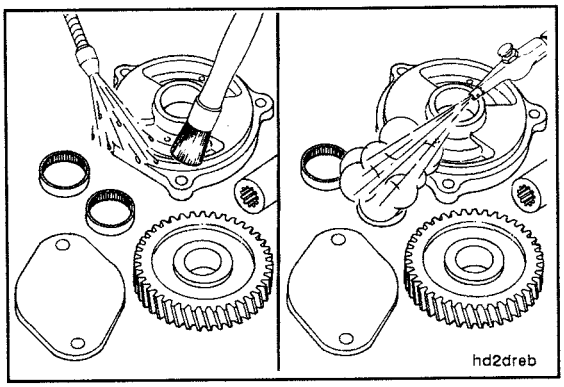
Remove the needle bearing from the hydraulic pump adapter.



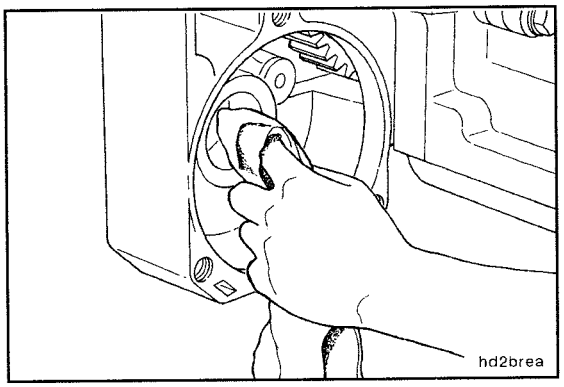
Clean (009-016-006)

Remove the gasket material from the hydraulic pump adapter and hydraulic pump, if equipped, or cover plate surface.

Clean the hydraulic pump adapter, cover plate, gear, and needle bearings with solvent. Dry with compressed air.

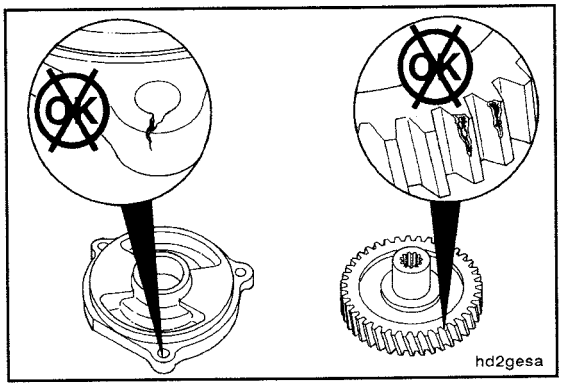


Clean the needle bearing bore in the gear housing with solvent and dry with a clean cloth.



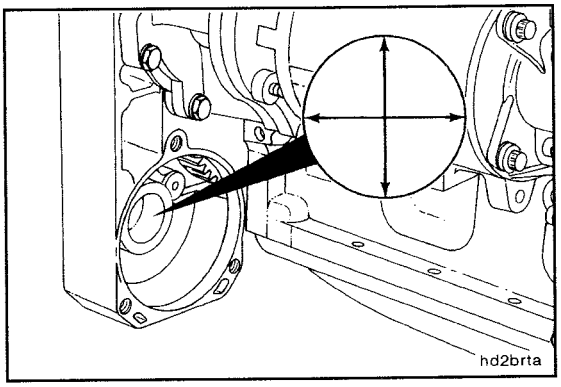
Inspect for Reuse (009-016-007)

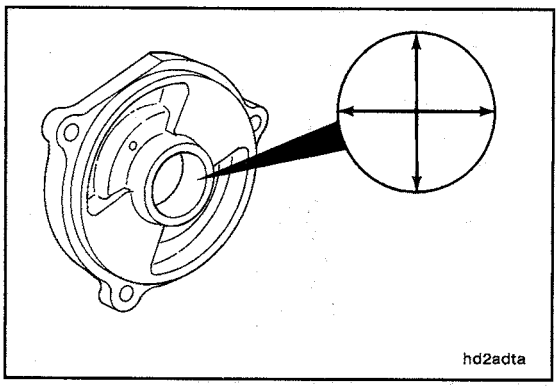
Inspect the components for damage.



Measure the inside diameter of the needle bearing bore in the gear housing.

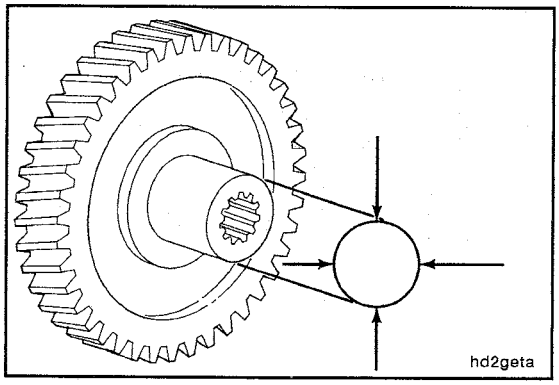
Needle Bearing Bore Inside Diameter (Gear Housing)		
mm		in
41.967	MIN	1.6522
41.992	MAX	1.6532





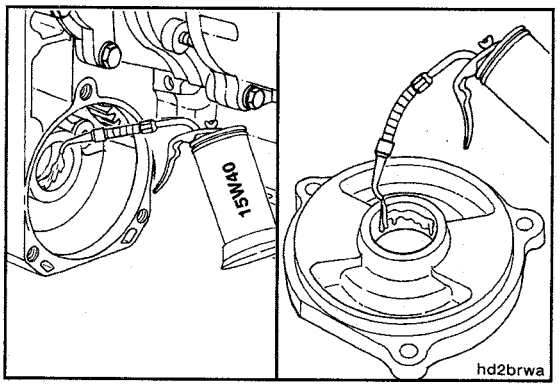
Measure the inside diameter of the needle bearing bore in the hydraulic pump drive adapter.

Needle Bearing Bore Inside Diameter (Hydraulic Pump Drive Adapter)		
mm		in
41.967	MIN	1.6522
41.992	MAX	1.6532



Measure the hydraulic drive shaft outside diameter.

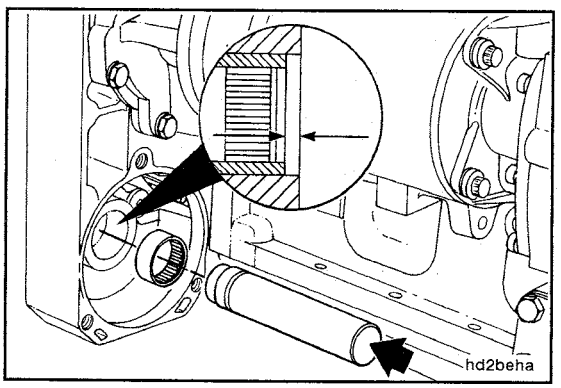
Hydraulic Drive Shaft Outside Diameter		
mm		in
34.984	MIN	1.3773
35.000	MAX	1.3780



Install (009-016-026)

Use clean 15W-40 oil to lubricate the outside diameter of the needle bearings.

Use clean 15W-40 oil to lubricate the needle bearing bores in the gear housing and the hydraulic pump drive adapter.



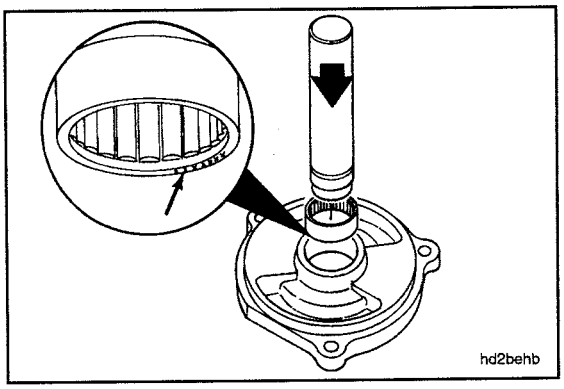
Use bearing installation tool, Part No. 3823776, included in bearing puller kit, Part No. 3823774, to install the needle bearings in the gear housing.

Tap the bearing gently until it comes in contact with the shoulder in the housing.

The bearing **must** be 0.25 to 0.76mm [0.010 to 0.030 in] past the outside edge of the gear housing bore surface.

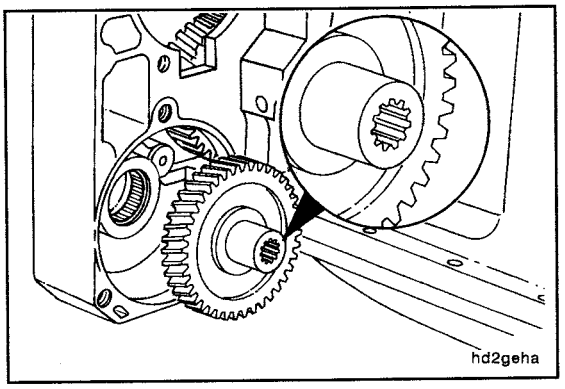
Install the needle bearing in the hydraulic pump drive adapter from the inside end (the end that will be closest to the hydraulic drive gear).

The bearing **must** be centered between the front and rear surfaces.



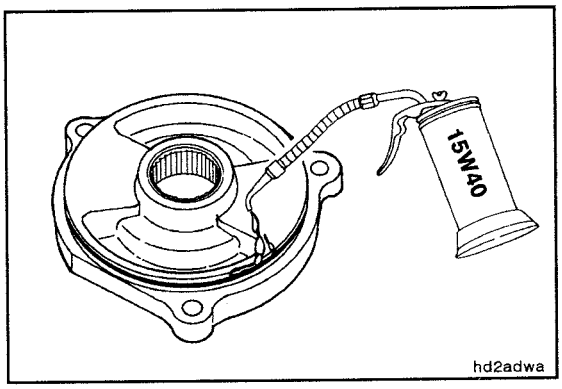
Use Lubriplate™ 105, or equivalent, to lubricate the needle bearing in the gear housing and the outside of the hydraulic driveshaft.

Install the shaft and gear assembly so the internal splines of the shaft are facing away from the gear housing and toward the rear of the engine.



Install a new o-ring on the hydraulic drive adapter. Lubricate the o-ring with clean 15W-40 oil.

Lubricate the hydraulic drive adapter needle bearing and bore with Lubriplate™ 105, or equivalent.



Install the hydraulic drive adapter over the shaft and gear assembly.

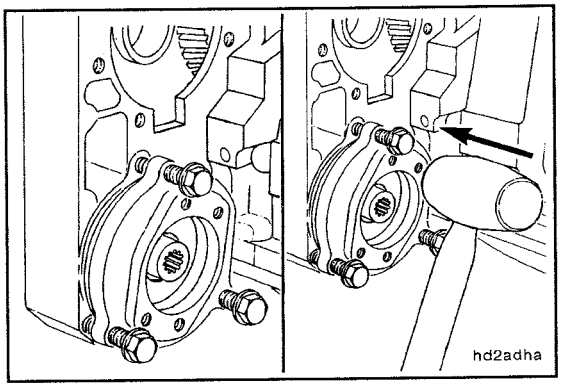
Start the three mounting capscrews by hand to align the hydraulic drive adapter with the gear housing.

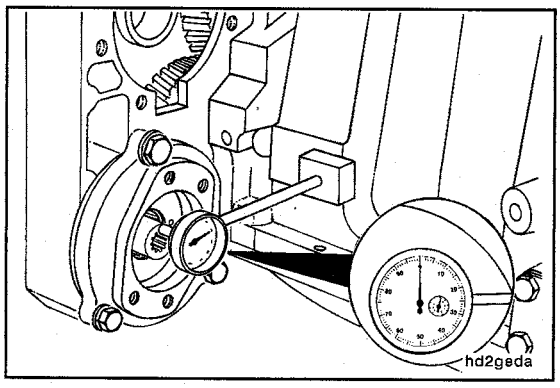
Using a rubber hammer, tap around the outside diameter of the adapter to install the adapter.

NOTE: Use care **not** to damage the o-ring during installation.

Tighten the mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]

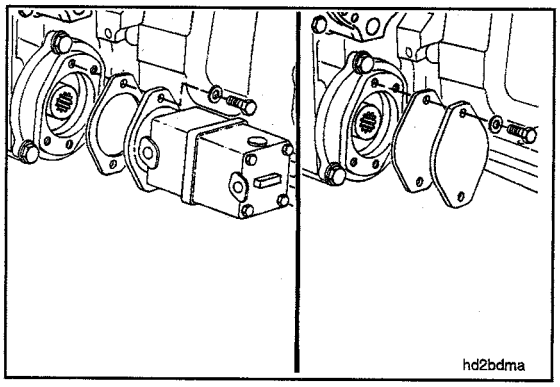




Measure the driveshaft's end clearance.

Use dial indicator assembly, Part No. 3376050, with extension, Part No. ST-537-4, and a magnetic base, Part No. 3377399.

Hydraulic Pump Driveshaft's End Clearance		
mm		in
0.076	MIN	0.003
0.635	MAX	0.025



Use a new gasket and install the hydraulic pump, if equipped, or the cover plate.

Install the two mounting capscrews and tighten.

Torque Value: 27 N•m [20 ft-lb]

Section 10 - Air Intake System - Group 10

Section Contents

Page

Air Intake Manifold 10-4
Clean 10-4
Inspect for Reuse 10-4
Install 10-5
Remove 10-4

Air Intake Restriction 10-13
Measure 10-13

Air Intake System - General Information 10-1
General Information 10-1

Air Leaks, Air Intake and Exhaust Systems 10-6
Maintenance Check 10-6

Charge Air Cooler (CAC) 10-8
Clean 10-8
Inspect for Reuse 10-9
Leak Test 10-9
Pressure Differential Test 10-11
Temperature Differential Test 10-10

Flow Diagram, Air Intake System 10-2
Flow Diagram 10-2

Service Tools 10-3
Air Intake System 10-3

Specifications 10-2
Air Intake System 10-2

Turbocharger 10-14
Check for Correct Component 10-19
Clean 10-15
Inspect for Reuse 10-16
Install 10-17
Remove 10-14

Turbocharger Axial Clearance 10-20
Measure 10-20

Turbocharger Blade Damage 10-20
Inspect for Reuse 10-20

Turbocharger Compressor Seal Leaks 10-21
Leak Test 10-21

Turbocharger Radial Bearing Clearance 10-22
Measure 10-22

Turbocharger Turbine Seal Leaks 10-23
Leak Test 10-23

Turbocharger Wastegate Actuator 10-25
Initial Check 10-25
Install 10-28
Remove 10-26
Test 10-27

Turbocharger Wastegate Controller 10-31
Disassemble 10-31
Inspect for Reuse 10-31
Install 10-32
Remove 10-31

Turbocharger Wastegate Valve Body 10-30
Maintenance Check 10-30

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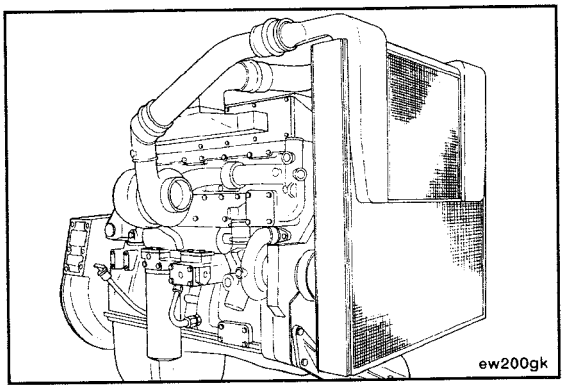
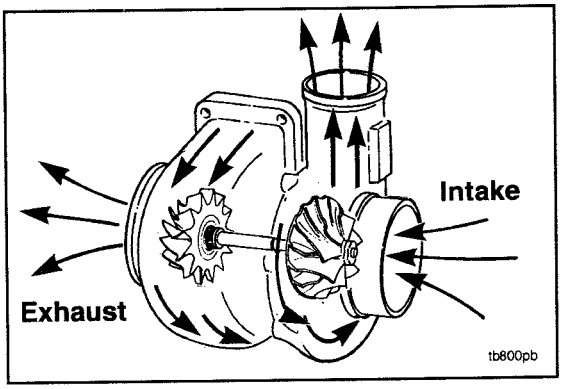
Air Intake System - General Information

General Information

The Combustion Air System on M Series engines consists of intake air piping, turbocharger, charge air piping, charge air cooler and exhaust gas piping.

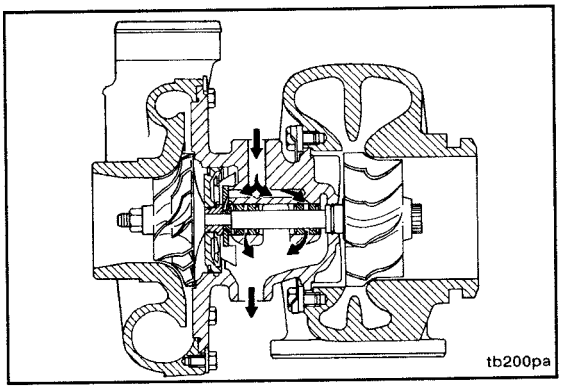


The turbocharger uses exhaust gas energy to turn the turbine wheel. The turbine wheel drives the compressor impeller which provides pressurized air to the engine for combustion. The additional air provided by the turbocharger allows more fuel to be injected to increase the power output from the engine.



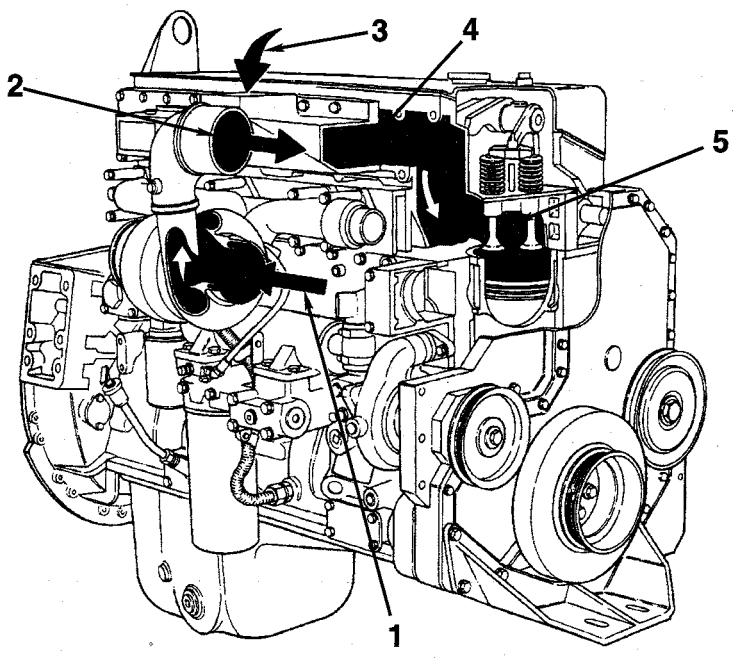
The turbine and compressor wheels, and the shaft are supported by two rotating bearings in the bearing housing. Passages in the bearing housing direct filtered, pressurized engine oil to the shaft bearings and thrust bearings. The oil is used to lubricate and cool the rotating components to provide for smooth operation. The oil then drains from the bearing housing to the engine sump through the oil drain line. A restricted oil drain line can cause the turbocharger bearing housing to be pressurized, causing oil to leak past the seal rings.

NOTE: An adequate supply of good, filtered oil is very important to the life of the turbocharger.



Flow Diagram, Air Intake System

Flow Diagram



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1. Filtered Intake Air to Turbocharger
2. Turbocharger air to Charge Air Cooler
3. Charge Air Cooler Intake Air to Intake Manifold
4. Intake Manifold
5. Intake Valve Ports.

Specifications

Air Intake System

Maximum Intake Restriction:
Clean Air Filter Element ..... 254 mm H_2O [10 in H_2O]
Dirty Air Filter Element ..... 635 mm H_2O [25 in H_2O]

Maximum Temperature Rise Between Ambient Air and Engine Inlet Air:
(ambient above 0° [32°F]) ..... 17°C [30°F]

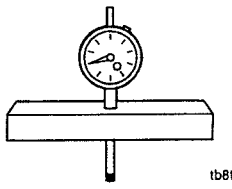
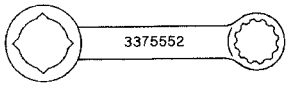
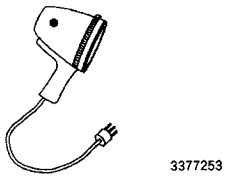
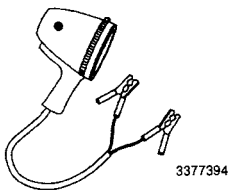
Maximum Allowable Pressure Drop From Turbocharger to Intake Manifold ..... 152 mm Hg [6 in Hg]

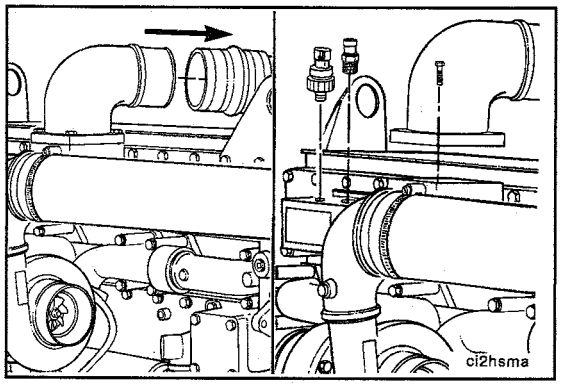
Maximum Allowable Pressure Drop Across Charge Air Cooler ..... 152 mm Hg [6 in Hg]

Service Tools

Air Intake System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-537	**Dial Depth Gauge** Measure turbocharger axial motion.	
3375552	**Torque Wrench Adapter** Torque compressor housing capscrews.	
3376891	**Fluorescent Tracer** Add to oil. Use with black light to find oil leaks.	
3377253	**Black Light (AC)** Inspect for oil or fuel leak.	
3377394	**Black Light (DC)** Inspect for oil or fuel leak.	

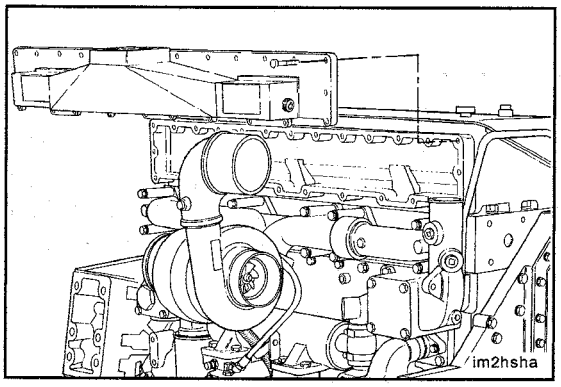


Air Intake Manifold (010-023)

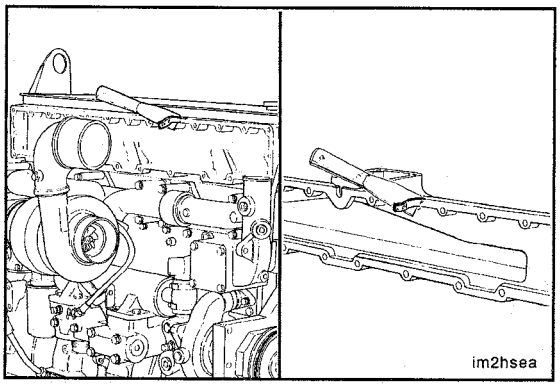
Remove (010-023-002)

Disconnect the air pipe from the charge air cooler to the inlet air connection.

Remove the inlet air connection and the sensors from the air manifold.



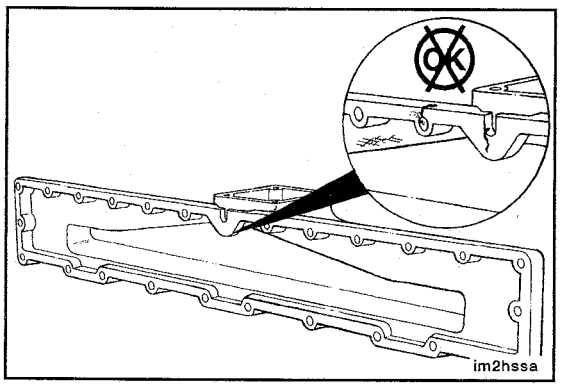
Remove the mounting capscrews and the intake manifold.



Clean (010-023-006)

Clean the intake manifold to rocker housing surface.

Clean the intake manifold gasket surface.



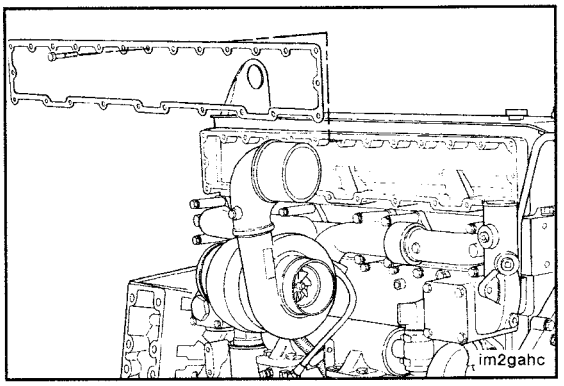
Inspect for Reuse (010-023-007)

Inspect the intake manifold for cracks or other damage.

NOTE: When inspecting the intake manifold for oil or debris from an air system failure, also inspect the intake ports in the rocker housing and cylinder head for oil and debris.

Install (010-023-026)

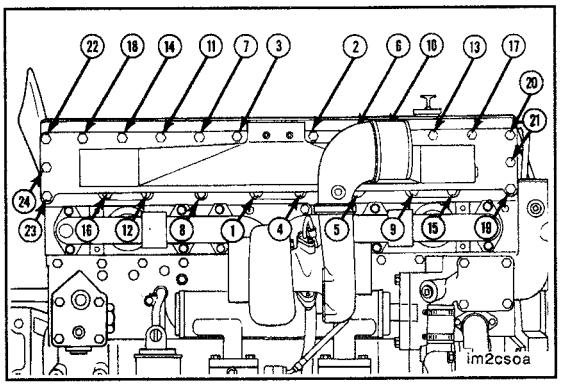
Install two guide pins in the rocker lever housing before installing a new gasket.



Install the intake manifold and capscrews.

Tighten the capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]



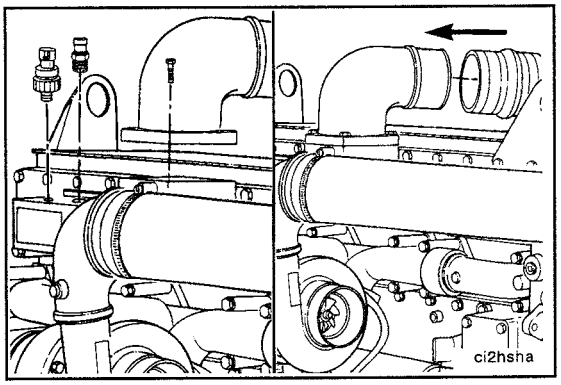
Use a new gasket, and install the inlet air connection.

Torque Value: 41 N•m [30 ft-lb]

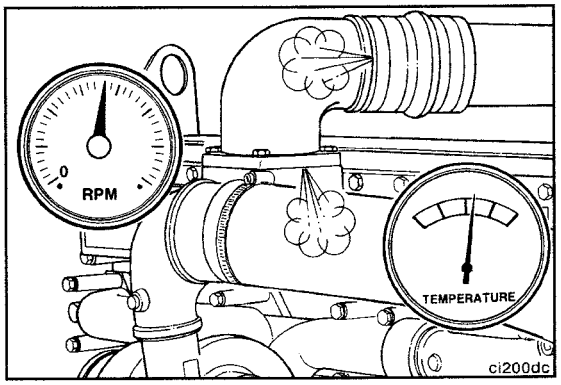
Install the sensors.

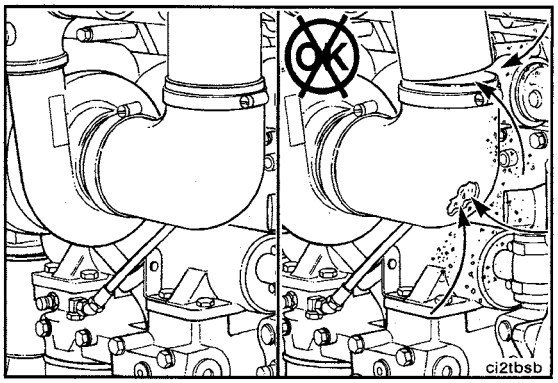
Install the air pipe from the charge air cooler to the intake connection. Tighten the clamps.

Refer to the manufacturer's specification for the correct torque value.



Operate the engine to normal operating temperature and check for air leaks.





Air Leaks, Air Intake and Exhaust Systems (010-024)

Maintenance Check (010-024-008)

⚠ CAUTION ⚠

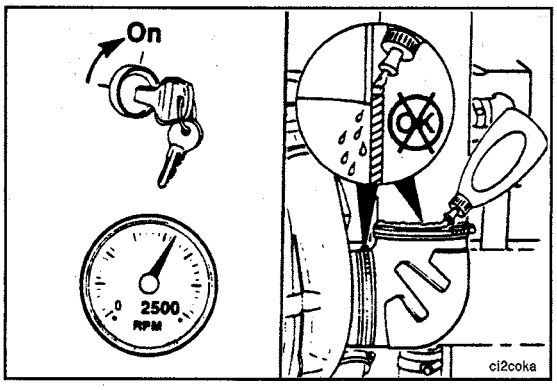
Engine intake air must be filtered to prevent dirt and debris from entering the engine. If intake air piping is damaged or loose, unfiltered air will enter the engine and cause premature wear.

Inspect the intake air piping for cracked hoses, damage, or loose clamps.

Replace damaged pipes and tighten loose clamps as necessary to make sure the air intake system does **not** leak.

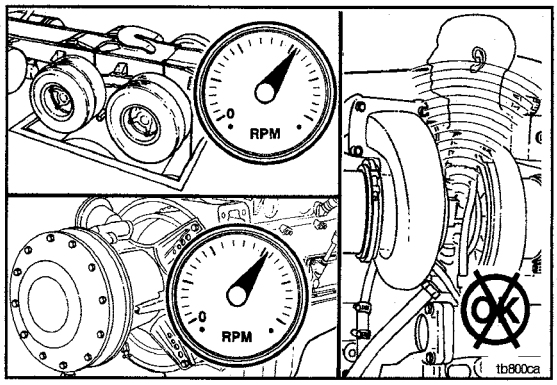
Torque Value: 8 N•m [72 in-lb]

Check for corrosion of the intake system piping under the clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system. Disassemble and clean as required.



Operate the engine at high idle, and use a solution of soapy water to spot intake air leaks.

If an air leak exists, the soap bubbles will be drawn in with the air.



Operate the engine at full throttle and rated rpm with maximum load.

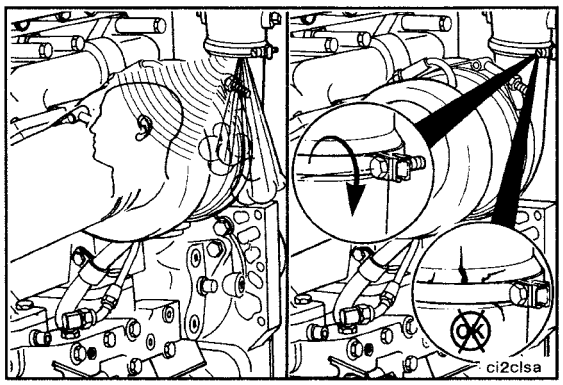
Listen for a high-pitched whistling noise from the turbocharger near piping and connections.

The noise can be caused by an air leak from the:

- turbocharger to discharge elbow connection

Inspect for damage. Tighten loose clamps.

Torque Value: 8 N•m [72 in-lb]

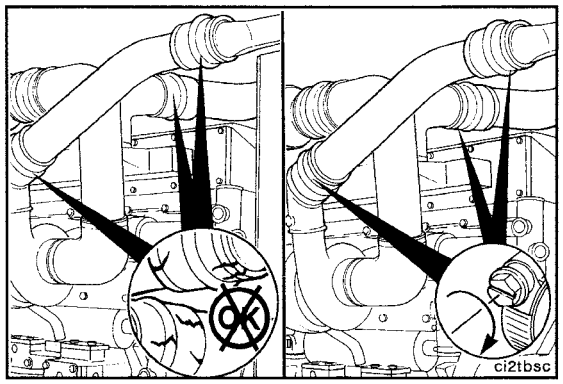


- any charge air cooler tubing or connecting hoses

Inspect the hose and tubing for damage.

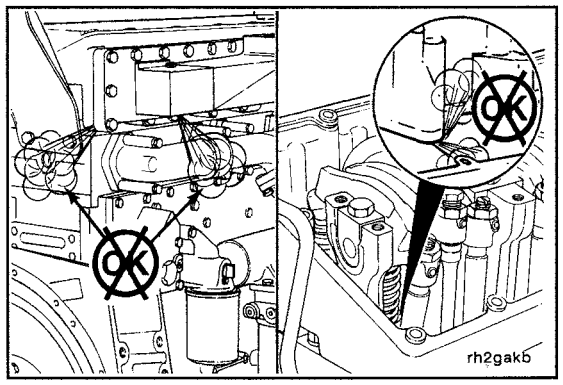
Tighten the hose clamps.

Refer to the manufacturer's specifications for the correct torque value.



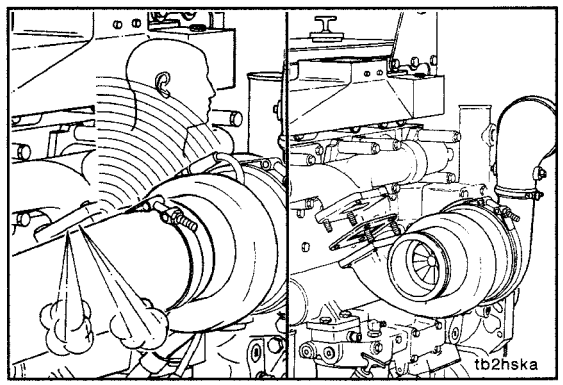
- rocker housing and intake manifold gaskets

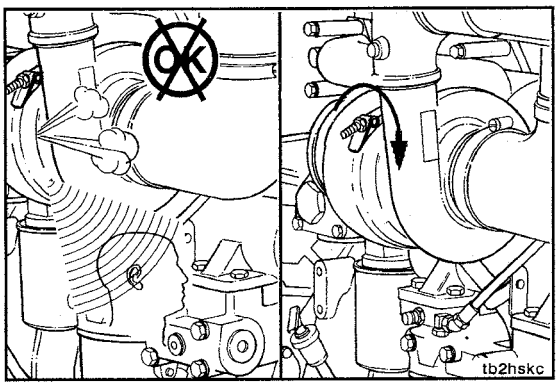
Inspect the intake manifold and rocker housing to cylinder head gasket joint. Replace the gasket if leaks are found. Refer to Procedure 003-013.



- turbocharger to exhaust manifold mounting gasket

Replace the gasket. Refer to Procedure 010-033 for turbocharger removal and installation.



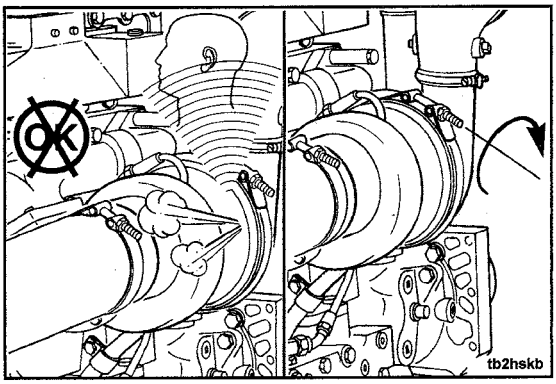


- Turbine housing sealing surface exhaust leak

Tighten the turbine housing capscrews or v-band clamps.

Torque Value:

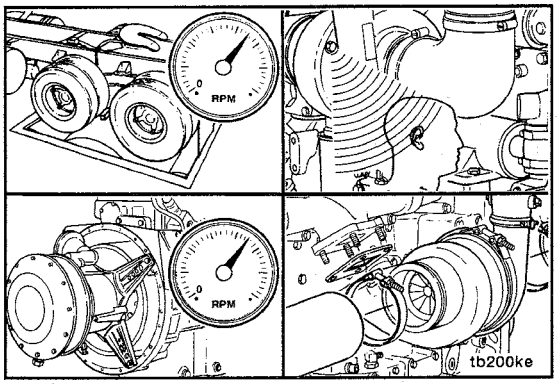
Capscrews	14 N•m	[120 in-lb]
V-band	9 N•m	[75 in-lb]



- compressor housing sealing surface air leak.

Tighten the compressor housing v-band clamp nut.

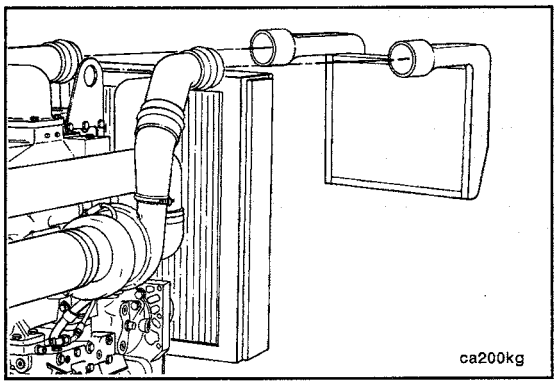
Torque Value: 9 N•m [75 in-lb]



Operate the engine at full throttle and rated rpm with maximum load.

Listen again for leaks.

Replace the turbocharger if the air piping is **not** damaged and the noise can still be heard. Refer to Procedure 010-033.



Charge Air Cooler (CAC) (010-027)

Clean (010-027-006)

If the engine experiences a turbocharger failure or any other occasion where oil or debris is put into the charge air cooler, the charge air cooler **must** be cleaned.

Remove the charge air cooler piping and charge air cooler from the vehicle. Refer to the manufacturer's instructions.

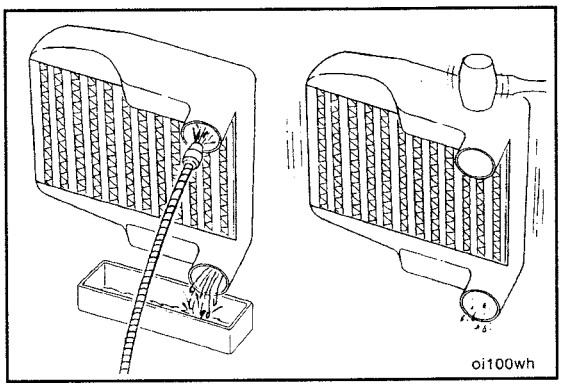
⚠ CAUTION ⚠

Do not use caustic cleaners to clean the charge air cooler. Damage to the charge air cooler will result.

Flush the charge air cooler internally with solvent in the opposite direction of normal airflow. Shake the charge air cooler and lightly tap on the end tanks with a rubber mallet to dislodge trapped debris. Continue flushing until all debris or oil is removed.

NOTE: Be sure the tubes are in the vertical direction when flushing.

If the debris **cannot** be totally removed from the charge air cooler, the charge air cooler **must** be replaced.

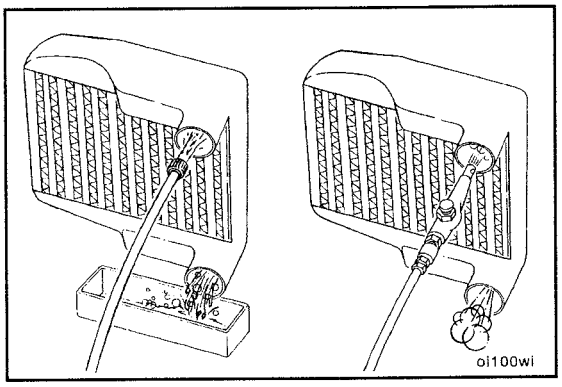


After the charge air cooler has been thoroughly cleaned of all oil and debris with solvent, wash the charge air cooler internally with hot soapy water to remove the remaining solvent. Rinse thoroughly with clean water.

Blow compressed air through the inside of the charge air cooler in the opposite direction of normal air flow until the charge air cooler is dry internally.

⚠ CAUTION ⚠

The charge air cooler must be rinsed, dried, and free of solvent, oil, and debris or engine damage will result.



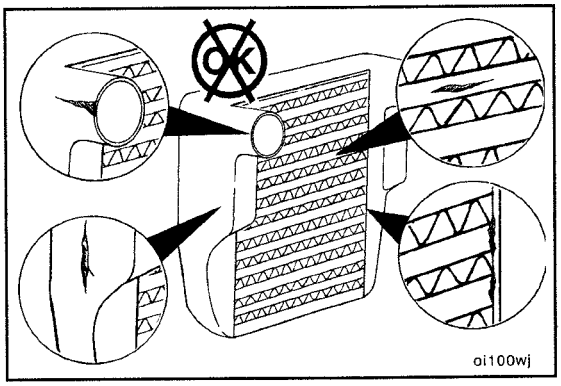
Inspect for Reuse (010-027-007)

Inspect the charge air cooler for cracks, holes, or damage.

Inspect the tubes, the fins, and the welds for tears, breaks, or other damage. If any damage causes the charge air cooler to fail the air leak check mentioned earlier in this procedure, the charge air cooler **must** be replaced.

Install the charge air cooler and charge air cooler piping on the vehicle. Refer to the manufacturer's instructions.

NOTE: Always clean and inspect the charge air cooler piping and hoses prior to installation.



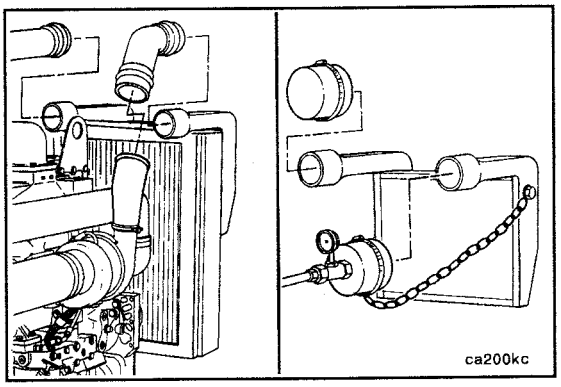
Leak Test (010-027-014)

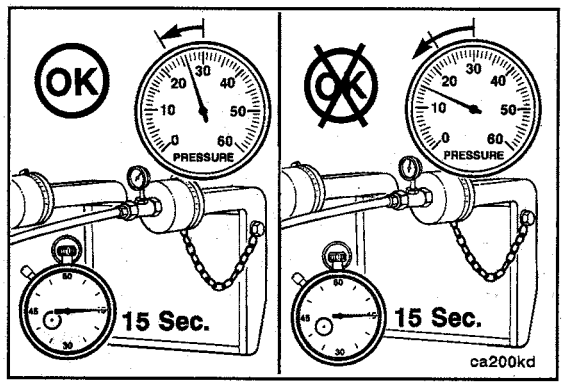
To check the charge air cooler for cracked tubes or header, remove the inlet and outlet hoses from the cooler. The charge air cooler does **not** have to be removed from the chassis.

⚠ WARNING ⚠

To prevent possible injury if either plug blows off during the test, secure safety chains on the test plugs to any convenient capscrew on the radiator assembly. This test must not be performed without securely fastened safety chains.

Install a plug or cap over the outlet side of the cooler. Install a pressure gauge and a regulated shop air supply line with a shutoff valve to the inlet side of the cooler.



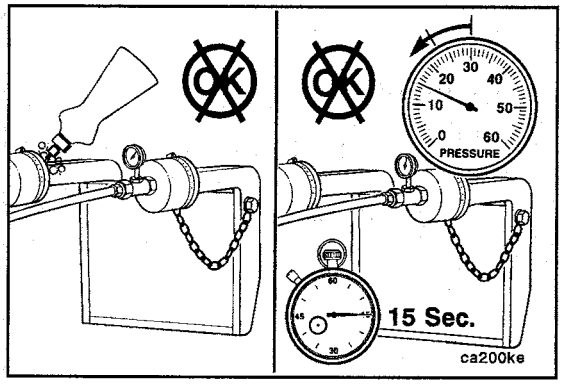


Apply air pressure to the cooler until the pressure gauge reads a steady 207 kPa [30 psi] of air pressure.

Shut off the airflow to the cooler, and start a stopwatch at the same time. Record the leakage at 15 seconds.

If the pressure drop is 34 kPa [5 psi] or less in 15 seconds, the cooler is functioning properly.

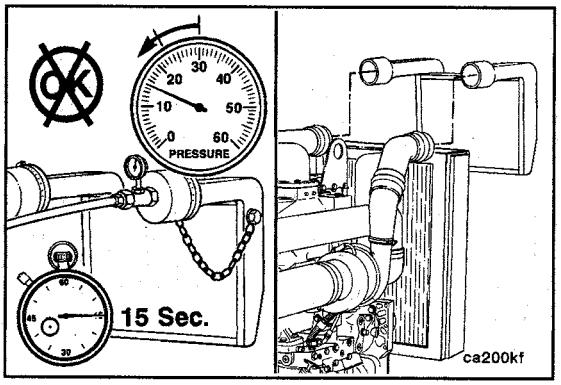
If the pressure drop is greater than 34 kPa [5 psi] in 15 seconds, check all connections again.



Determine if the pressure drop is caused by a leak in the charge air cooler or from a leaky connection. Use a spray bottle filled with soapy water applied to all hose connections, and watch for bubbles to appear at the location of the leak.

If the pressure drop is caused by a leaky connection, repair the connection, and repeat the test. If the leak is within the charge air cooler, repeat the test to verify the accuracy of the pressure drop measurement. Similar pressure drop readings **must** be obtained at least three consecutive tests before the reading can be considered accurate.

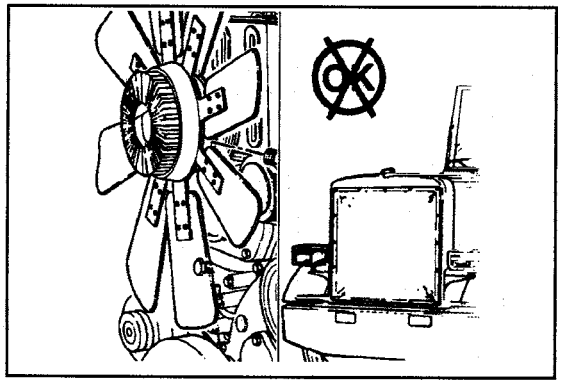
NOTE: If a charge air cooler leaks more than 34 kPa [5 psi] in 15 seconds, it will appear as a major leak in a leak tank.



If the pressure drop is greater than 34 kPa [5 psi] in 15 seconds, the charge air cooler **must** be replaced.

Refer to the manufacturer's repair manual for replacement instructions.

NOTE: Charge air coolers are **not** designed to be 100-percent leak free. If the pressure drop is less than 34 kPa [5 psi] in 15 seconds, then the charge air cooler does **not** need to be replaced.



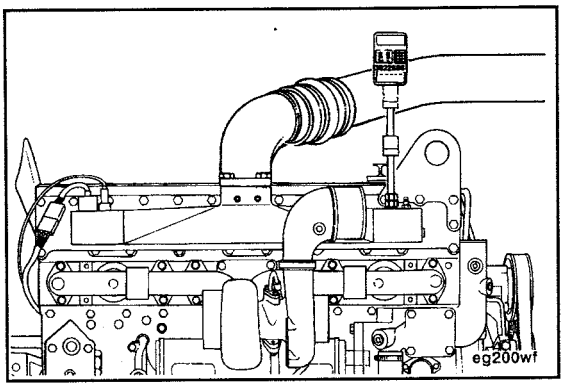
Temperature Differential Test (010-027-049)

Inspect the charge air cooler fins for obstructions to airflow. Remove obstructions such as a winterfront or debris. Manually lock shutters in the open position if equipped.

Lock the fan drive in the ON mode to prevent erratic test results. This can be done by installing a jumper wire across the temperature switch.

Install Fluke digital thermometer, Part No. 3822666, and thermocouple wire kit, Part No. 3822988, into the intake manifold at the 1/8-inch NPT tap near the air horn connection with the intake manifold.

Install another thermocouple at the air cleaner inlet to measure ambient air temperature.

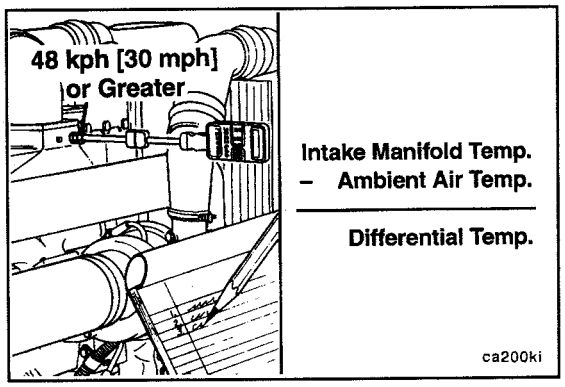


Perform a road test with the engine at peak power and a vehicle speed of 48 kph [30 mph] or greater.

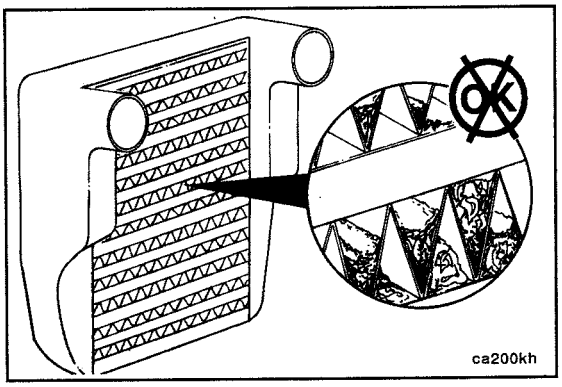
Record the intake manifold temperature and the ambient air temperature.

Calculate the differential temperature:

Intake Manifold Temperature	-	Ambient Air Temperature	=	Differential Temperature
Maximum Differential Temperature: 28°C [50°F]				



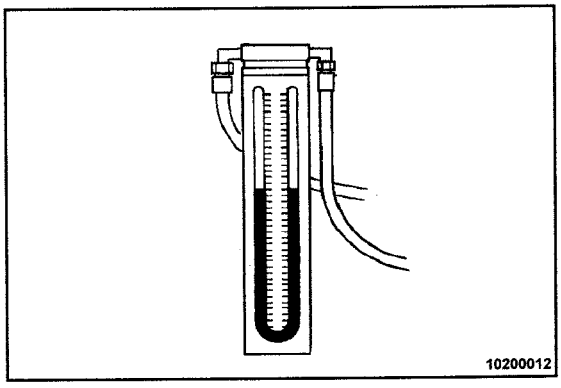
If the temperature differential is greater than the specifications, check the charge air cooler for dirt and debris on the fins and clean as necessary. If the problem still exists, check the charge air cooler for debris in the fins or between the charge air cooler and radiator. Confirm full fan engagement.

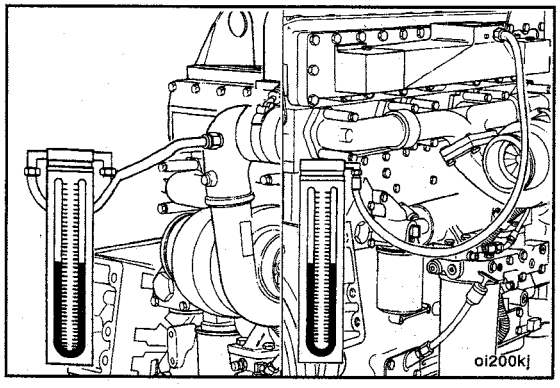


Pressure Differential Test (010-027-063)

Preferred Method

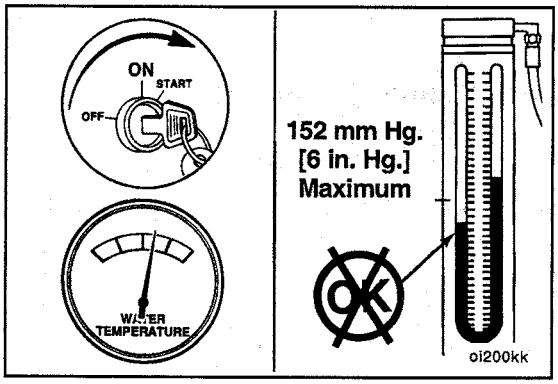
Measure the charge air cooler system pressure drop with a mercury manometer, Part No. ST-1111-3.





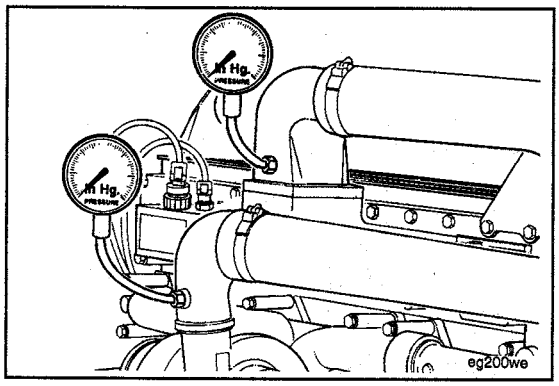
Install one end of a mercury manometer to the fitting in the turbocharger compressor outlet elbow.

Install the other end of the mercury manometer to the intake manifold.



Operate the engine at rated rpm and load. Record the readings on the manometer.

If the differential pressure is greater than 152 mm Hg [6 in Hg], check the charge air cooler and associated piping for plugging. Clean or replace if necessary.

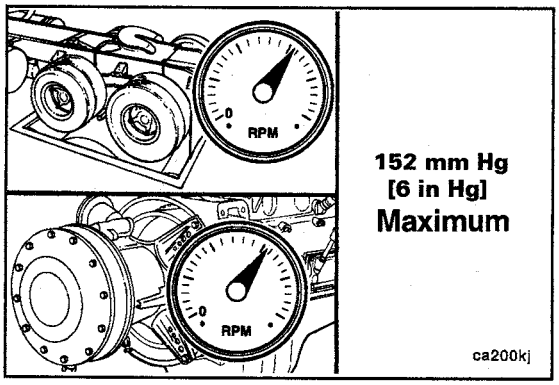


Optional Method

Obtain two (2) pressure gauges, Part No. ST-1273. Check both gauges on the same pressure source at 206 kPa [30 psi] for consistency.

Install pressure gauge, Part No. ST-1273, to the 1/8-inch fitting in the turbocharger compressor outlet elbow.

Install the other pressure gauge in the intake manifold.



Operate the engine at rated rpm and load. Record the readings on the two gauges.

If the differential pressure is greater than 152 mm Hg [6 in Hg], check the charge air cooler and associated piping for plugging, restrictions, or damage.

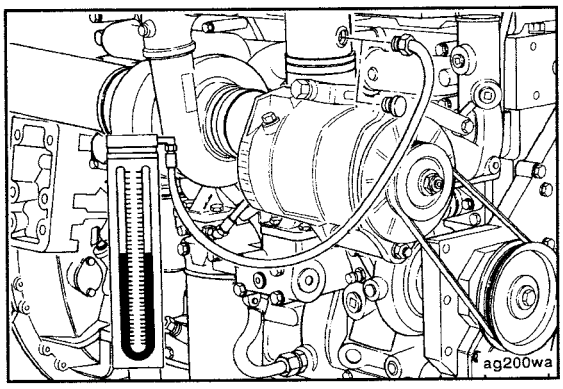
Clean or replace if necessary.

Air Intake Restriction (010-031)

Measure (010-031-010)

Install a vacuum gauge or water manometer in the intake air piping.

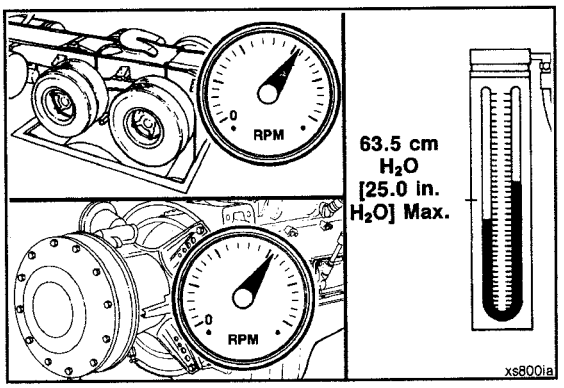
The gauge adapter **must** be installed at a 90-degree angle to the airflow in a straight section of pipe, one pipe diameter before the turbocharger.



Operate the engine at full throttle and rated rpm with maximum load.

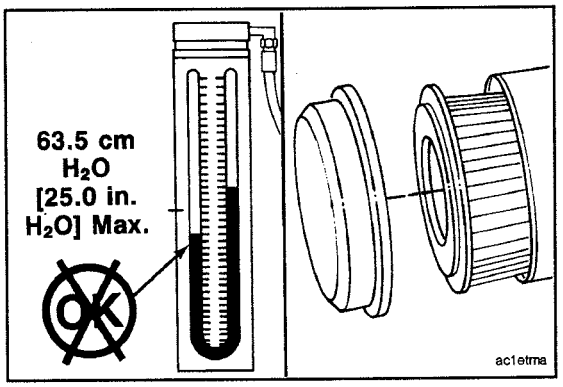
Record the data on the gauge or manometer.

Inlet Air Restriction		
mm H_2O		in H_2O
63.5	MAX	25.0

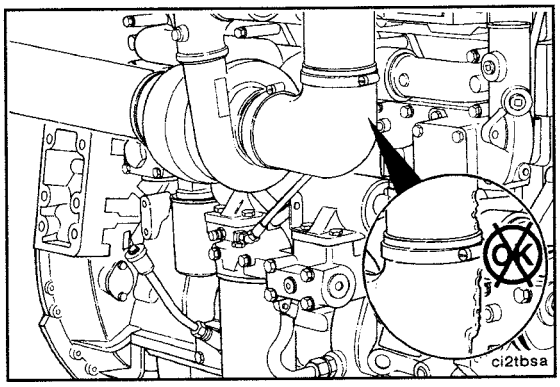


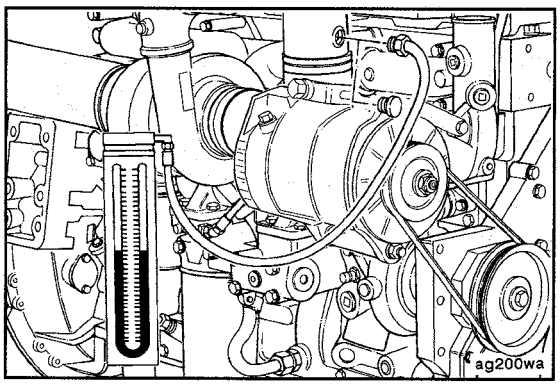
If restriction exceeds specifications:

- Replace or clean the air filter element. Refer to the equipment manufacturer's instructions.

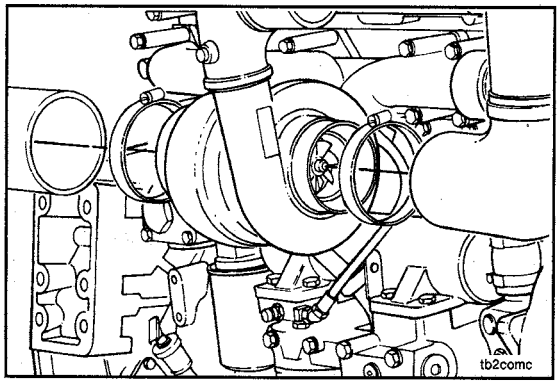


- Inspect the intake piping for damage. Refer to the equipment manufacturer's repair instructions.





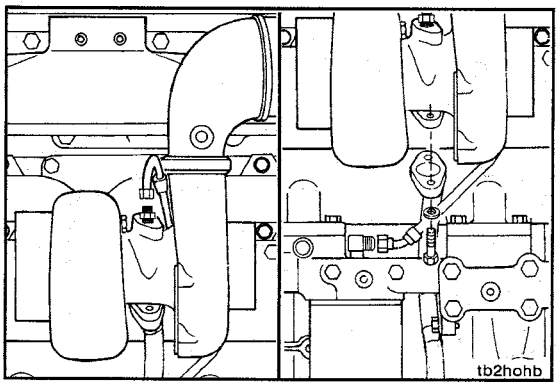
Remove the test equipment.



Turbocharger (010-033)

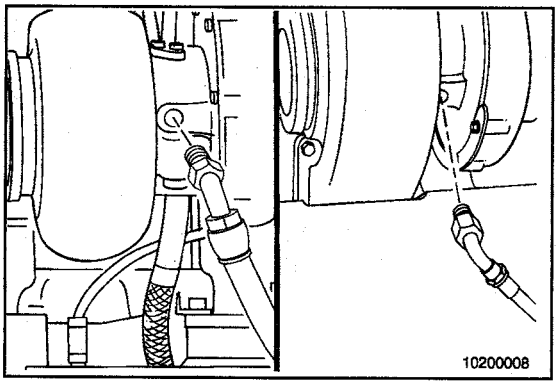
Remove (010-033-002)

Remove the intake and exhaust pipes from the turbocharger.



Remove the oil supply line from the turbocharger.

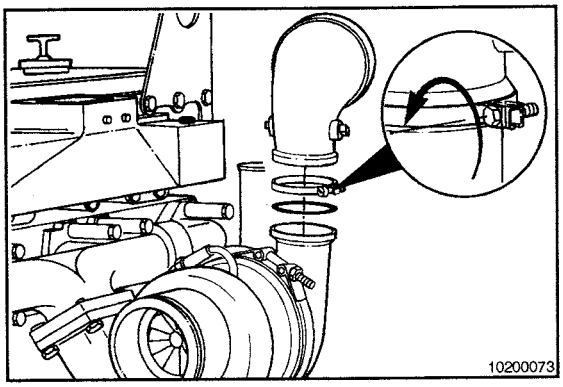
Remove the oil drain line from the turbocharger.



NOTE: Some applications use water-cooled turbochargers.

If a water-cooled turbocharger is used, drain the cooling system, and remove the water supply and return lines from the turbocharger.

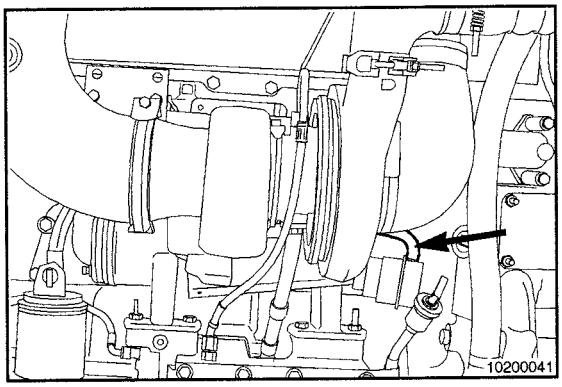
Remove the v-band clamp, discharge elbow, and o-ring from the turbocharger compressor discharge outlet.



NOTE: Some applications use wastegated turbochargers.

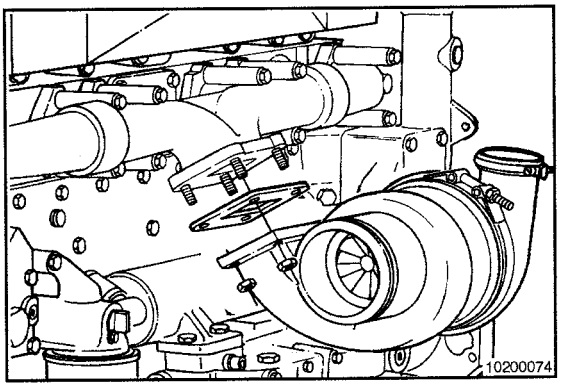
NOTE: A new hose clamp, Part No. 3914419, will be required to reinstall the signal line.

If a wastegated turbocharger is used, remove the wastegate actuator signal line by cutting the crimped hose clamp.



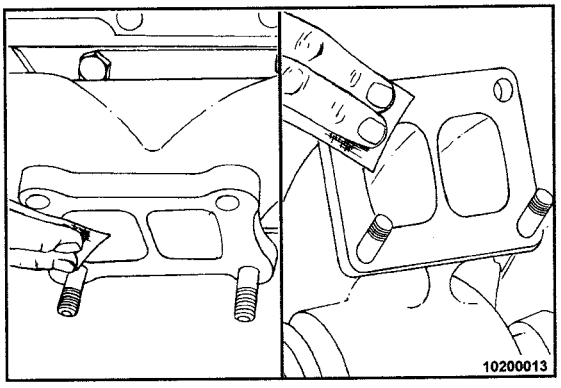
Remove the four turbocharger mounting nuts.

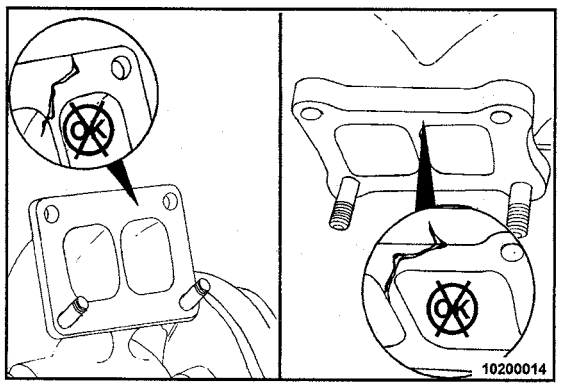
Remove the turbocharger and gasket.



Clean (010-033-006)

Clean the turbocharger and exhaust manifold gasket surfaces.

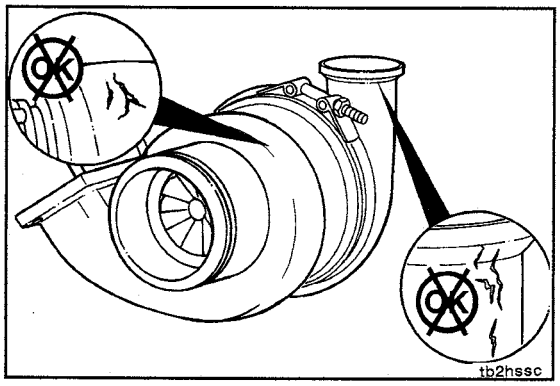




Inspect for Reuse (010-033-007)

NOTE: For wastegated turbochargers, refer to procedure 010-050 for wastegate actuator inspection.

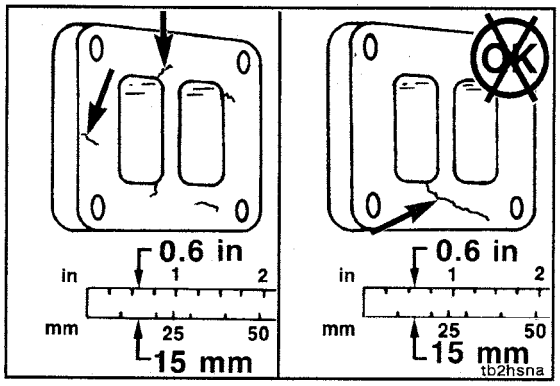
Inspect the turbocharger and exhaust manifold gasket surfaces, and mounting studs for cracks or damage.



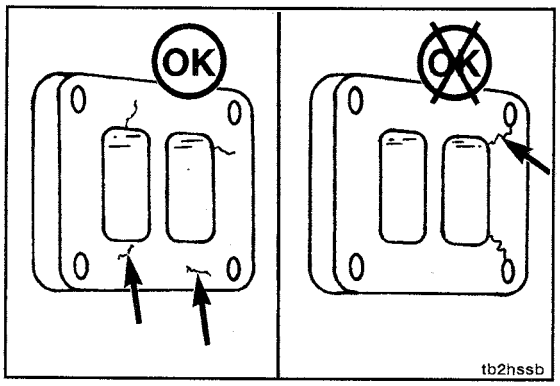
Inspect the turbine and compressor housings.

If cracks exist on the outer walls the housing **must** be replaced.

NOTE: A charge air cooler failure can cause progressive damage to the turbine housing. If the turbine housing is damaged, check the charge air cooler. Refer to Procedure 010-027.

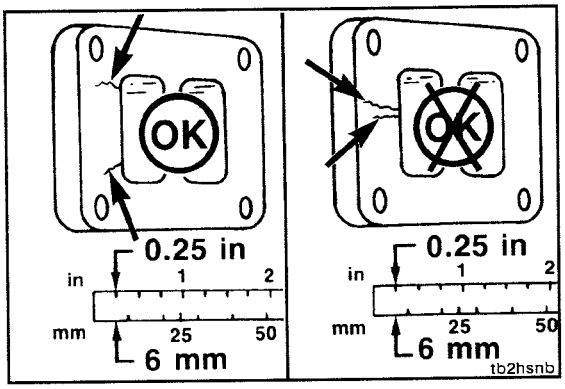


Cracks in the mounting flange longer than 15 mm [0.6-in] are **not** acceptable.

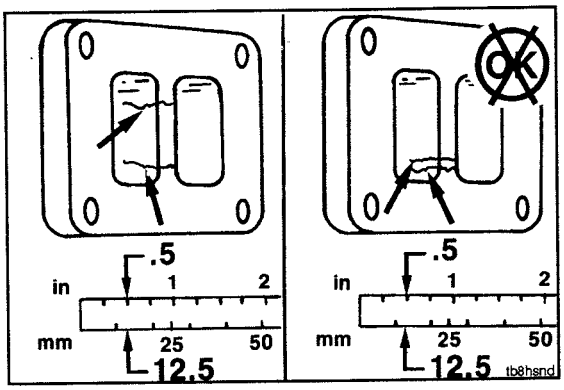


Cracks of any length that reach mounting holes are **not** acceptable.

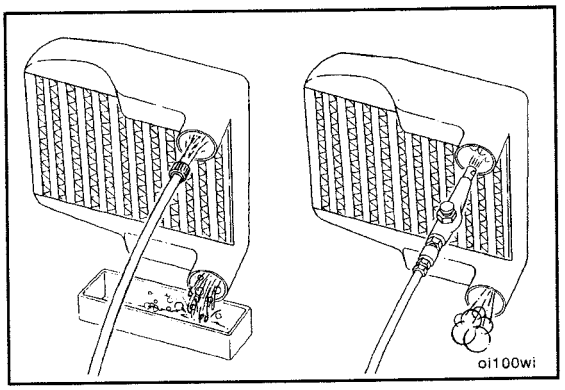
Two cracks **must** be separated by at least 6.4-mm [0.25-in].



Cracks of any length that extend through the divider are acceptable **only** if they are separated by at least 12.5-mm [0.50-in].



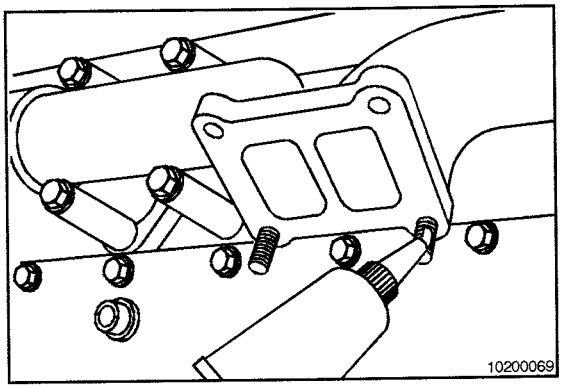
NOTE: If the engine experiences a turbocharger failure or any other occasion where oil or debris is put into the charge air system, the charge air system **must** be inspected and cleaned. Refer to Procedures 010-027 and 010-023.

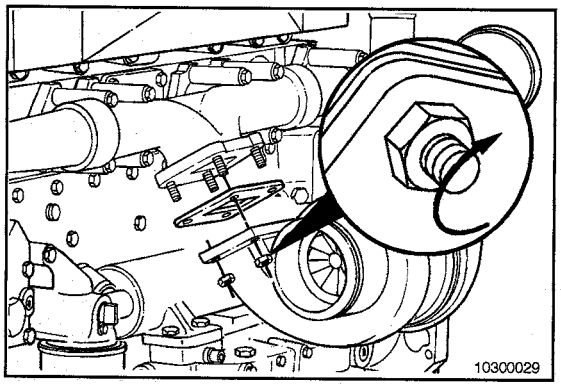


Install (010-033-026)

NOTE: For wastegated turbochargers refer to section 010-050 for wastegate actuator installation.

Apply a film of anti-seize lubricant, Part No. 3824879, to the turbocharger mounting studs.

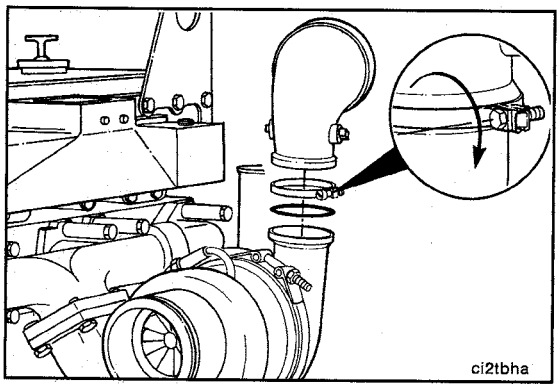




Use a new gasket when installing the turbocharger.

Install and tighten the four mounting nuts.

Torque Value: 61 N•m [45 ft-lb]



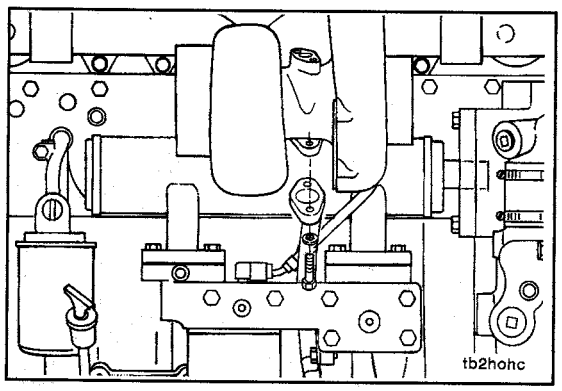
Install a new o-ring seal on the turbocharger compressor discharge outlet.

Install the discharge elbow and v-band clamp.

NOTE: Be sure the elbow is seated properly before the v-band clamp is tightened.

Tighten the clamp.

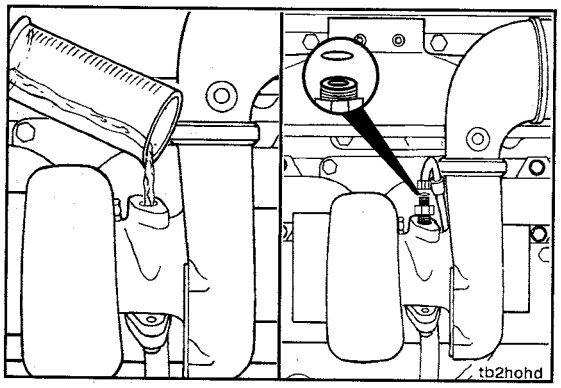
Torque Value: 8 N•m [75 in-lb]



Install a new gasket on the turbocharger oil drain line connection, and install the drain line to the bottom of the turbocharger.

Tighten the two turbocharger oil drain line mounting capscrews.

Torque Value: 27 N•m [20 ft-lb]



Pour 50 to 60 cc [2.0 to 3.0 oz] of clean engine oil in the turbocharger oil supply inlet.

Install and tighten the turbocharger oil supply line.

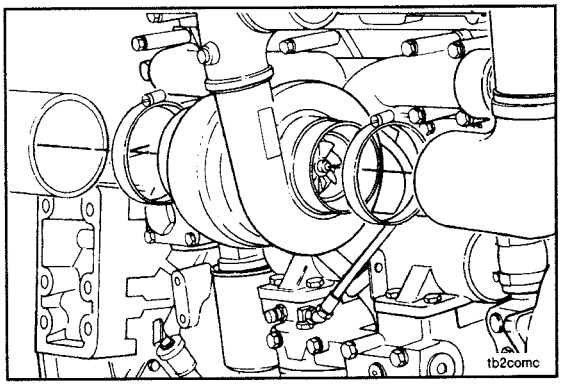
Torque Value: 20 N•m [15 ft-lb]

Install the intake pipe, and tighten the clamp.

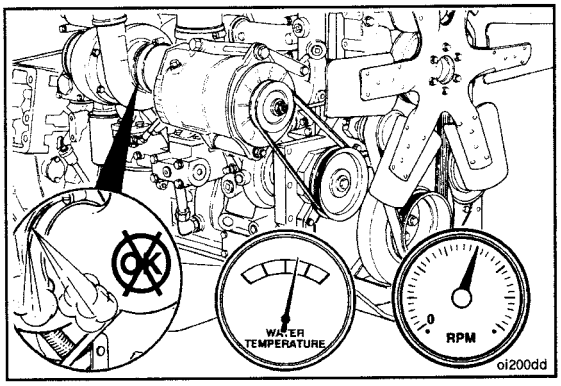
Torque Value: 8 N•m [72 in-lb]

Install the exhaust pipe, and tighten the clamp.

Torque Value: 8 N•m [72 in-lb]

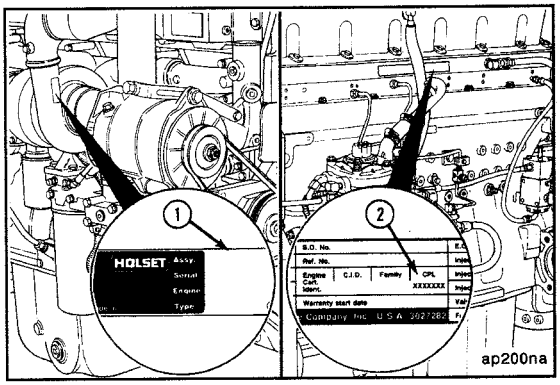


Operate the engine until it reaches a temperature of 160°F and check for air leaks.

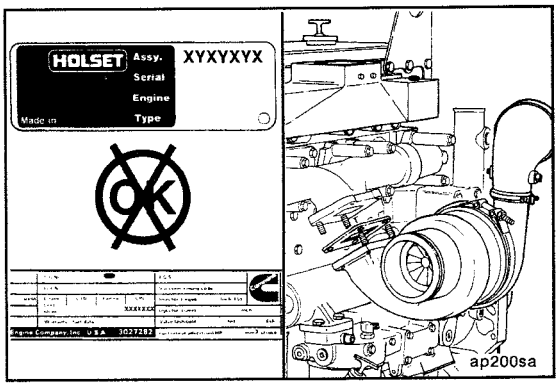


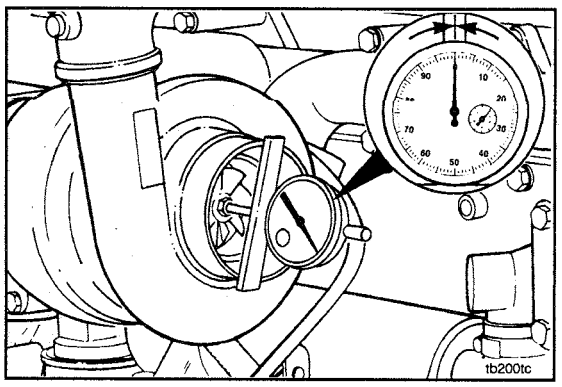
Check for Correct Component (010-033-048)

Compare the assembly number (1) on the turbocharger data tag with the turbocharger specified in the engine control parts list (CPL) number (2) listed on the engine data tag.



If the correct turbocharger was **not** installed, remove it, and install the correct turbocharger. Refer to Procedure 010-033.





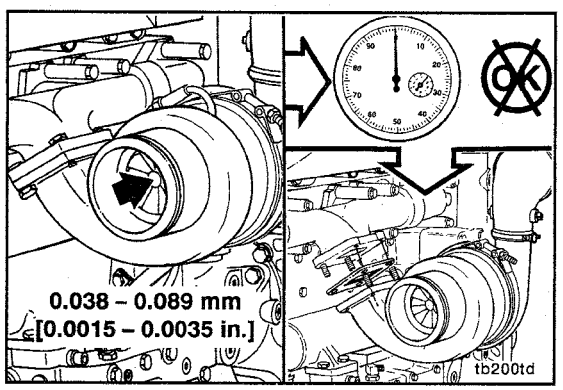
Turbocharger Axial Clearance (010-038)

Measure (010-038-010)

Use dial depth gauge, Part No. ST-537.

Push the rotor assembly away from the gauge.

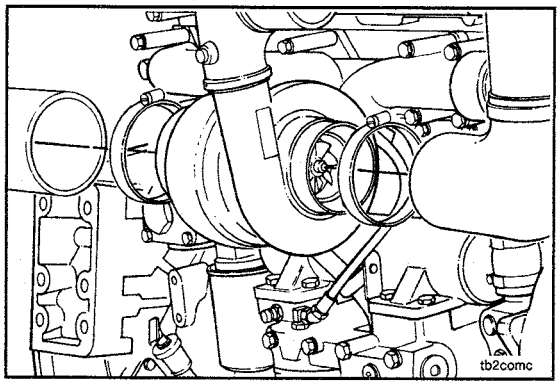
Set the gauge on zero (0).



Push the rotor assembly toward the gauge, and record the reading.

Axial Clearance		
mm		in
0.038	MIN	0.0015
0.089	MAX	0.0035

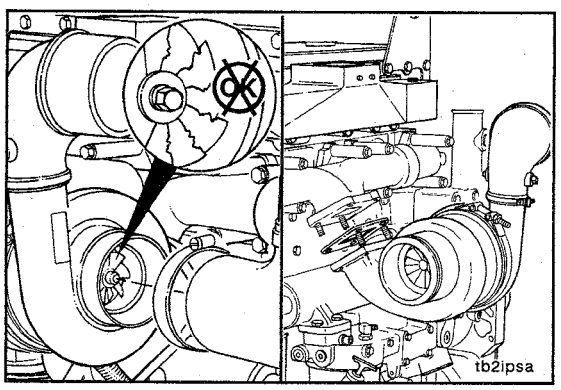
Replace the turbocharger if the clearance does **not** meet the specifications. Refer to Procedure 010-033 for the replacement procedure.



Install the exhaust pipe, and tighten the clamp.

Install the intake pipe, and tighten the clamp.

Torque Value: 8 N•m [72 in-lb]



Turbocharger Blade Damage (010-039)

Inspect for Reuse (010-039-007)

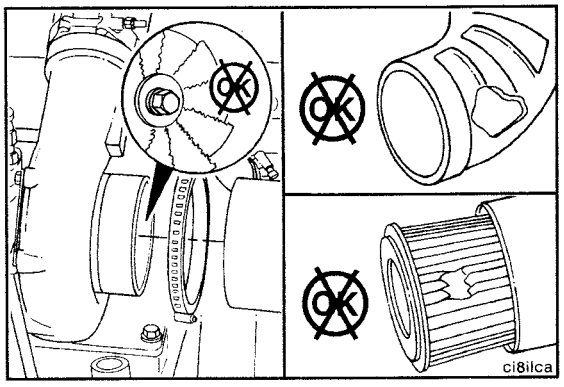
Remove the intake pipe from the turbocharger.

Inspect the turbocharger compressor impeller blades for damage.

Replace the turbocharger if damage is found. Refer to Procedure 010-033.

If the compressor impeller is damaged, inspect the intake piping and filter element for damage.

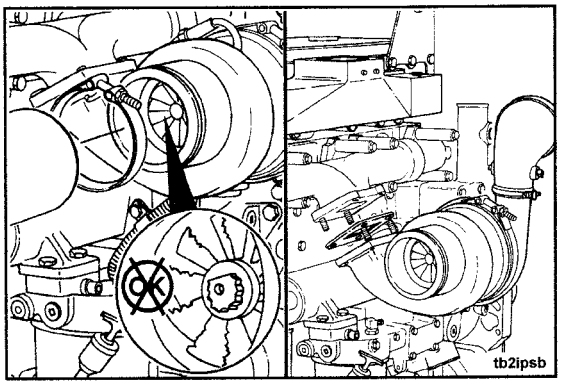
Repair any damage before operating the engine.



Remove the exhaust pipe from the turbocharger.

Inspect the turbine wheel for damage.

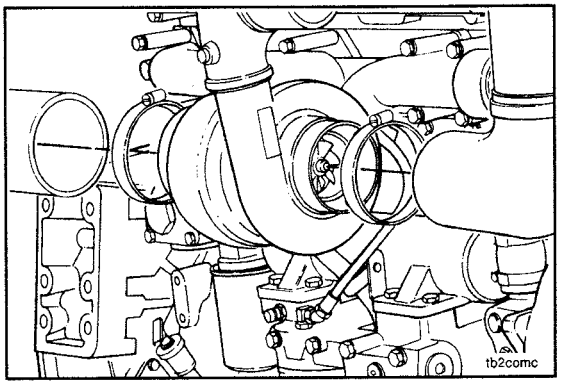
Replace the turbocharger if damage is found. Refer to Procedure 010-033.



Install the intake pipe, and tighten the clamp.

Install the exhaust pipe, and tighten the clamp.

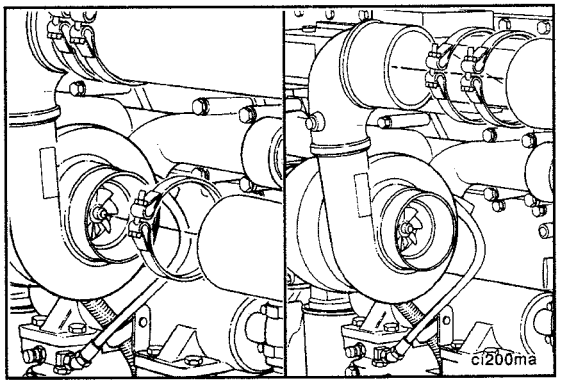
Torque Value: 8 N•m [72 in-lb]

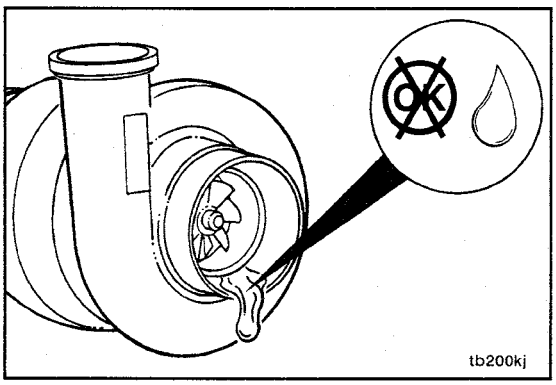


Turbocharger Compressor Seal Leaks (010-040)

Leak Test (010-040-014)

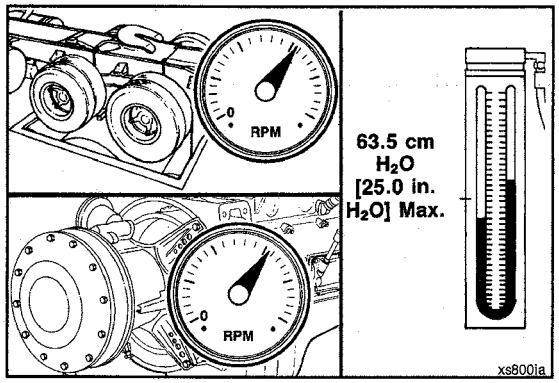
Remove the air intake and charge air cooler (CAC) piping from the turbocharger.





Inspect the compressor intake and discharge for oil.

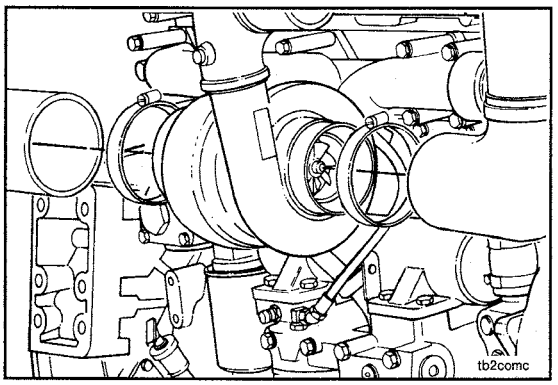
If oil is present in the compressor intake, as well as in the discharge, check upstream from the turbocharger for the source of the oil.



If oil is present **only** in the discharge side, install the air intake and charge air cooler piping.

Check for intake restriction. Refer to Procedure 010-031.

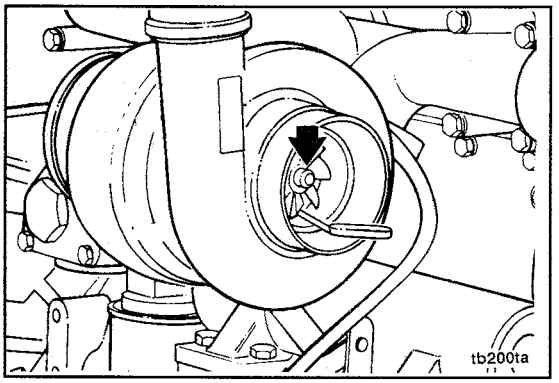
If no intake restriction is found, replace the turbocharger. Refer to Procedure 010-033.



Turbocharger Radial Bearing Clearance (010-047)

Measure (010-047-010)

Remove the intake and exhaust pipes from the turbocharger.



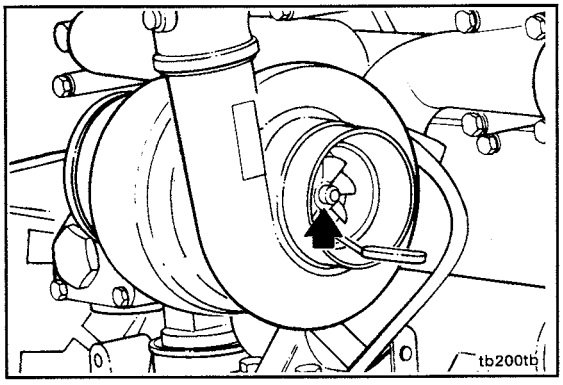
Use a wire type feeler gauge to measure the clearance between the compressor wheel and housing.

Gently push the compressor wheel toward the compressor housing and gauge.

Record this clearance.

With the feeler gauge in the same location, gently push the compressor wheel away from the compressor housing, and measure the clearance between the compressor wheel and housing.

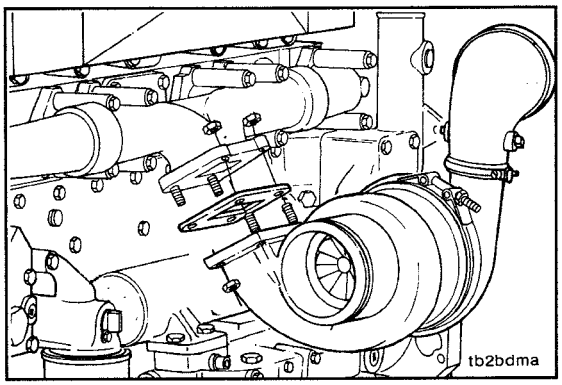
Record this clearance.



Subtract the smaller clearance from the larger clearance. This is the radial bearing clearance.

Radial Bearing Clearance		
mm		in
0.15	MIN	0.006
0.64	MAX	0.025

Replace the turbocharger if the radial bearing clearance does **not** meet the specifications. Refer to Procedure 010-033 for the replacement procedure.

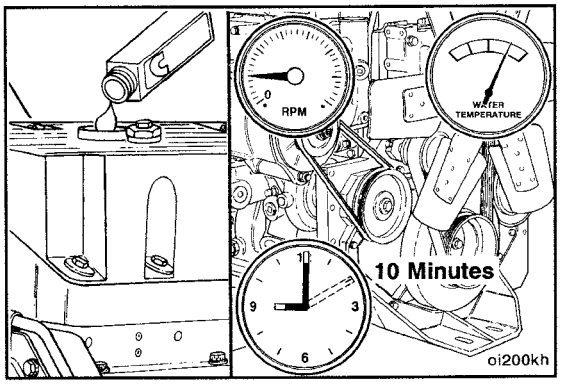


Turbocharger Turbine Seal Leaks (010-049)

Leak Test (010-049-014)

Add one unit of fluorescent tracer, Part No. 3376891, to each 38 liters [10.0 gal] of engine lubricating oil.

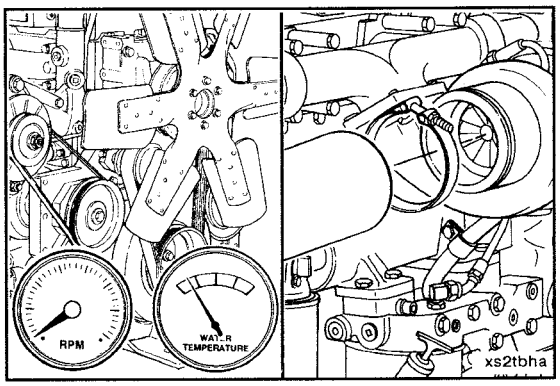
Operate the engine at low idle for 10 minutes.

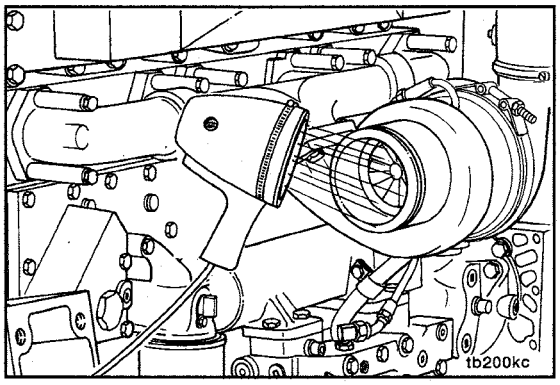


Shut off the engine.

Allow the turbocharger to cool.

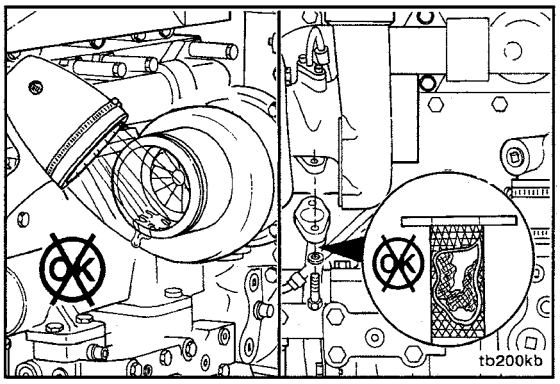
Remove the exhaust pipe from the turbine housing.



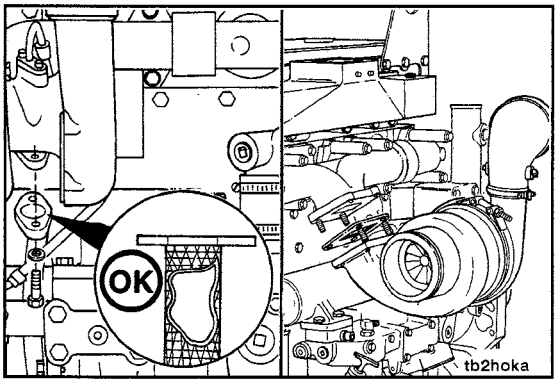


Use a high-intensity black light, Part No. 3377253 or 3377394, to inspect the turbine outlet for leaks.

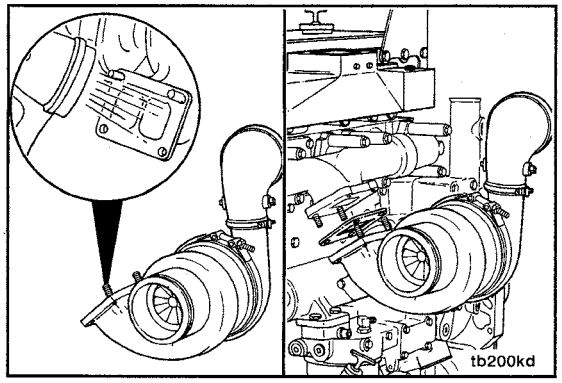
A dark blue glow indicates a fuel leak. Refer to Procedure 007-044. A yellow glow indicates an oil leak.



If oil is found on the turbine housing, remove the oil drain line and check for restrictions. Clear any restrictions found, or replace damaged components as required.



If the oil drain line is **not** restricted, remove the turbocharger. Refer to Procedure 010-033.



Use a high-intensity black light, Part No. 3824524 or 3824754, to inspect the turbine inlet for leaks.

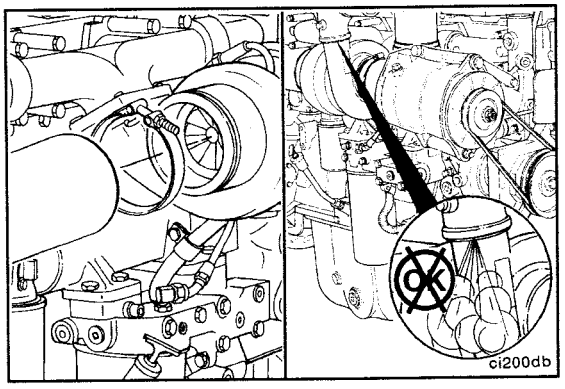
A yellow glow indicates an oil leak from the engine.

If a yellow glow is not seen in the turbine inlet, replace the turbocharger. Refer to Procedure 010-033.

Install the exhaust pipe to the turbocharger, and tighten the clamp.

Torque Value: 8 N•m [72 in-lb]

Operate the engine and check for air leaks.

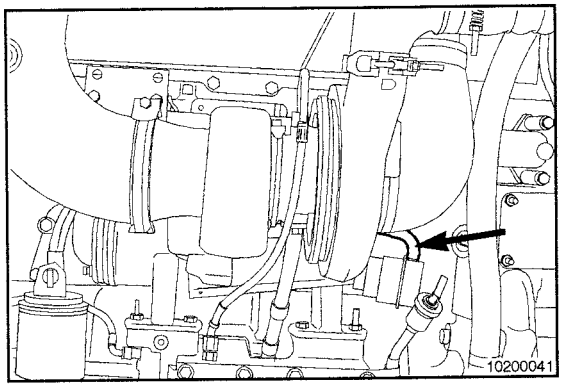


Turbocharger Wastegate Actuator (010-050)

Initial Check (010-050-001)

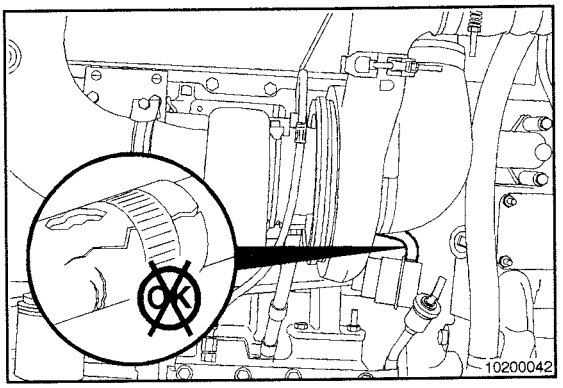
Some M Series engines are equipped with wastegate turbochargers to limit the peak boost level and increase engine response at low rpm.

The wastegate actuator hose takes boost pressure from the intake manifold via the control valve to the wastegate capsule.



Inspect the wastegate actuator hose for cracks or holes.

Replace the hose if damaged.

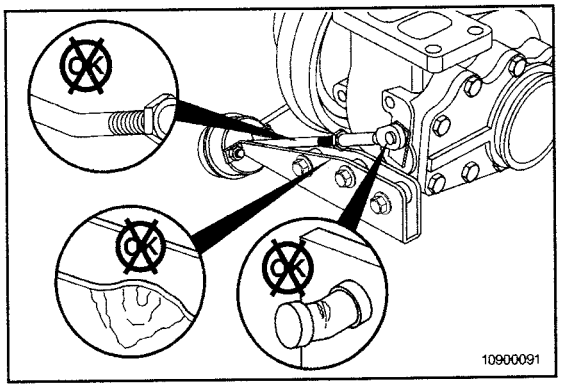


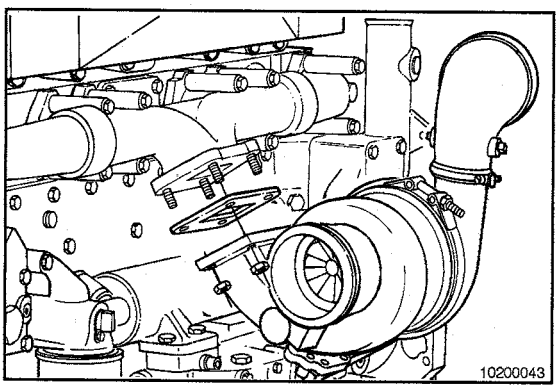
△ CAUTION △

A bent wastegate mounting bracket, actuator rod, or lever can cause improper operation.

Inspect the wastegate mounting bracket, actuator rod, and lever for damage.

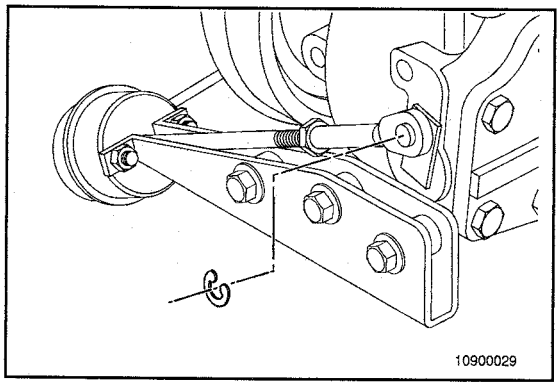
If the wastegate mounting bracket, actuator rod, or lever is bent, it **must** be replaced.



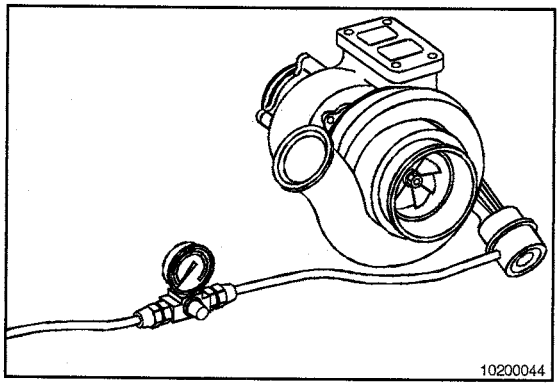


Remove (010-050-002)

NOTE: In most applications, the turbocharger **must** be removed in order to remove the wastegate actuator. Refer to Procedure 010-033.



Remove the retaining clip from the control lever.



⚠ WARNING ⚠

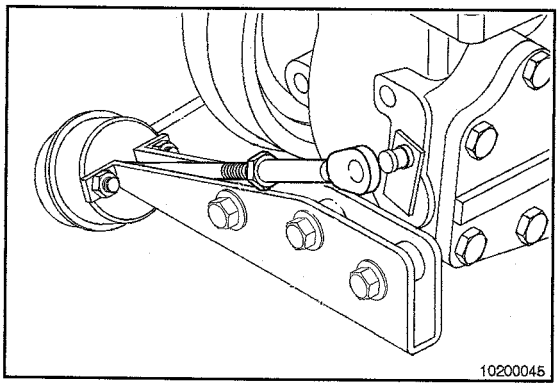
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

△ CAUTION △

Be careful not to bend the control lever.

Air Regulator with Pressure Gauge

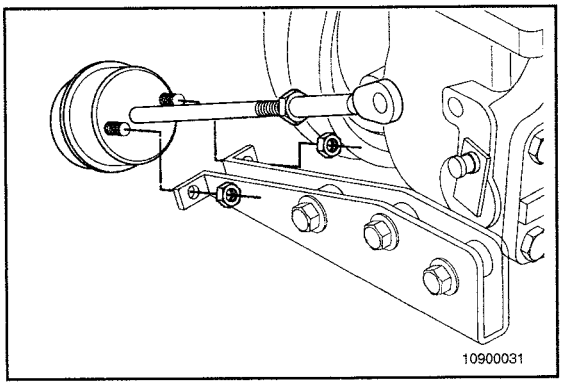
Disconnect the boost capsule actuator rod end from the turbocharger wastegate lever. This can be accomplished by slowly applying regulated air pressure to the boost capsule until the control rod is activated. A maximum of 310 kPa [45 psi] can be used.



NOTE: If the boost capsule diaphragm material is ruptured and will **not** hold air pressure, it may be required to manually pull the control rod outward in order to overcome boost capsule spring-tension for removal of the control rod from the turbocharger wastegate lever pin while applying air pressure.

Disconnect the control rod from the turbocharger wastegate lever pin.

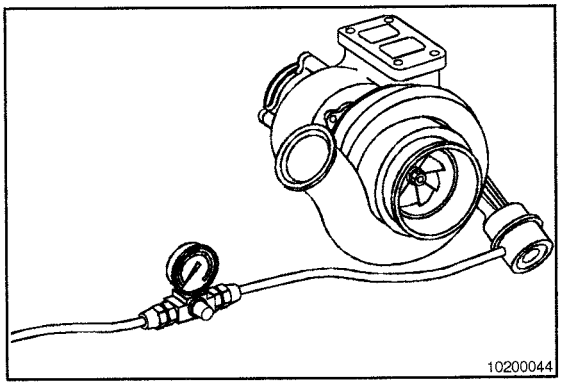
Loosen the boost capsule mounting capscrews, disconnect the wastegate actuator hose, and remove assembly from the mounting bracket.



Test (010-050-012)

In most applications, the turbocharger **must** be removed in order to test the wastegate actuator. Refer to OFF engine test.

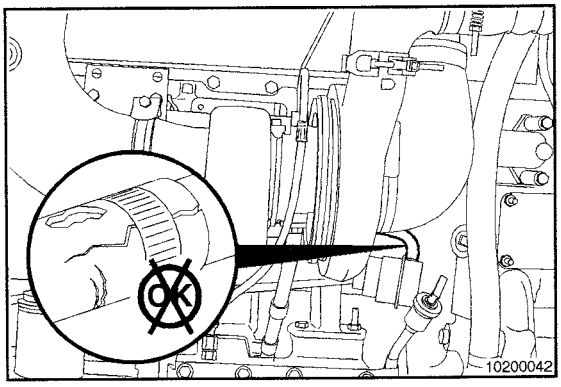
In some cases it may be possible to test the capsule while the tubocharger is installed on the engine. Refer to ON engine test.



ON Engine Test

NOTE: A new hose clamp, Part No. 3914419, will be required to reinstall the signal line.

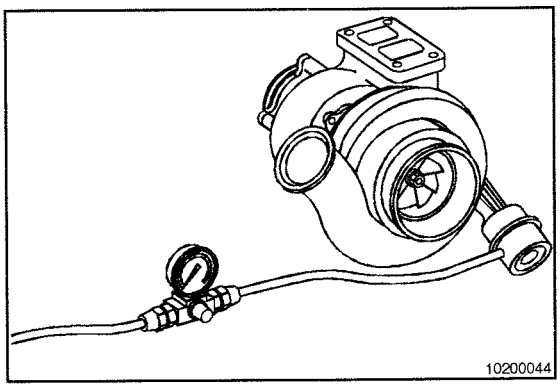
Disconnect the actuator hose form the wastegate actuator by cutting the crimped hose clamp.

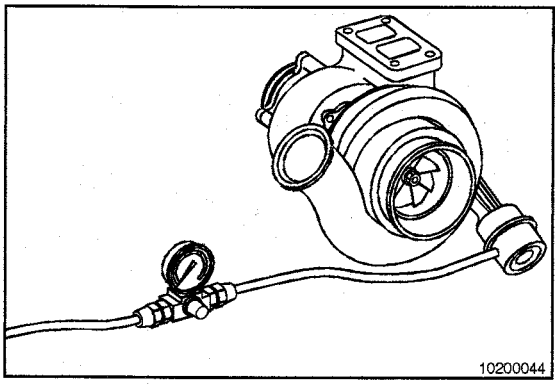


NOTE: No air should be heard (i.e., leaking noise) through a functional wastegate capsule.

Connect clean regulated air pressure and a pressure gauge to the actuator.

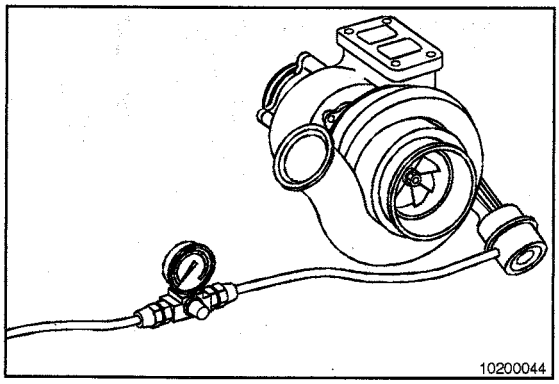
Apply a maximum of 310 kPa [45 psi] to make sure the wastegate is functioning properly.





The actuator rod should extend appoximately 0.05 in when 45 psi air pressure is applied.

If less than 0.05 in or no movement of the actuator rod and lever is detected, remove the turbocharger from the engine and perform the off engine test.



NOTE: No air should be heard (i.e., leaking noise) through a functional wastegate capsule.

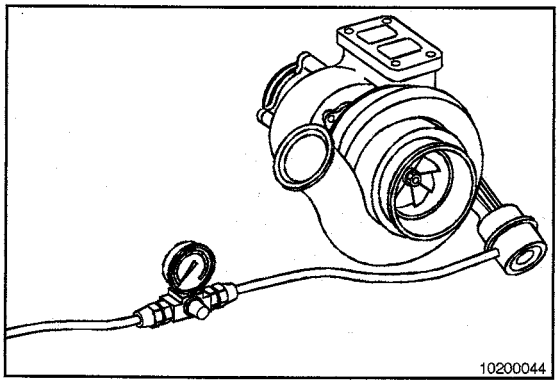
Refer to Procedure 010-033 for turbocharger removal.

OFF engine test

Connect clean, regulated air pressure and a pressure gauge to the actuator.

Apply a maximum of 310 kPa [45 psi] to make sure the wastegate is functioning properly.

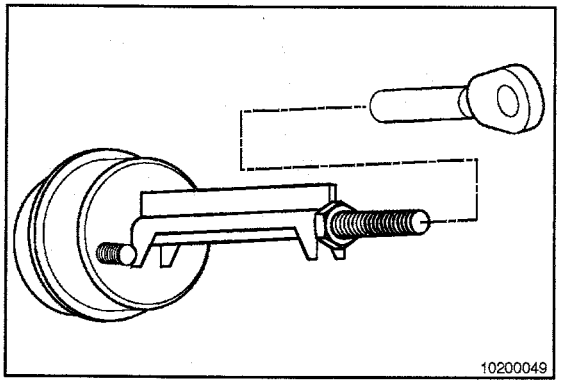
The actuator should extend approximately 0.05 in when 45 psi air pressure is applied.



If less than 0.05 in or no movement of the actuator rod and lever is detected, remove the actuator rod from the pin. Refer to Procedure 010-050.

Actuate the wastegate lever by hand.

If the lever moves, replace the actuator, if the lever does **not** move, replace the turbocharger.

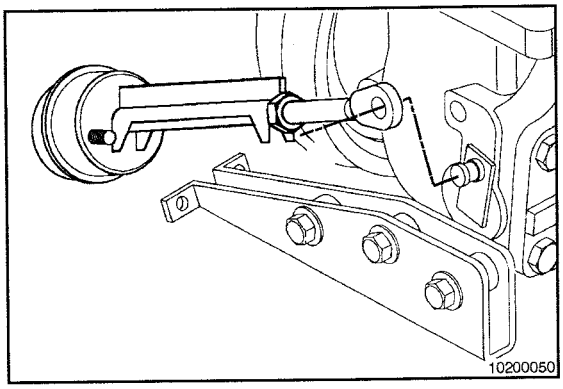


Install (010-050-026)

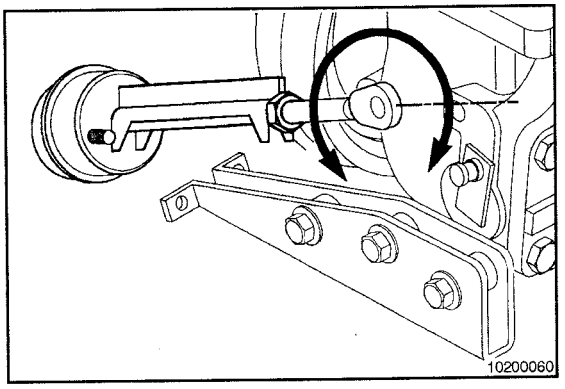
If a new actuator is being installed, install the adjusting end-link onto the shaft of the precalibrated wastegate actuator assembly.

Fit end-link over turbocharger wastegate lever pin. With spine of spacer visible and turbocharger wastegate lever pushed toward the rod, lay the actuator alongside the mounting bracket.

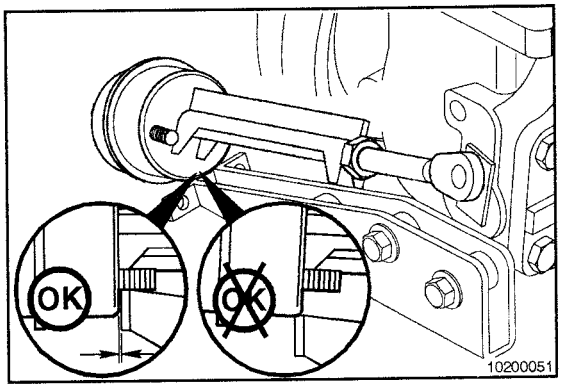
NOTE: Do **not** fit the two studs into the mounting holes at this time.



Adjust the length of the actuator assembly by rotating the end-link, and re-fitting until the underside of the actuator will just fit over the mounting bracket.



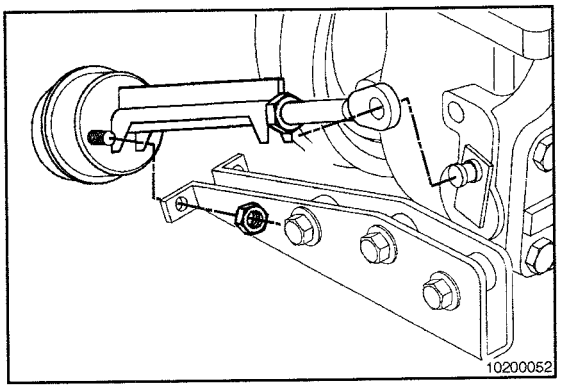
NOTE: The setting is correct when the underside of the actuator will just fit over the mounting bracket with less than 0.20-in (0.5-mm) gap.

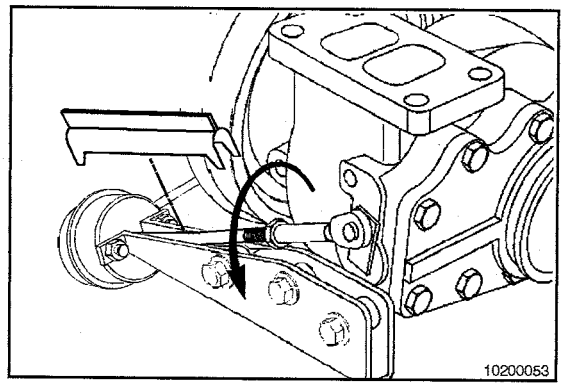


Fit the actuator mounting studs into the holes in the bracket, and install both actuator mounting capscrews.

Refit end-link onto the wastegate lever pin. Install the control rod retaining clip.

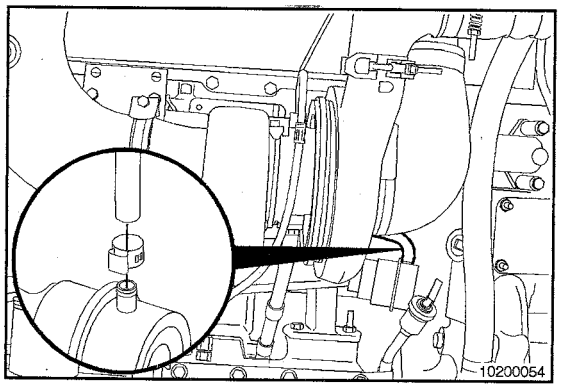
Torque Value: 8.5 N•m [75 in-lb]





Snug the control rod jam nut against the end-link. Cut the tie wrap, remove and discard tie wrap and spacer piece. Continue turning jam nut in the same direction, and tighten against end-link.

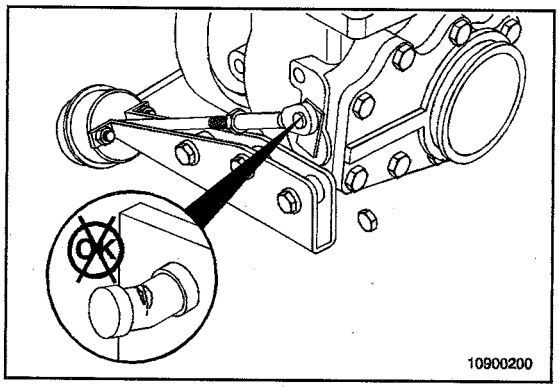
Torque Value: 8.5 N•m [75 in-lb]



NOTE: The hose clamp will need to be crimped for proper installation.

NOTE: New hose clamps are **not** included in new actuator kits.

Refit the wastegate actuator hose to the actuator using a new hose clamp, Part No. 3914419.



Turbocharger Wastegate Valve Body (010-055)

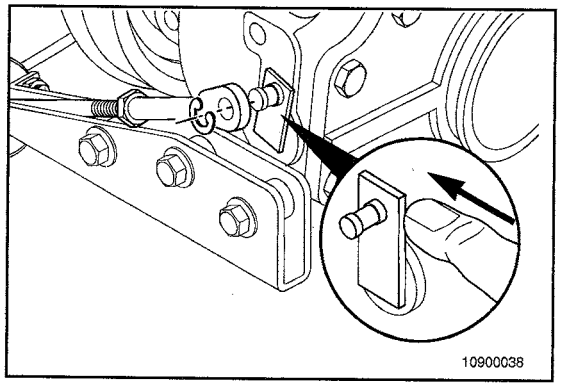
Maintenance Check (010-055-008)

NOTE: The wastegate actuator end-link must be removed to inspect the turbocharger wastegate. Refer to procedure 010-050.

Inspect the lever pin.

If the lever pin is worn excessively, replace the turbocharger.

Refer to the Turbocharger Master Repair Manual, Bulletin No. 3380555.



Actuate the lever by hand to verify that the shaft rotates freely and is **not** seized.

Check for excessive movement between the shaft and bushing.

Replace the turbine housing if the shaft and bushing are damaged or seized.

Maximum allowable clearance is 0.003-in. If the clearance is determined to be above the maximum allowable, replace the turbocharger.

Refer to the Turbocharger Master Repair Manual, Bulletin No. 3380555.

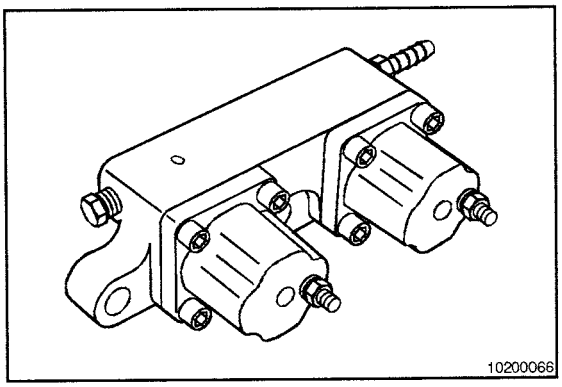
Turbocharger Wastegate Controller (010-109)

Remove (010-109-002)

Remove the electrical leads of each coil of the wastegate controller.

Remove the wastegate actuator hose from the wastegate controller.

Remove the wastegate controller capscrews.



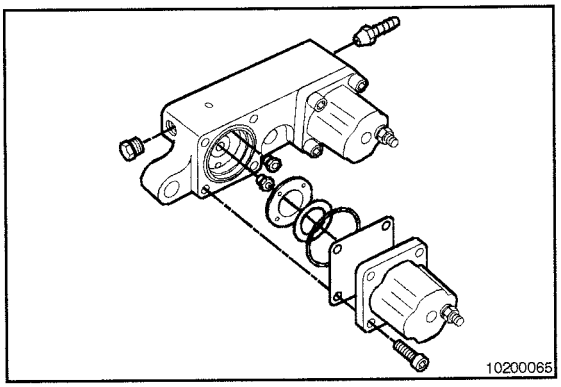
Disassemble (010-109-003)

Remove the rectangular ring seal from the intake manifold inlet of the wastegate controller.

Remove the four capscrews for the coil.

Remove the coil and shutoff valve shield.

Remove the valve spring, valve disc, and rectangular ring seal from the controller housing.



Inspect for Reuse (010-109-007)

⚠ CAUTION ⚠

Controller orifices can not be removed from the controller housing.

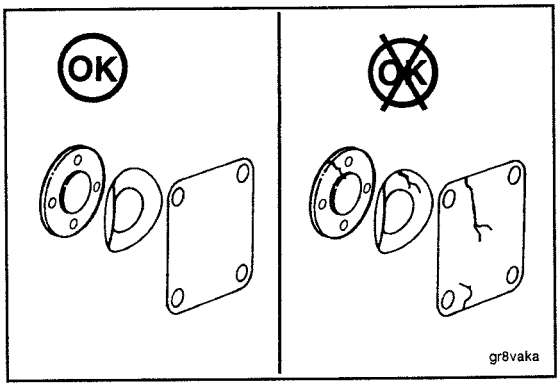
Check for plugged orifices in the controller housing. All of the parts **except** the coil assembly can be cleaned using mineral spirits.

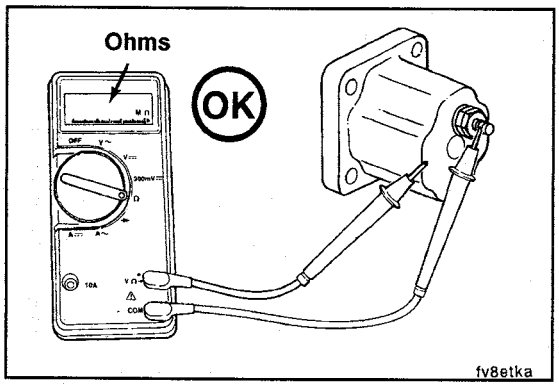
NOTE: Do **not** get solvent on the coil. Clean the coil with a dry cloth. Use a 200 grit emery cloth and a flat surface to polish the coil surface.

NOTE: A wire brush can **only** be used on the coil terminal.

Visually check the valve disc, valve spring, and shutoff valve shield for dirt, metal parts, bonding separation, corrosion, cracks, or wear. Replace if necessary.

Use a wire brush to clean any corrosion from the coil terminal.





Check the coil assembly with a multimeter.

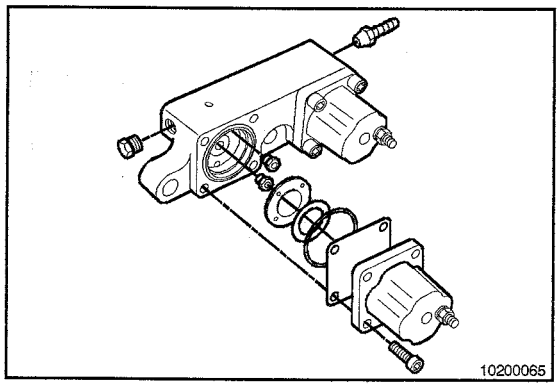
Replace the coil if **not** within specifications.

NOTE: If the coil assembly shows zero ohms, there is an electrical short in the coil.

24 VDC solenoid	26-40 Ohms	-18°C to 100°C [0°F to 212°F]
12 VDC solenoid	6-10 Ohms	-18°C to 100°C [0°F to 212°F]

Tighten the nut that holds the electrical connection post on the coil.

Torque Value: 1.695 N•m [15 in-lb]

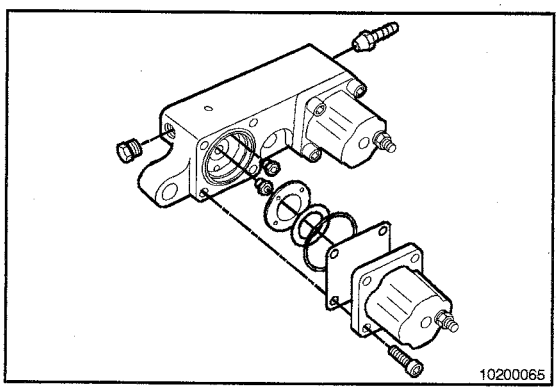


Install (010-109-026)

Assemble the valve as shown.

Install these parts as follows:

- Install a new rectangular ring seal in the controller housing.
- Install the valve disk with the rubber bulls-eye side down
- Install the valve spring on the valve disc with the cavity side positioned upward.

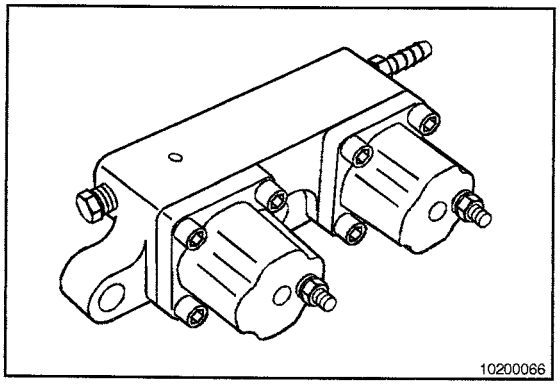


NOTE: The coil **must** be orientated with the electrical connection post at the three o'clock position, when the controller is installed on the engine.

NOTE: Make sure the coil is the correct voltage. The coil voltage and part number are cast into the terminal connection end of the coil.

- Install the shutoff shield and coil on the control valve body.
- Tighten the capscrews.

Torque Value: 8 N•m [72 in-lb]



- Install a new rectangular ring seal around the intake manifold connection of the wastegate controller.
- Place the wastegate controller on the intake manifold and tighten the capscrews.

Torque Value: 47 N•m [35 ft-lb]

- Refit the wastegate actuator hose to the wastegate controller.
- Install the electrical connections on the coils.
- Install the nut on the threaded post of the coils.
- Use two wrenches to hold the post of the nut firmly while tightening the connection nut.

Torque Value: 1.695 N•m [15 in-lb]

Section 11 - Exhaust System - Group 11

Section Contents

Page

Exhaust Manifold, Dry 11-5
Assemble 11-6
Clean 11-5
Disassemble 11-5
Inspect for Reuse 11-6
Install 11-6
Remove 11-5

Exhaust Restriction 11-7
Measure 11-7

Exhaust System - General Information 11-1
General Information 11-1

Flow Diagram, Exhaust System 11-3
Flow Diagram 11-3

Specifications 11-4
Exhaust System 11-4

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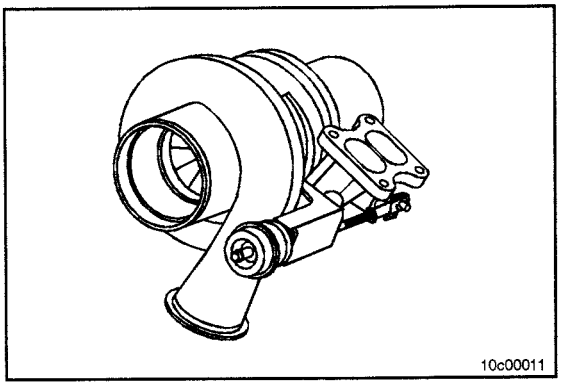
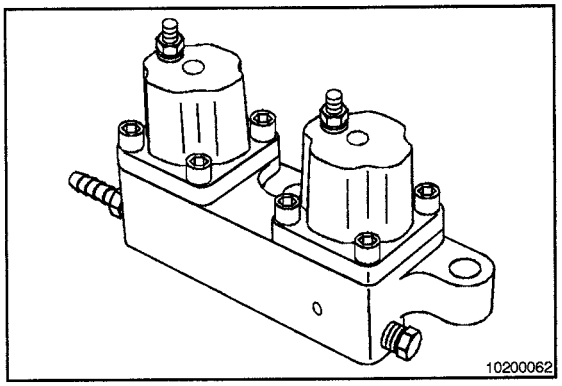
Exhaust System - General Information

General Information

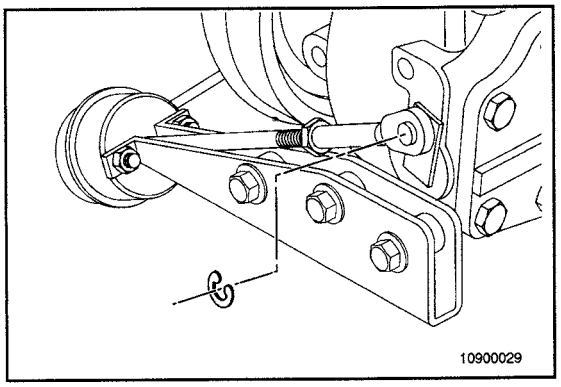
The wastegated turbocharger is a Holset model HX55. It is comprised of a turbocharger, wastegate actuator, and wastegate valve in the turbine housing. A wastegated turbocharger provides improved response at low engine speeds without sacrificing turbocharger durability at high speeds. This is accomplished by allowing exhaust gases to bypass the turbine wheel during certain modes of engine operation. During low rpm operation, the turbocharger operates as a closed-system turbocharger where the gases' energy is transferred to the compressor wheel and used to compress intake air. During high rpm operation however, the turbocharger becomes an open-system turbocharger and allows exhaust gas to bypass the turbine. Since exhaust gas is gated around the turbine wheel, less energy is absorbed through the turbine and transferred to the compressor, reducing intake manifold pressures and turbine speeds.

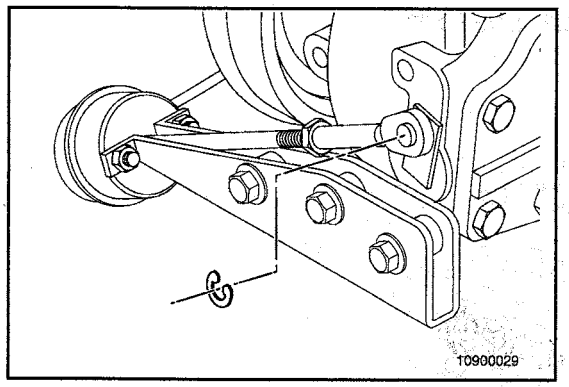


The wastegate controller in mounted on the rear of the intake manifold on the turbocharger side of the engine and is controlled by the ECM. The wastegate controller regulates the percentage of the intake manifold pressures sent to the wastegate actuator. Two solenoids, similar to the fuel pump shutoff valves of the Celect™ product, are used in conjunction with four orifices to regulate this percentage.



The wastegate actuator is mounted on the turbocharger and consists of a pressure canister, diaphragm, and rod. As pressure changes in the canister, as dictated by the wastegate controller, the actuator rod adjusts the wastegate valve accordingly.

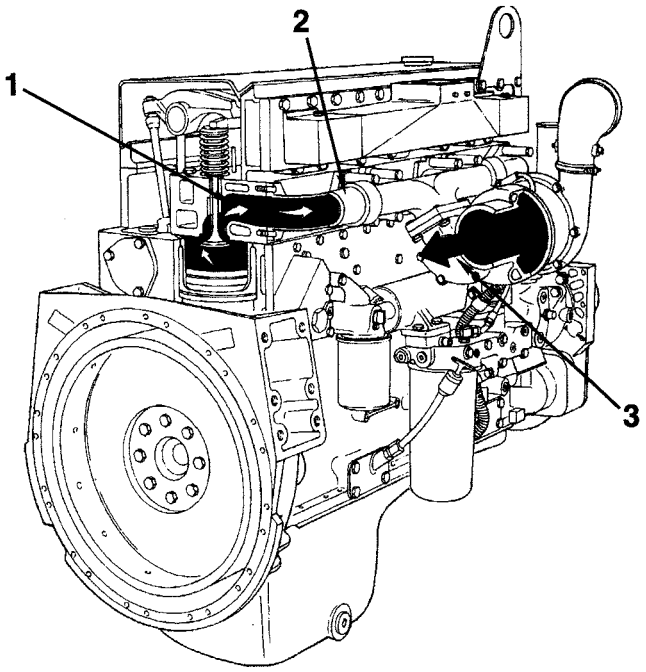




The wastegate valve is mounted inside the turbocharger in the turbine housing. As the valve opens, exhaust gas is allowed to bypass the turbine wheel, lowering turbine speed to adjust intake manifold pressure.

Flow Diagram, Exhaust System

Flow Diagram



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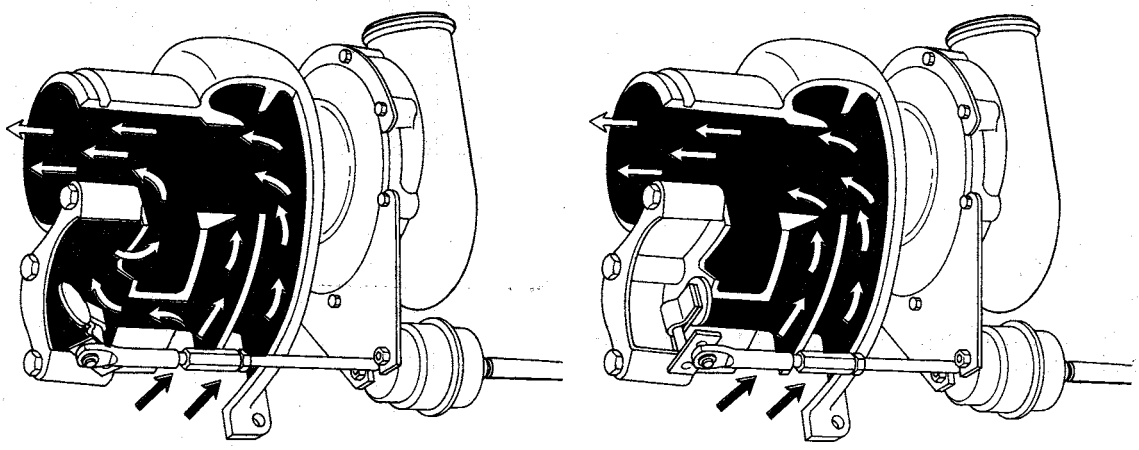
1. Exhaust Valve Ports
2. Exhaust Manifold
3. Turbocharged Exhaust Outlet.

Wastegate Actuation



12200016

Wastegate OPEN **Wastegate CLOSED**

Specifications

Exhaust System

Maximum Back Pressure From Piping and Silencer (combined):
- Without Catalyst
  - Hg ..... 76 mm [3 in]
  - H_2O ..... 1016 mm [40 in]
- With Catalyst
  - Hg ..... 152 mm [6 in]
  - H_2O ..... 2082 mm [82 in]

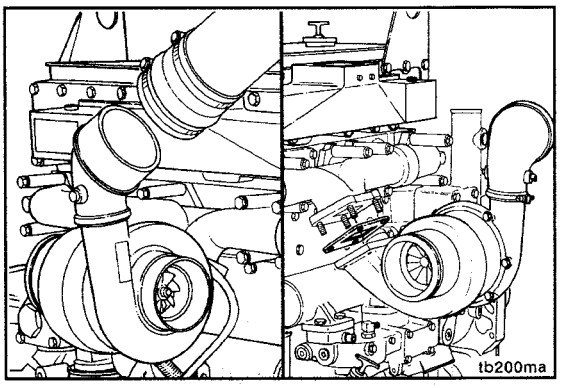
Exhaust Pipe Size (normally acceptable inside diameter) ..... 127 mm [5 in]

Exhaust Manifold, Dry (011-007)

Remove (011-007-002)

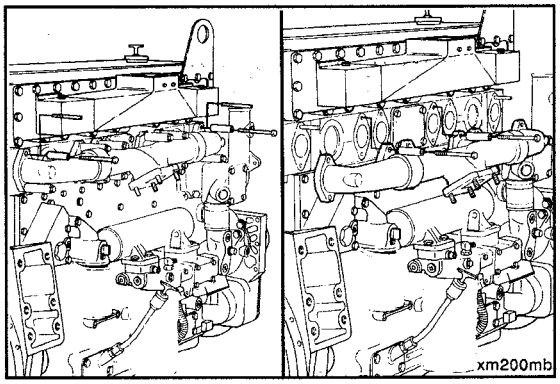
Remove the air piping from the turbocharger.

Remove the turbocharger. Refer to Procedure 010-033.



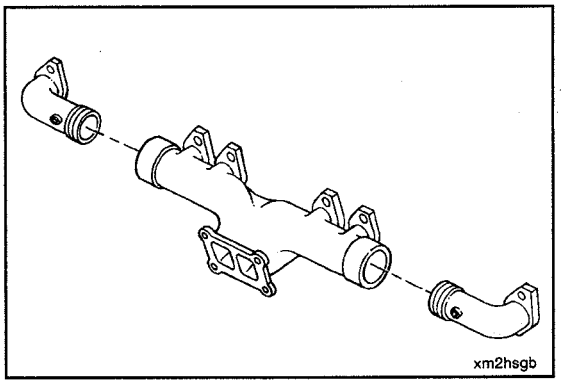
Remove two upper capscrews from the end sections of the exhaust manifold and install two guide studs, Part No. 3376488.

Remove the remaining capscrews, exhaust manifold assembly and gaskets.



Disassemble (011-007-003)

Remove the exhaust manifold end sections.



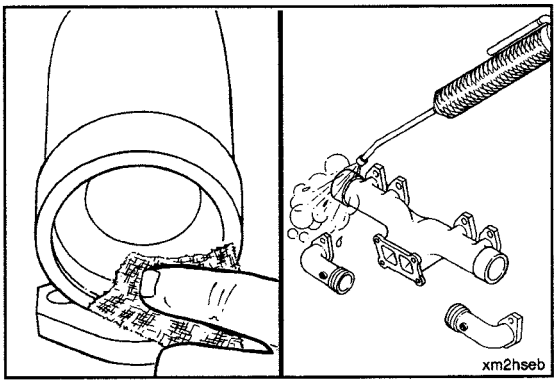
Clean (011-007-006)

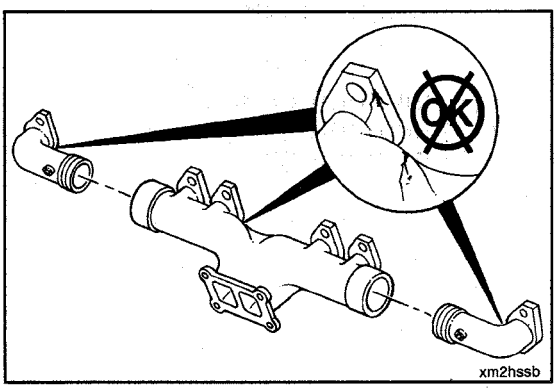
⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

Use 240-grit emery cloth to remove carbon deposits from the sealing surfaces.

Use steam to clean the exhaust manifold. Dry with compressed air.

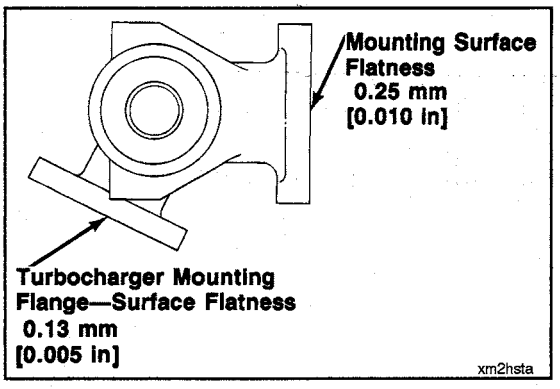




Inspect for Reuse (011-007-007)

Inspect the parts for cracks or damage.

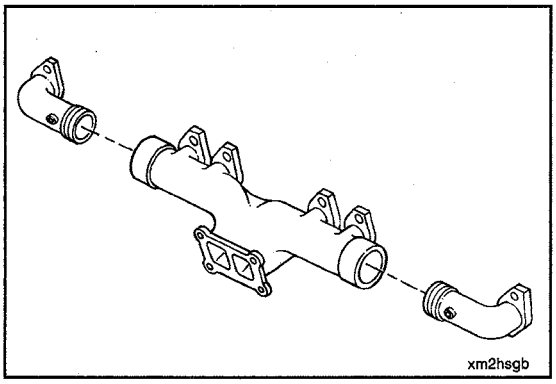
NOTE: A charge air cooler failure can cause progressive damage to the exhaust manifold. If the exhaust manifold is damaged, check the charge air cooler. Refer to Procedure 010-027.



Inspect the mounting surfaces for flatness.

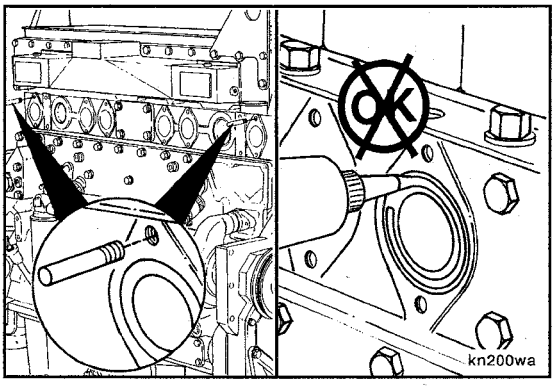
The exhaust manifold mounting surface **must** be flat to within 0.25 mm [0.010 in]. The turbocharger mounting flange **must** have a surface flatness of 0.13 mm [0.005 in].

If these surfaces are **not** within the flatness specifications, refer to L10 Alternative Repair Manual, Bulletin No. 3810310.



Assemble (011-007-025)

Install the exhaust manifold end sections to the center section.



Install (011-007-026)

Install two guide studs, Part No. 3376488, in the two top end holes of the cylinder head exhaust ports.

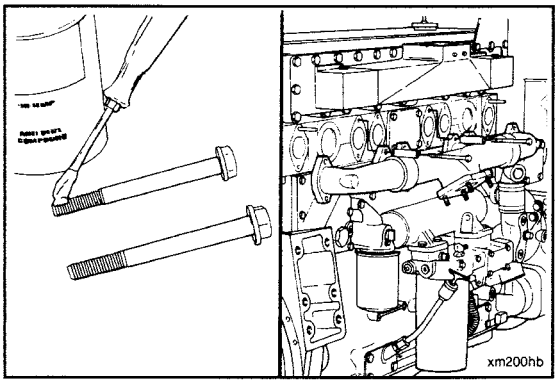
Install a new gasket over each guide stud.

Do **not** use any kind of adhesive to hold the gaskets.

To aid in future capscrew removal, apply a coating of high temperature antiseize compound to the capscrew threads.

Install the exhaust manifold, tubular spacers, and capscrews.

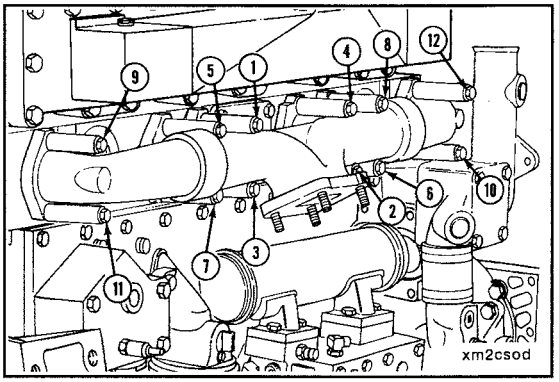
NOTE: The exhaust manifold can be titled back enough to install a new gasket on each exhaust port as the capscrews are being installed.



Tighten the capscrews in the sequence shown.

NOTE: The torque values given have been established using antiseize compound as a lubricant.

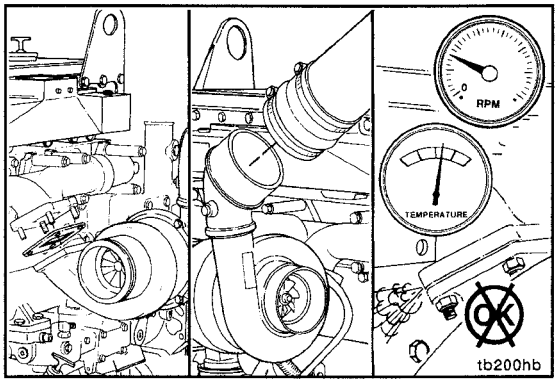
Torque Value: Step 1 27 N•m [20 ft-lb]
2 47 N•m [35 ft-lb]



Install the turbocharger. Refer to Procedure 010-033.

Install the air piping to the turbocharger. Refer to the manufacturer's specifications for the correct torque value.

Operate the engine to check for leaks.

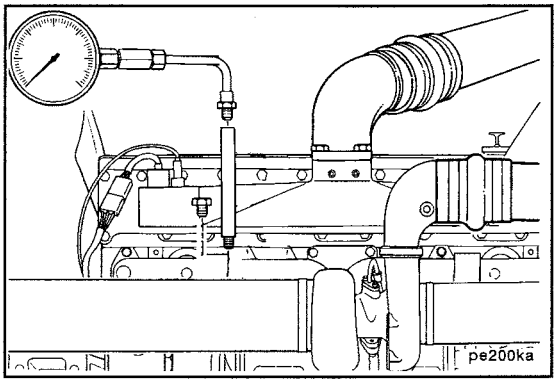


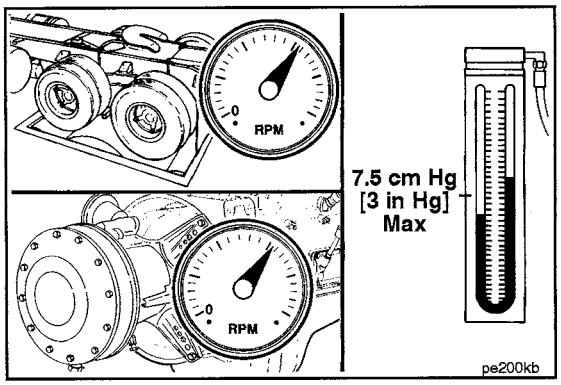
Exhaust Restriction (011-009)

Measure (011-009-010)

Connect a manometer or pressure gauge, Part No. ST-1273, in a straight section of the exhaust pipe located one pipe diameter from the turbine outlet.

Protect the hose from heat by using a 305 mm [12 in] minimum length of metal tubing leading from the exhaust pipe connection.

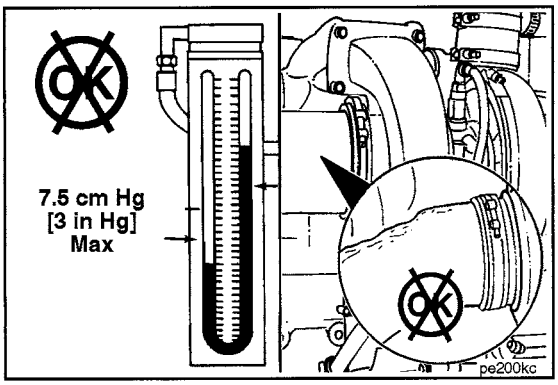




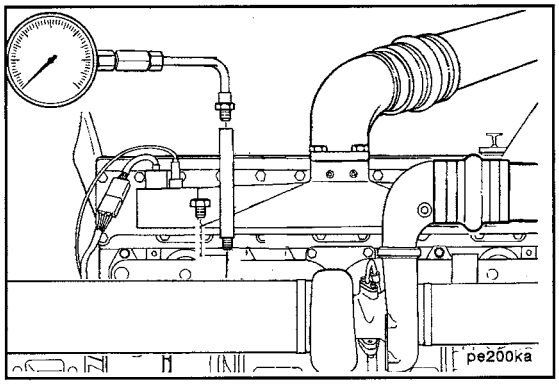
Operate the engine at rated rpm and load. Record the reading on the manometer.

Exhaust Restriction (Without Catalyst)			
	mm		in
Hg	75	MAX	3
H_2O	1016	MAX	40

Exhaust Restriction (With Catalyst)			
	mm		in
Hg	152	MAX	6
H_2O	2082	MAX	82



If exhaust pressure exceeds the specifications, inspect the exhaust piping for damage. Refer to the OEM repair instructions.



Remove the test equipment.

Section 12 - Compressed Air System - Group 12

Section Contents

Page

Air Compressor 12-23
Inspect for Reuse 12-25
Install 12-25
Remove 12-23

Air Compressor Carbon Buildup 12-11
Initial Check 12-11

Air Compressor Pin Bore Wear 12-16
Initial Check 12-16

Air Compressor Unloader and Valve Assembly 12-19
Clean 12-21
Initial Check 12-19
Inspect for Reuse 12-21
Install 12-21
Remove 12-20

Air Governor (Air Compressor Pumps Continuously) 12-28
Initial Check 12-28

Air Governor (Air Compressor Will Not Pump) 12-27
Initial Check 12-27

Air Leaks, Compressed Air System 12-30
Initial Check 12-30

Compressed Air System - General Information 12-1
General Information 12-1

Flow Diagram, Compressed Air System 12-3
Compressed Air System 12-3

Service Tools 12-9
Compressed Air System 12-9

Specifications 12-5
Compressed Air System 12-5
Cummins 18.7 CFM Model 12-5
Cummins 37.4 CFM Model 12-6
Holset® Compressor Spring Force Specifications 12-8
Holset® SS296/SS296E/QE296 A/C Models 12-5
Holset® SS338/QE338 A/C Models 12-6
Holset® ST676 A/C Model 12-7

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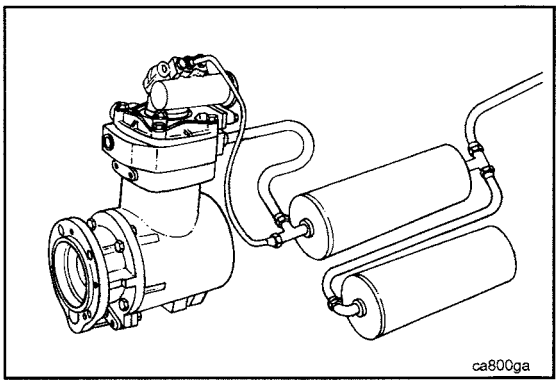
Compressed Air System - General Information

General Information

The compressed air system normally consists of a gear-driven air compressor, an air governor, air tanks and all necessary plumbing.

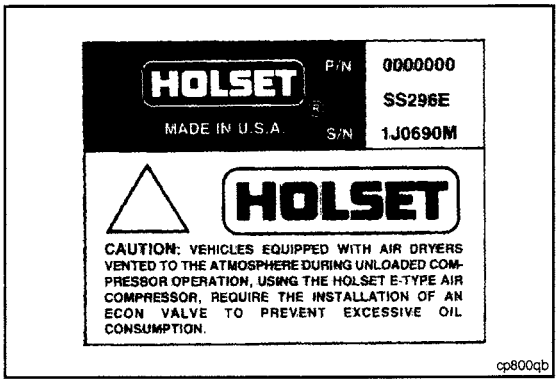
The Holset and Cummins single and two cylinder air compressors are engine-driven, piston-type compressors which supply compressed air to operate air activated devices. The compressor runs continuously, but has a loaded and unloaded operating mode.


ca800ga

E-Type Air Compressor

Holset SS and ST model air compressors built with the E-Type unloader can be identified by the letter "E" (SS296E, SS338E, ST676E, and ST773E), and by the caution on the data plate.

All QE (QE296 and QE338) model air compressors are equipped with the E-Type unloader.

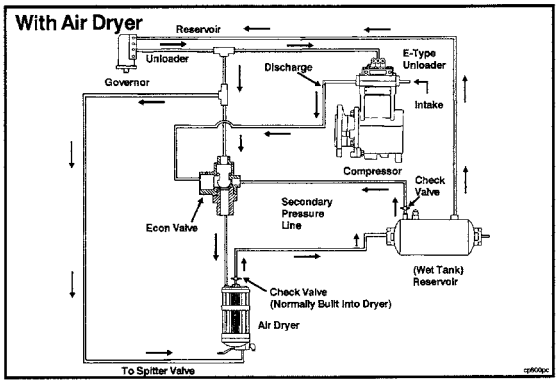


cp800qb

E-Type System With Air Dryer

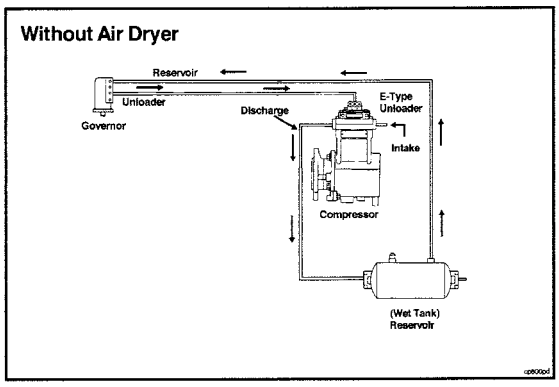
Vehicles equipped with air dryers vented to the atmosphere during unloaded compressor operation, using the Holset E-Type air compressor, require the installation of an econ valve to prevent excessive oil consumption.

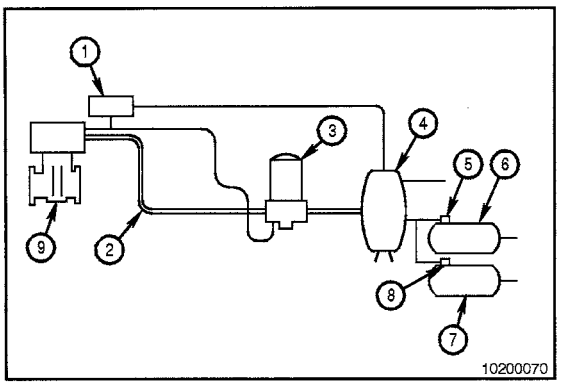
NOTE: Some air dryers can have a built-in econ valve. Check with the manufacturer as to which type is installed.



E-Type System Without Air Dryer

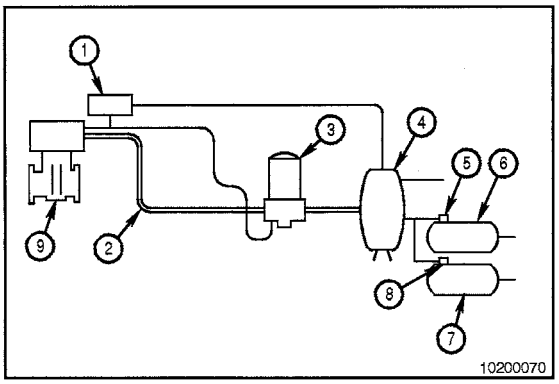
Air systems **without** air dryers, or with air dryers **not** vented to the atmosphere during unloaded compressor operation, can use the Holset E-Type unloader valve without modifying the air system.





Cummins Single Cylinder Air System

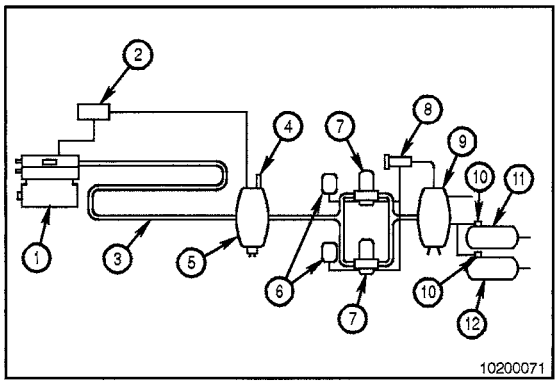
1. Air Governor
2. Discharge Line
3. Air Dryer
4. Supply Tank
5. Check Valve
6. Primary Tank
7. Secondary Tank
8. Check Valve
9. Air Compressor



Holset Single Cylinder Air System QE and SS-E-Type

1. Air Governor
2. Discharge Line
3. Air Dryer*
4. Supply Tank
5. Check Valve
6. Primary Tank
7. Secondary Tank
8. Check Valve
9. Air Compressor

NOTE: * Any dryer that will maintain air pressure in the discharge line when the compressor is in the unloaded mode can be used.



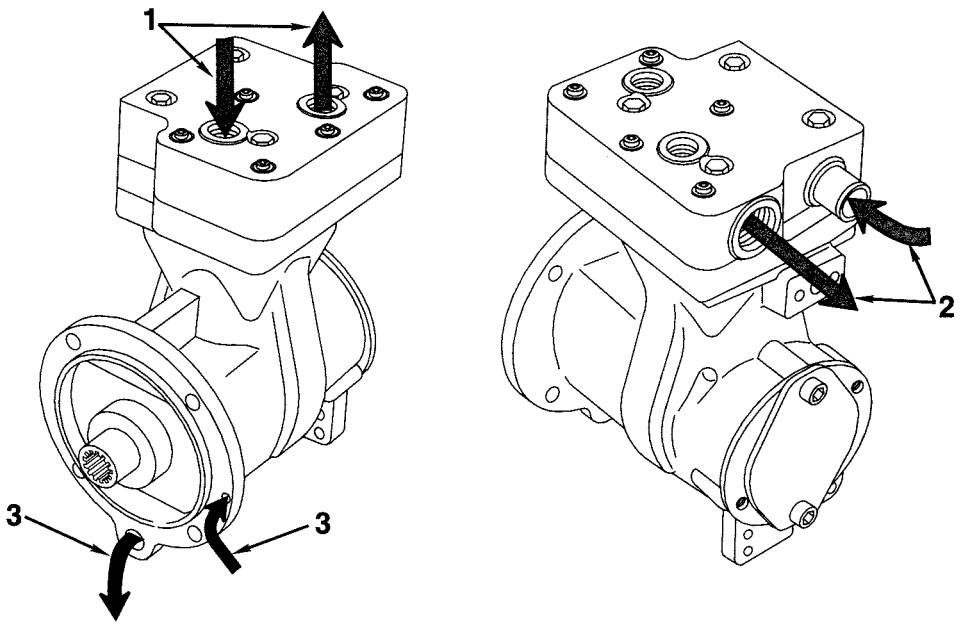
Typical Twin Cylinder Air System

1. Air Compressor
2. Air Governor
3. Discharge Line
4. Safety Valve
5. Supply Tank
6. Purge Tank
7. Air Dryer
8. Air Governor
9. Supply Tank
10. Check Valve
11. Primary Tank
12. Secondary Tank

Flow Diagram, Compressed Air System

Compressed Air System

Cummins



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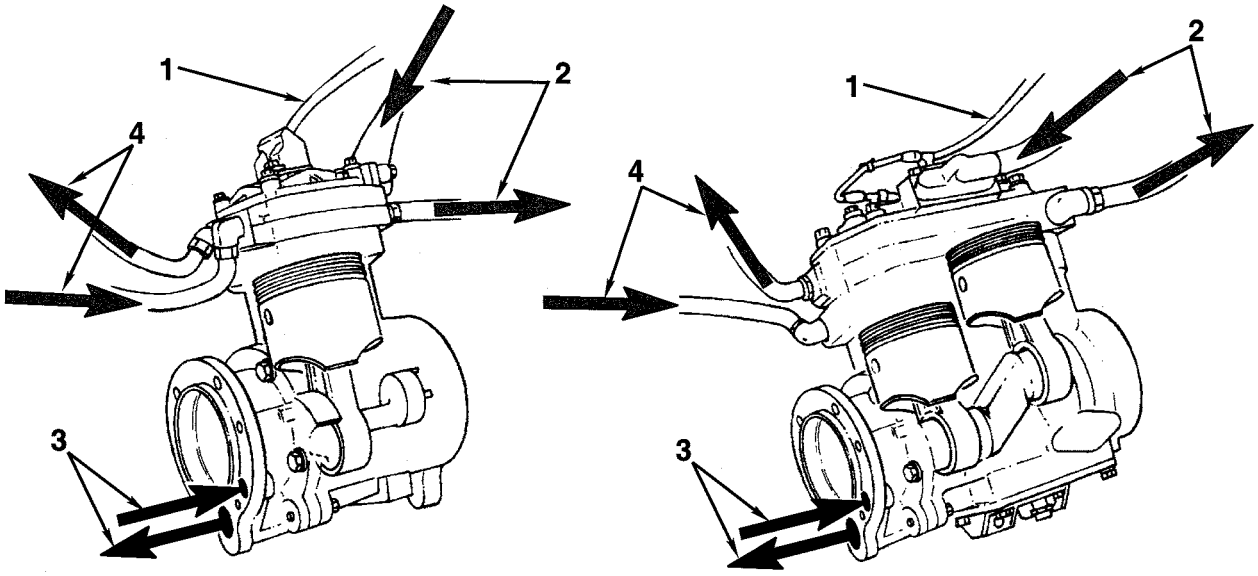
1. Coolant
2. Air
3. Lubricant

Holset



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1. Air Governor Signal
2. Air
3. Lubricant
4. Coolant

Specifications

Compressed Air System

Cummins 18.7 CFM Model

Cylinders 1

Compressor Swept Volume @ 1250 RPM ..... 6.6 L/sec. [14.0 CFM]

Piston Displacement ..... 318 cc [19.405 C.I.D.]

Bore ..... 85 mm [3.346 in]

Stroke ..... 56 mm [2.204 in]

Speed ..... Engine Speed

Cooling ..... Engine Coolant

Lubrication ..... Engine Lubricating Oil

Plumbing Line Sizes:
- Coolant Inlet and Outlet ..... 3/4 x 16 STOR
- Air Inlet ..... 1-in Nominal Hose
- Air Outlet ..... M27 x 2 STOR
- Unloader Port ..... M10 x 1 STOR
- Governor Mounting Direct ..... M8 x 1.25

Height, Overall (Approximate) ..... 217.4 mm [8.559 in]

Width, Overall (Approximate) ..... 142 mm [5.590 in]

Length, Overall (Approximate) ..... 216 mm [8.503 in]

Weight (Approximate) ..... 15 Kg [35.0 lbs]

Holset® SS296/SS296E/QE296 A/C Models

Cylinders 1

Compressor Swept Volume @ 1250 RPM ..... 6.2 L/sec. [13.20 CFM]

Piston Displacement ..... 296 cc [18.06 C.I.D.]

Bore ..... 92.08 mm [3.625 in.]

Stroke ..... 44.45 mm [1.750 in.]

Speed ..... Engine Speed

Cooling ..... Engine Coolant

Lubrication ..... Engine Lubricating Oil

Plumbing Line Sizes
- Coolant Inlet and Outlet (Pipe Fitting) ..... 0.375 in. NPTF
- Air Inlet (Inside Diameter) ..... 22.22 mm [0.875 in.]
- Air Outlet (Minimum Inside Diameter) ..... 12.7 mm [0.50 in.]

Height, Overall (Approximate) ..... 31.1 cm [12.25 in.]

Width, Overall (Approximate) ..... 14.6 cm [5.75 in.]

Length, Overall (Approximate) ..... 22.9 cm [9.00 in.]

Weight (Approximate) ..... 18 kg [40.0 lbs]

Holset® SS338/QE338 A/C Models

Cylinders 1

Compressor Swept Volume @ 1250 RPM ..... 7.1 L per sec. [15.0 CFM]

Piston Displacement ..... 338 cc [20.63 C.I.D.]

Bore ..... 98.4 mm [3.875 in]

Stroke ..... 44.5 mm [1.75 in]

Speed ..... Engine Speed

Cooling ..... Engine Coolant

Lubrication ..... Engine Lubricating Oil

Plumbing Line Sizes:
- Coolant Inlet and Outlet (Pipe Fitting) ..... 0.375 in NPTF
- Air Inlet ..... 22.22 mm [0.875 in]
- Air Outlet ..... 12.7 mm [0.50 in]

Height, Overall (Approximate) ..... 31.1 cm [12.25 in]

Width, Overall (Approximate) ..... 14.6 cm [5.75 in]

Length, Overall (Approximate) ..... 22.9 cm [9.00 in]

Weight (Approximate) ..... 18 Kg [40.0 lbs]

Cummins 37.4 CFM Model

Cylinders 2

Compressor Swept Volume @ 1250 RPM ..... 15.5 L/sec. [35.5 CFM]

Piston Displacement ..... 636 cc [39 C.I.D.]

Bore ..... 85 mm [3.35 inch]

Stroke ..... 56 mm [2.2 inch]

Speed ..... Engine Speed

Cooling ..... Engine Coolant

Lubrication ..... Engine Oil

Plumbing Line Sizes:
- APEX ..... M18 x 1.5
- Coolant Inlet and Outlet ..... 3/4 x 16 STOR
- Air Inlet ..... 1-in Nominal Hose
- Air Outlet ..... M27 x 2 STOR
- Unloader Port ..... M10 x 1 STOR
- Governor Mounting Direct ..... M8 x 1.25

Height, Overall (Approximate) ..... 306 mm [12 inch]

Width, Overall (Approximate) ..... 142 mm [5.6 inch]

Length, Overall (Approximate) ..... 286.7 mm [11.29 inch]

Weight (Approximate) ..... 17.24 kg [38 lbs]

Holset® ST676 A/C Model

Cylinders	2
Compressor Swept Volume @ 1250 RPM	14.2 L per sec. [30.00 CFM]
Piston Displacement	676 cc [41.3 C.I.D.]
Bore	92.08 mm [3.625 in.]
Stroke	50.8 mm [2.00 in.]
Speed	Engine Speed
Cooling	Engine Coolant
Lubrication	Engine Lubricating Oil
Coolant Inlet and Outlet (Pipe Fitting)	0.50 in. NPTF
Air Inlet (Inside Diameter)	22.22 mm [0.875 in.]
Air Outlet (Minimum Inside Diameter)	15.88 mm [0.625 in.]
Height, Overall (Approximate)	34.3 cm [13.50 in.]
Width, Overall (Approximate)	17.8 cm [7.00 in.]
Length, Overall (Approximate)	28.7 cm [11.30 in.]
Weight (Approximate)	33.5 kg [74.50 lbs.]

NOTE: In applications where duty cycles average 10 percent or more, or air pressures are above 862 kPa [125 psi]; use a discharge line with a minimum inside diameter of 15.9 mm [0.625 in] for single cylinder compressors and 25.4 mm [1.00 in] for twin cylinder compressors to prevent carbon buildup. Examples of these applications are as follows: refuse trucks, pickup and delivery trucks, transit buses and equipment with high accessory air usage.

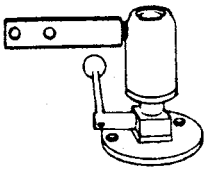
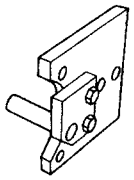
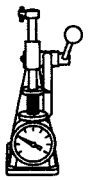
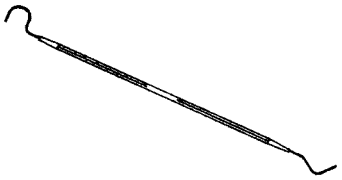
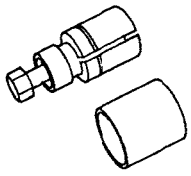
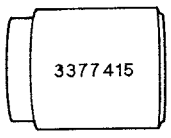
Holset® Compressor Spring Force Specifications

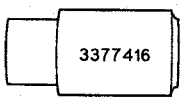
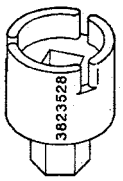
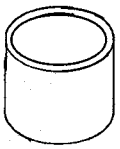
						Load Required to Compress Spring to Measurement Length	
Spring Part No.	Spring Use	Approx. Free Length mm [inch]	Number of Coils	Wire Diameter mm [inch]	Measurement Length mm [inch]	Minimum kg [lb]	Maximum kg [lb]
128080	Exhaust Valve	17.02 [0.670]	3.0	2.03 [0.080]	7.11 [0.280]	3.6 [8.55]	4.7 [10.35
190334	Intake Valve	12.70 [0.500]	2.8	1.58 [0.062]	7.11 [0.280]	0.35 [0.65]	0.5 [1.10
150631	Unloading Valve (naturally aspirated) center unloading valve - twin	41.91 [1.650]	11.5	2.03 0.080	24.89 [0.980]	14.5 [32.00]	17.2 [38.00]
3023101	Unloading Valve (all turbocharged engines)	41.91 [1.650]	10.8	1.65 [0.065]	24.89 [0.980]	5.9 [13.00]	7.7 [17.00]
3049553	E-Type Unloader Valve	41.91 [1.650]	11.25	1.93 [0.076]	24.89 [0.980]	10.4 [23.00]	12.2 [27.00]
800399-XW	Unloader	17.02 [0.67]	6	1.04 [0.041]	6.60 [0.260]	N/A	2.54 [5.60]
					10.03 [3.95]	1.71 [3.78]	N/A
802000-FZ	Intake and Exhaust	10.16 [0.40]	4.25	0.79 [0.031]	4.57 [0.18]	N/A	0.36 [0.80]
					5.99 [0.275]	0.20 [0.45]	N/A
3054489	Exhaust Valve	21.49 [0.846]	4.5	2.54 [0.100]	15.21 [0.599]	3.88 [8.55]	4.74 [10.45]

Service Tools

Compressed Air System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

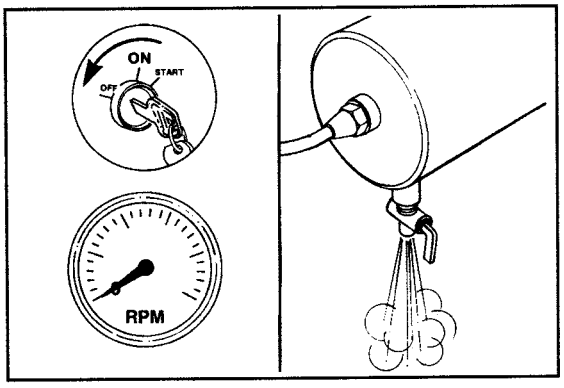
Tool No.	Tool Description	Tool Illustration
ST-302	**Ball Joint Vise** Use to hold the air compressor for disassembly or assembly.	
ST-749 or 3823597	**Mounting Plate** Use to mount the air compressor to the vise.	
3375182	**Valve Spring Tester** Use to check the exhaust valve, intake valve, and unloader valve cap springs.	
3376399	**O-Ring Pick** Use to remove and install o-rings.	
3376663	**Coupling Puller** Use to remove the spline coupling hub.	
3377415	**Air Compressor Seat Installation Tool** Use to install the exhaust valve seats.	

Tool No.	Tool Description	Tool Illustration
3377416	**Air Compressor Seat Removal Tool** Use to remove the exhaust valve seats.	 3377416
3823528	**Air Compressor Seat Socket** Use to remove the exhaust valve seat and the inlet valve cage.	 3823528
3823923	**Spacer** Use with coupling puller, Part No. 3376663, to remove the hydraulic pump drive coupling.	 3823923

Air Compressor Carbon Buildup (012-003)

Initial Check (012-003-001)

Holset®



⚠ WARNING ⚠

Compressed air can drive debris into eyes and ears. Keep head well away and wear protective eye wear.

NOTE: The illustrations shown will be of the SS model single cylinder air compressor. Differences in procedures for SS, QE and ST model Holset® air compressors will be shown where necessary.

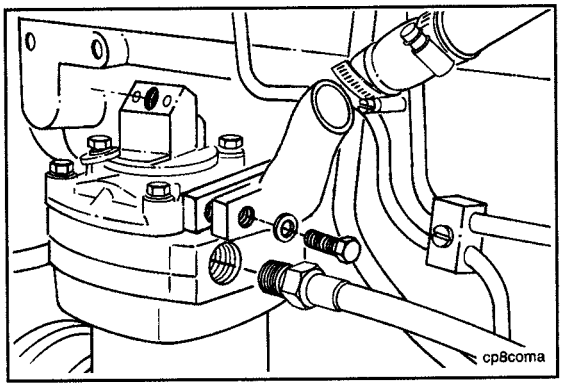
Shut off the engine.

Open the drain cock on the wet tank to release compressed air from the system.

⚠ WARNING ⚠

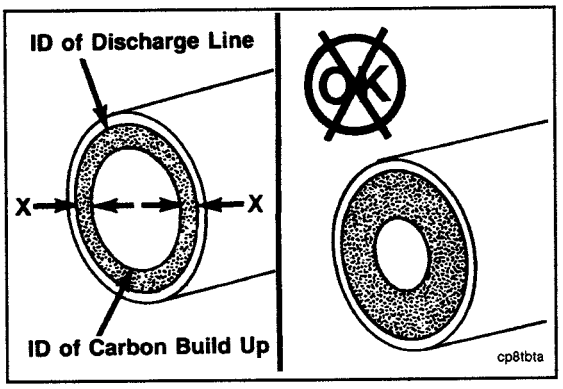
Air discharge lines can be very hot. Be sure the lines are cool before touching to prevent personal injury.

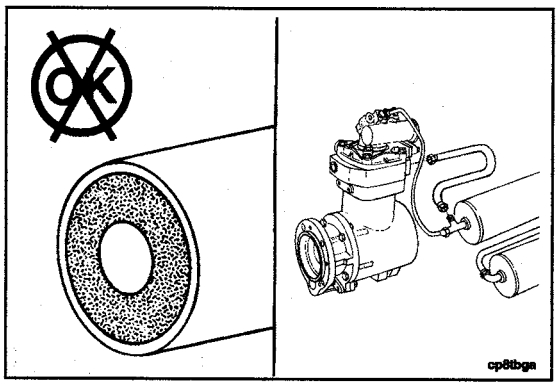
Remove the air inlet and outlet connections from the air compressor.



Measure the total carbon deposit thickness inside the air discharge line as shown.

NOTE: The carbon deposit thickness **must not** exceed 1.6 mm [0.06 (1/16)-inch].

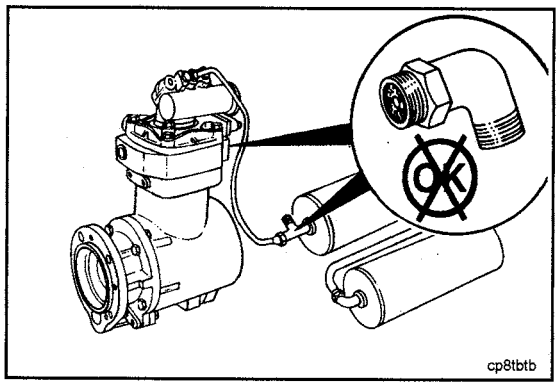




⚠ WARNING ⚠

The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the manufacturer's specifications.

NOTE: If the total carbon deposit thickness exceeds specification, remove and clean, or replace the air discharge line. Refer to the manufacturer's material specifications.

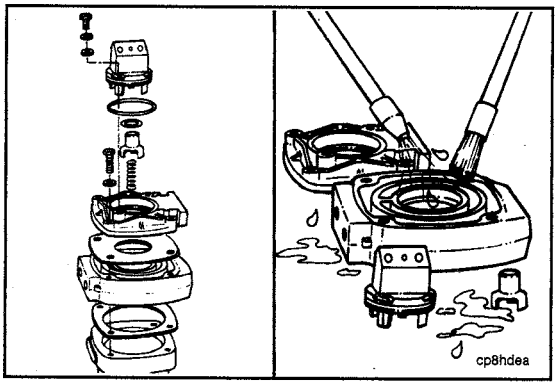


⚠ WARNING ⚠

The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the manufacturer's specifications.

Continue to check for carbon buildup in the air discharge line connections up to the first connection, or wet tank.

Clean or replace any lines and fittings with carbon deposits greater than 1.6 mm [0.06 (1/16)-inch]. Refer to the manufacturer's specifications for cleaning or replacement instructions.



△ CAUTION △

Do not use a sharp object to remove carbon. The sealing surfaces can be damaged.

Remove the air compressor head and valve assembly. Refer to the Holset® Air Compressor Master Repair Manual, Bulletin No. 3666121.

NOTE: Not all air compressors referenced may be used on your engine or application.

△ CAUTION △

Do not use caustic cleaners on aluminum parts.

Clean the compressor head and valve assembly components with solvent and a nonmetallic brush to remove carbon.

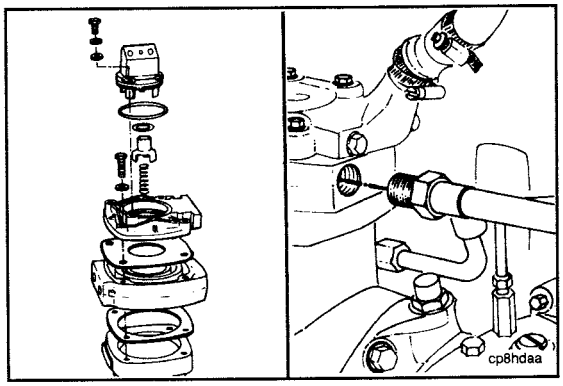
Inspect the valve assembly components for reuse. Refer to the Holset® Air Compressor Master Repair Manual, Bulletin No. 3666121.

NOTE: Not all air compressors referenced may be used on your engine or application.

Assemble the air compressor using new gaskets and o-rings. Refer to the Holset® Air Compessor Master Repair Manual.

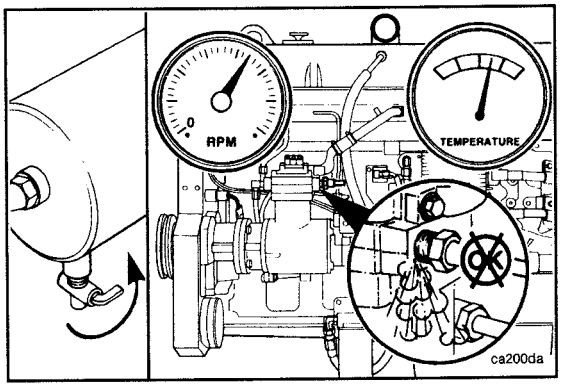
NOTE: Not all air compressors referenced may be used on your engine or application.

Install and tighten the air inlet and outlet connections.



Close the wet tank drain cock.

Operate the engine and check for air leaks.



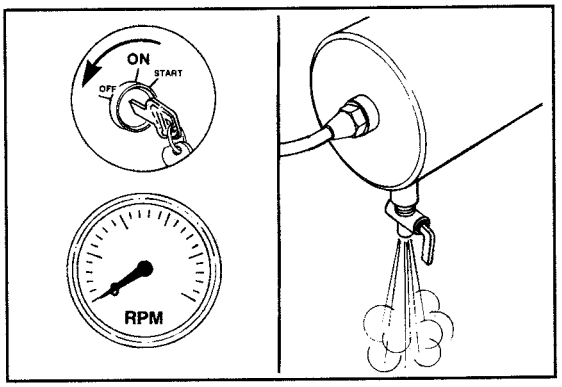
Cummins

⚠ WARNING ⚠

Compressed air can drive debris into eyes and ears. Keep head well away and wear protective eyewear.

Shut off the engine.

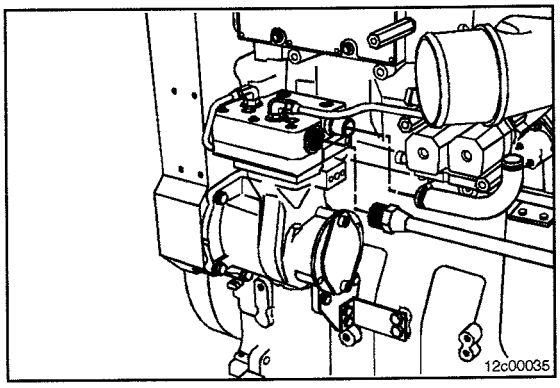
Open the drain cock on the wet tank to release compressed air from the system.

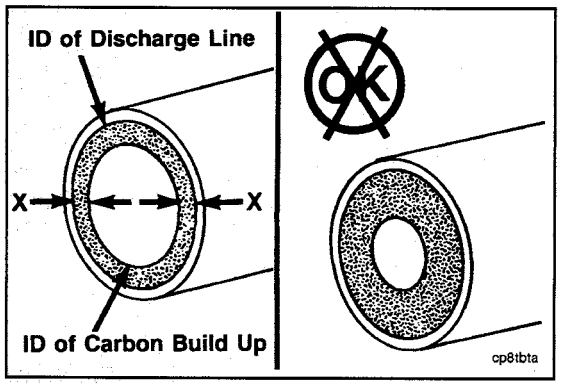


⚠ WARNING ⚠

Air discharge lines can be very hot. Be sure the lines are cool before touching to prevent personal injury.

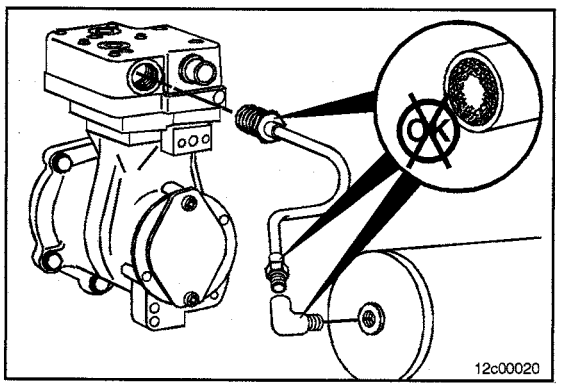
Remove the air inlet and outlet connections from the air compressor.





Measure the total carbon deposit thickness inside the air discharge line as shown.

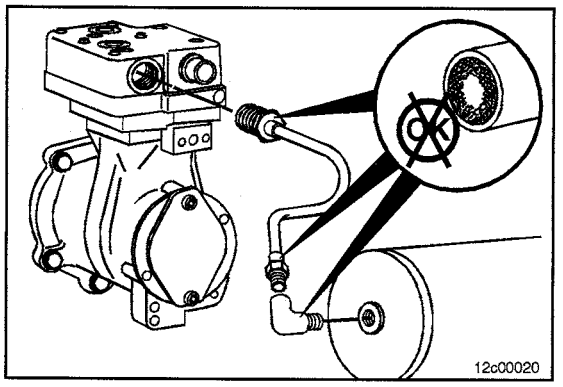
NOTE: The carbon deposit thickness **must not** exceed 1.6 mm [0.06 in].



⚠ WARNING ⚠

The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the OEM specifications.

NOTE: If the total carbon deposit thickness exceeds specification, remove and clean, or replace the air discharge line.



⚠ WARNING ⚠

The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the manufacturer's specifications.

Continue to check for carbon buildup in the air discharge line connections up to the first connection or wet tank.

Clean or replace any lines and fittings with carbon deposits greater than 1.6 mm [0.06 in]. Refer to the OEM specifications for cleaning or replacement instructions.

Cummins Air Compressor Cylinder Head Removal

NOTE: Note the position of these parts in respect to the crankcase for reassembly. Paint marker can be used.

NOTE: If carbon is present on the cylinder head, replace with a new cylinder head. If no carbon is present, reuse the cylinder head, but new capscrews **must** be used.

Drain the coolant system.

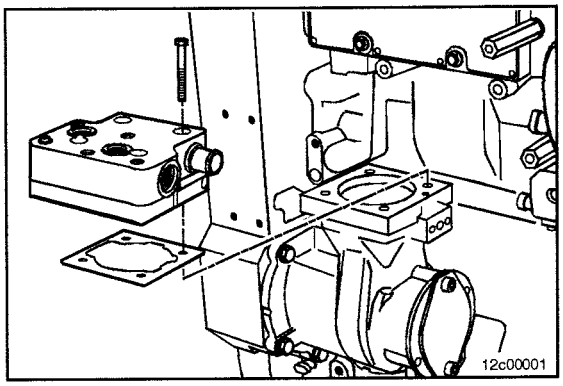
Remove the coolant lines.

Remove the air governor (if equipped).

Remove the air inlet and outlet connections from the air compressor.

Remove the four 8-mm capscrews.

Remove the head, valve, and gasket.



Cummins Air Compressor Cylinder Head Installation

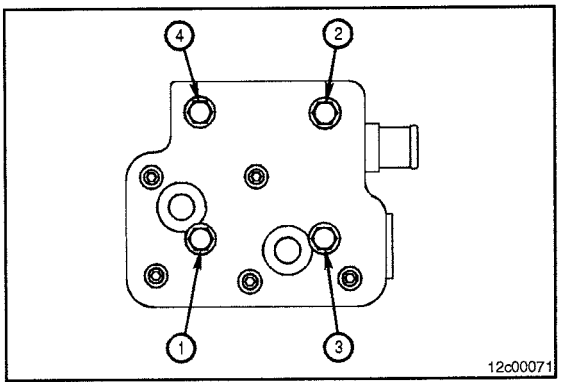
Assemble the air compressor using a new gasket.

Install the head and gasket.

Install the four 8-mm capscrews.

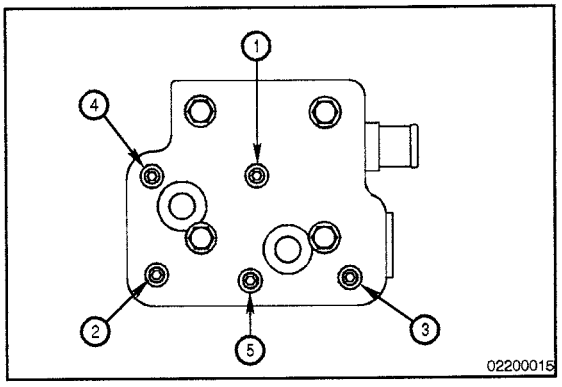
Tighten the capscrews in the sequence shown. Use the torque plus angle method.

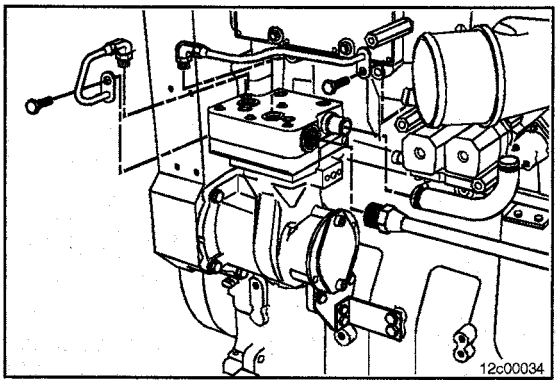
Torque Value: Step 1 25 N•m [15 ft-lb]
2 Rotate 90 degrees except No. 4 which is rotated only 60 degrees.



Tighten the capscrews in the sequence shown. Use the torque plus angle method.

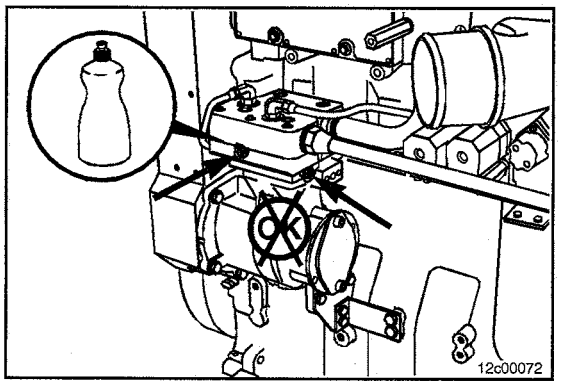
Torque Value: Step 1 6 N•m [53 in-lb]
2 Rotate 90 degrees.





Install and tighten the air inlet and outlet connections.

Install the coolant lines.

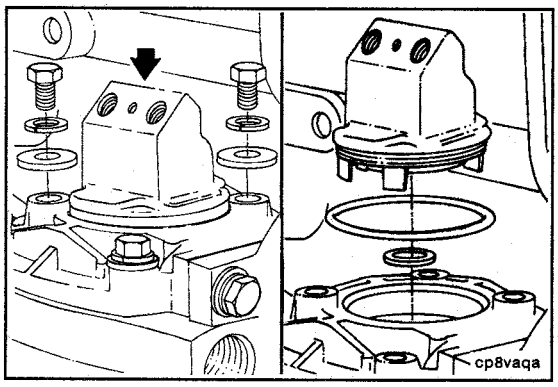


Close the wet tank drain cock.

Fill coolant system.

Operate the engine and check for air leaks.

NOTE: If cylinder head replacement does **not** correct the problem, replace the compressor assembly.



Air Compressor Pin Bore Wear (012-010)

Initial Check (012-010-001)

Holset®

NOTE: This procedure applies to SS and ST models only.

⚠ WARNING ⚠

The unloader valve body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eye wear.

Hold the unloader valve body down and remove the two captive washer capscrews and the two plain washers.

Remove the unloader valve body.

Remove the o-ring seal.

Remove the rectangular ring seal.

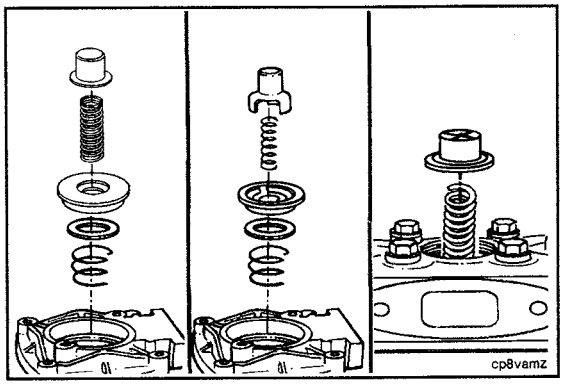
Remove the unloader valve cap and the unloader valve spring.

NOTE: Disassembly of the center unloader valve on Holset® two cylinder air compressors is similar to the single cylinder unloader valve.

Remove the intake valve seat and valve.

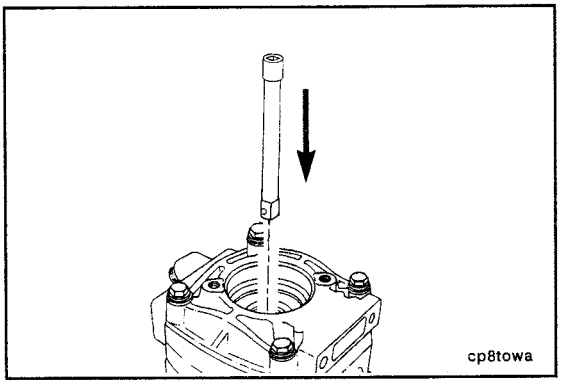
Remove the intake valve spring.

To avoid damage to the air compressor, do **not** allow any debris to fall into the air compressor cylinder.

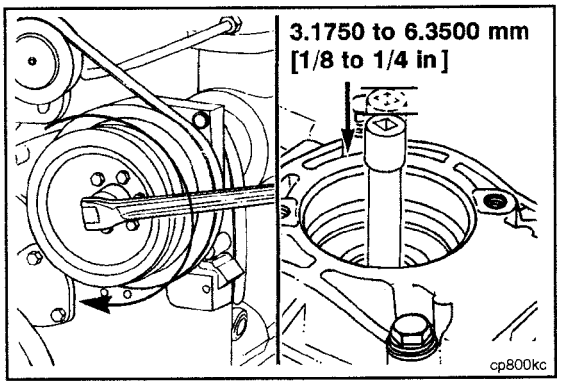


NOTE: Do **not** use a screwdriver. A screwdriver can gouge the top of the piston.

Insert the small end of a 3/8 inch drive socket extension (6 to 10 inches long) through the exhaust valve seat onto the top of the piston.

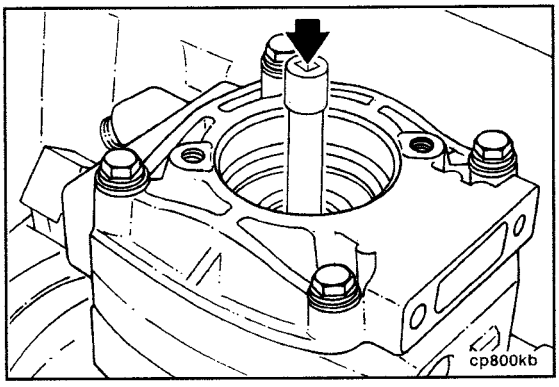


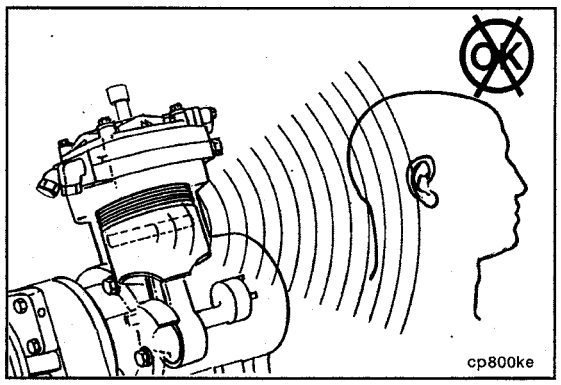
Bar the crankshaft over until the compressor piston reaches top dead center (TDC), and the extension starts to move downward approximately 3 to 6 mm [1/8 to 1/4 inch].



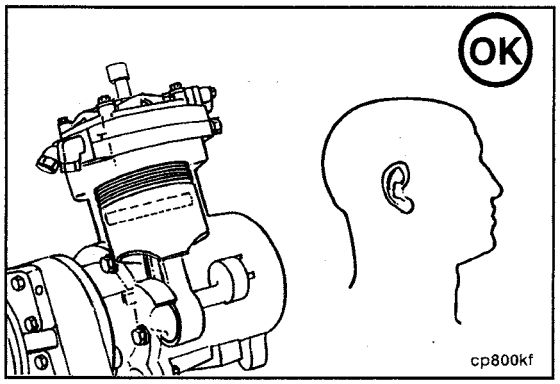
NOTE: To prevent damage to the top of the piston, do **not** use a hammer.

Give a quick, hard push downward on the extension and listen for a metallic click as wear clearance is taken up.



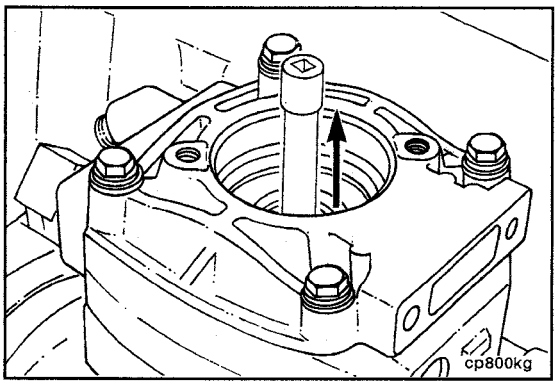


If significant piston motion is felt or a metallic click is heard, the pin bores can be worn, and the compressor **must** be examined further.

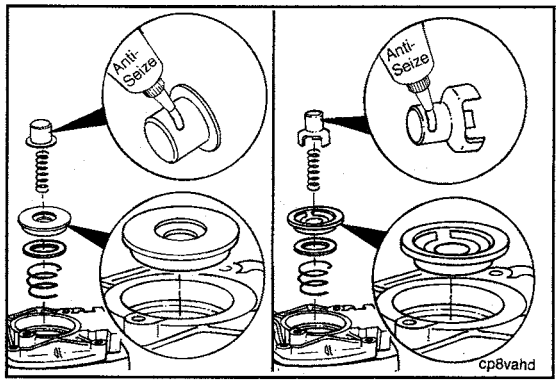


If no motion or sound is heard, the compressor is in satisfactory condition and does **not** need to be replaced.

NOTE: All air compressors will **not** exhibit pin bore wear.



Remove the extension.



Install the intake valve spring with the tang down.

Install the intake valve.

Install the intake valve seat with the flange side up.

Install the unloader valve cap spring.

Install the unloader valve cap.

Use high temperature grease (Accrolube Lubrication Teflon Grease or equivalent) to lubricate the outside diameter of the cap.

NOTE: The rectangular ring seal **must** be installed with the grooved side up.

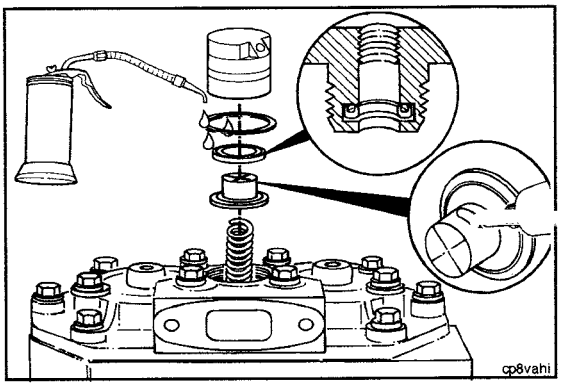
Install the rectangular ring seal.

Install the o-ring seal.

Use clean 15W-40 engine oil to lubricate the o-ring seal.

Install the unloader valve body.

NOTE: Press the unloader valve body down to be sure the tangs of the unloader valve cap are in the three slots of the intake valve seat.



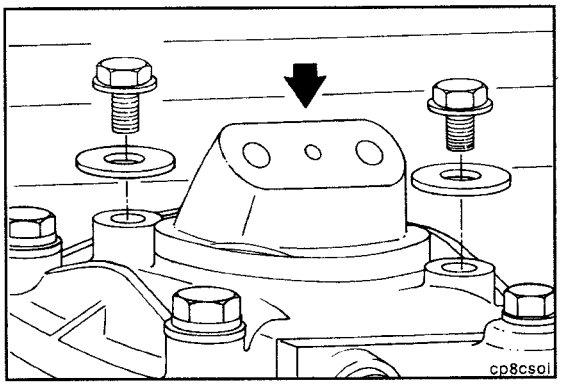
⚠ CAUTION ⚠

Do not overtorque. Compressor damage will result.

Hold the unloader body down and install the two plain washers and captive washer capscrews.

Tighten the capscrews.

Torque Value: 14 N•m [10 ft-lb]



Air Compressor Unloader and Valve Assembly (012-013)

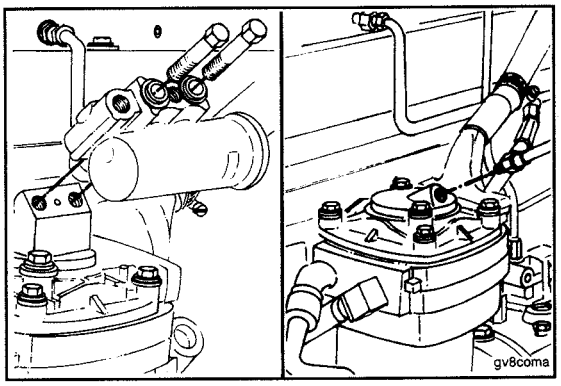
Initial Check (012-013-001)

⚠ WARNING ⚠

Air pressure must be released from system before removing the air governor to prevent personal injury.

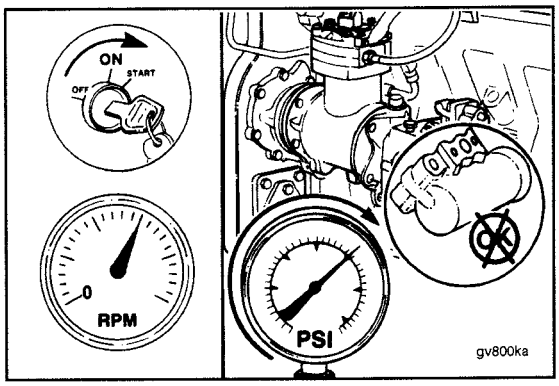
NOTE: The following procedures are for Holset® air compressors **only**. The illustrations shown will be of the SS model single cylinder air compressor. Differences in procedures for SS, QE and ST model Holset® air compressors will be shown where necessary.

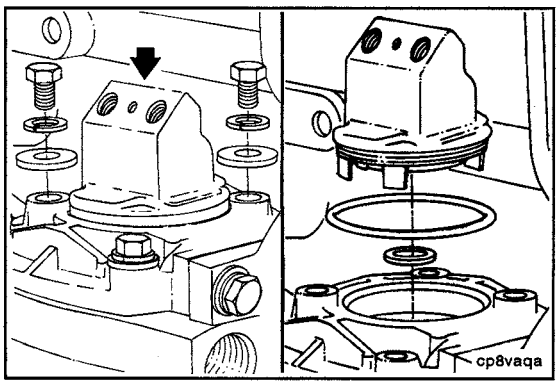
Remove the air governor or air governor hose from the air compressor unloader body.



Operate the engine to activate the air compressor.

If the air compressor is **not** pumping, the unloader valve is malfunctioning and **must** be repaired or replaced.





Remove (012-013-002)

Holset® SS, E-Type, and ST Models

⚠ WARNING ⚠

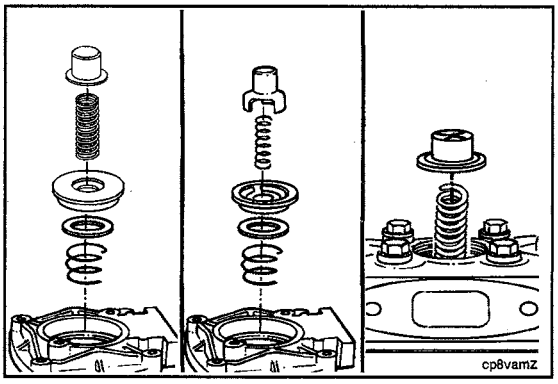
The unloader valve body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eye wear.

Hold the unloader valve body down and remove the two captive washer capscrews and the two plain washers.

Remove the unloader valve body.

Remove the o-ring seal.

Remove the rectangular ring seal.

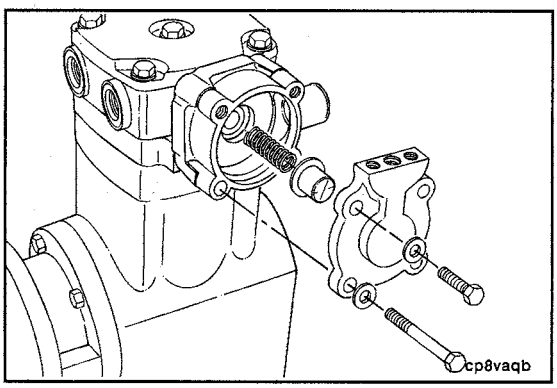


Remove the unloader valve cap and the unloader valve spring.

NOTE: Disassembly of the center unloader valve on Holset® two cylinder air compressors is similar to the single cylinder unloader valve.

Remove the intake valve seat and valve.

Remove the intake valve spring.



Holset® QE Models

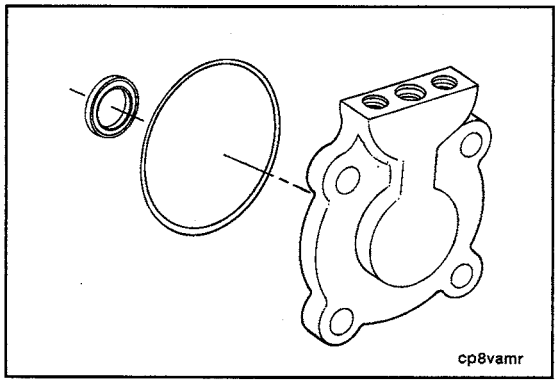
⚠ WARNING ⚠

The unloader body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eye wear.

Hold the unloader valve body down and remove the four capscrews.

Remove the unloader valve spring.

Remove the unloader valve cap.



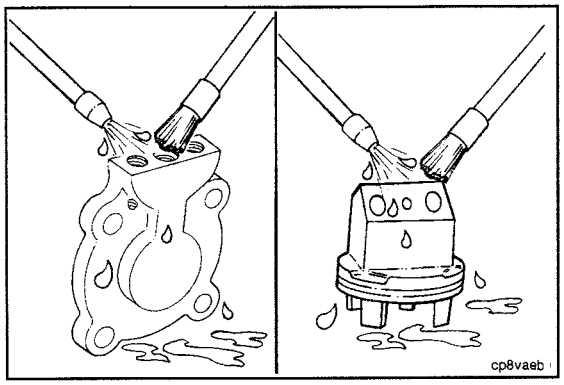
Remove the unloader body gasket and unloader valve cap rectangular ring seal.

Clean (012-013-006)

⚠ CAUTION ⚠

Do not use caustic cleaners. Caustic cleaners may cause damage to component parts.

Remove all carbon and varnish from the unloader valve cap body.



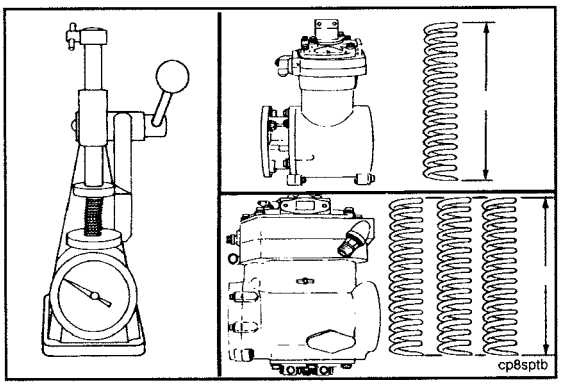
Inspect for Reuse (012-013-007)

Use a valve spring tester to check the unloader spring.

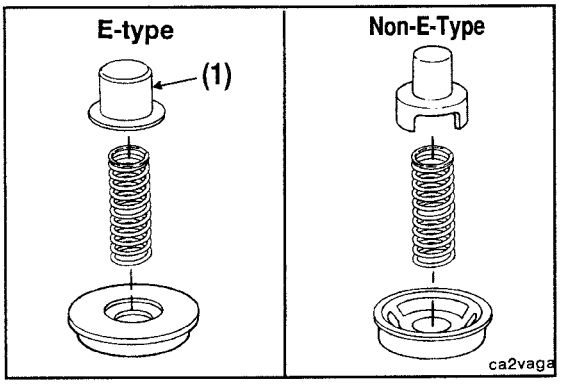
Refer to the Compressor Spring Force Specifications chart shown at the beginning of this section.

Replace the unloader spring if it does **not** meet the specifications shown, or the wrong spring has been used.

NOTE: For Holset® two cylinder air compressors, check both cylinder and center unloader springs. Holset Engineering Co., Inc., recommends that new springs be installed during rebuild.



NOTE: If the compressor has a flat hat type unloader cap (1), it **must** use an unloader spring and valve seat different than that used with the three prong unloader.



Install (012-013-026)

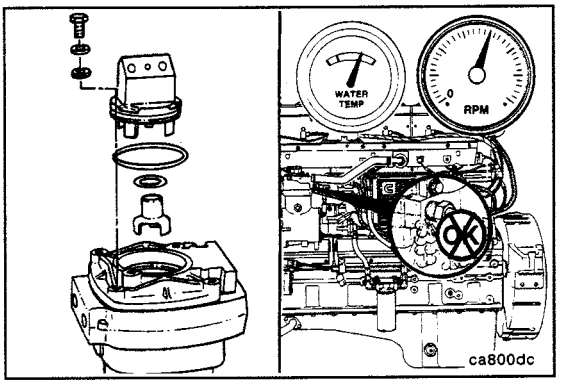
Holset® SS, E-Type, and ST Models

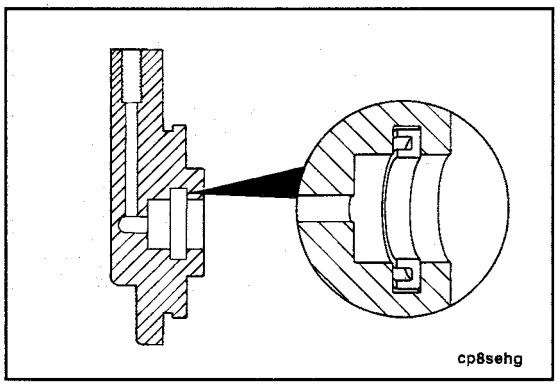
Assemble the air compressor.

Grease rectangular ring seal, unloader cap and unloader body bore with high temperature grease (Accrolube Lubrication Teflon Grease or equivalent).

Torque Value: 14 N•m [10 ft-lb]

Operate the engine and check the compressor for air leaks.



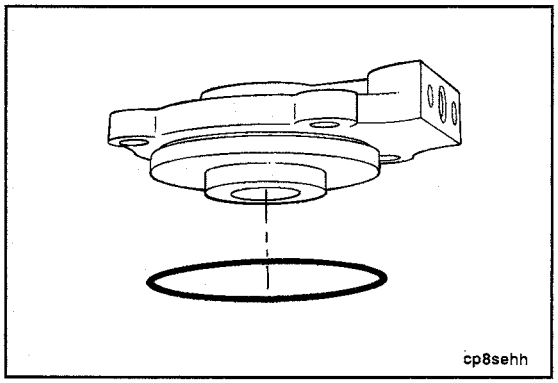


Holset® QE Models

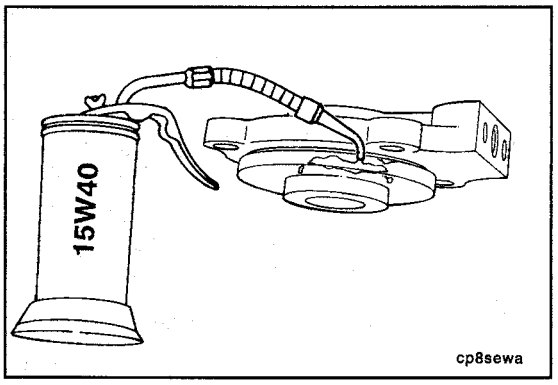
Install the new rectangular V-seal into the unloader body.

NOTE: The seal **must** be installed with the grooved side up.

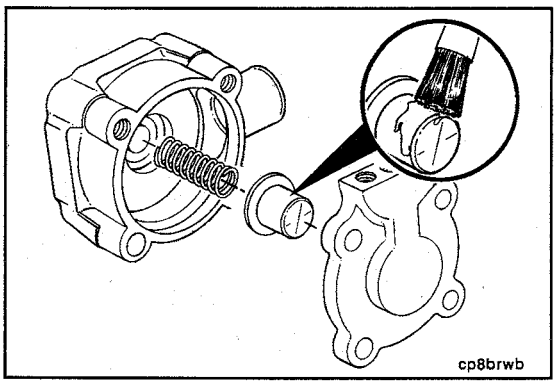
Liberally lubricate the unloader valve bore above and below the rectangular ring seal with high temperature grease (Accrolube Lubrication Teflon Grease or equivalent).



Install a new o-ring seal on the unloader valve body.



Use clean 15W40 engine oil, Accrolube Lubrication Teflon Grease, or equivalent to lubricate the seal.



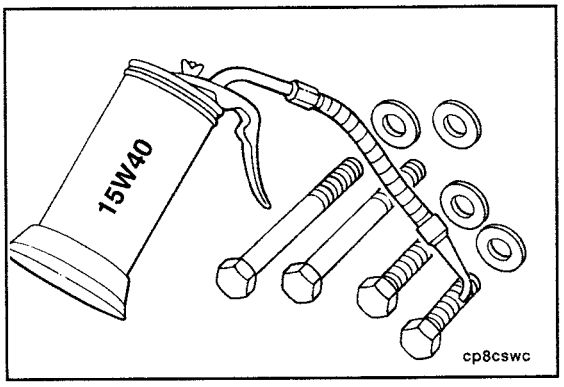
Liberally lubricate the unloader valve body bore and unloader cap with high temperature grease (Accrolube Lubrication Teflon Grease or equivalent).

Install the unloader cap.

Install the unloader spring.

Lubricate the unloader screw threads and underhead with clean engine oil (SAE 15W40), before installation.

NOTE: The two unloader body screws **must not** be used to attach any brackets.

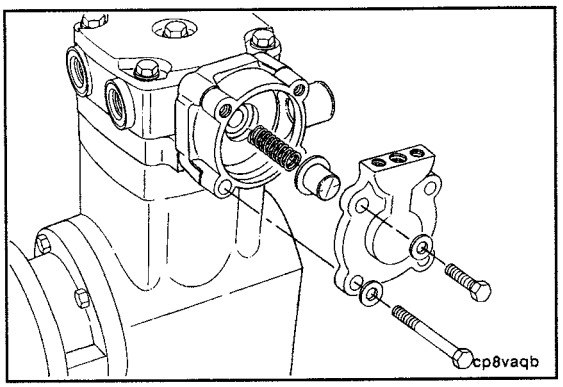


Assemble the unloader components and attach the unloader assembly to the valve plate with the four capscrews and washers.

NOTE: The longer capscrews are used to mount the manifold to the air compressor.

Torque Value: 27 N•m [20 ft-lb]

Operate the engine and check the air compressor for air leaks.



Air Compressor (012-014)

Remove (012-014-002)

⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam can cause serious personal injury.

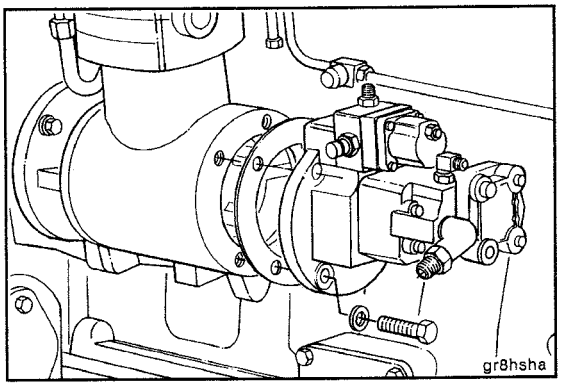
NOTE: The illustrations shown will be of the SS model single cylinder air compressor. Differences in procedures for SS, QE and ST model Cummins air compressors will be shown where necessary.

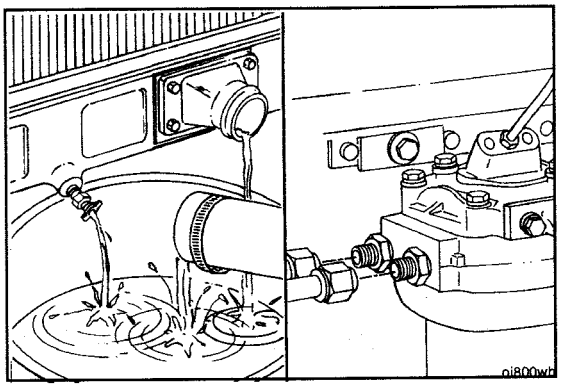
Use steam to clean the air compressor. Dry with compressed air.

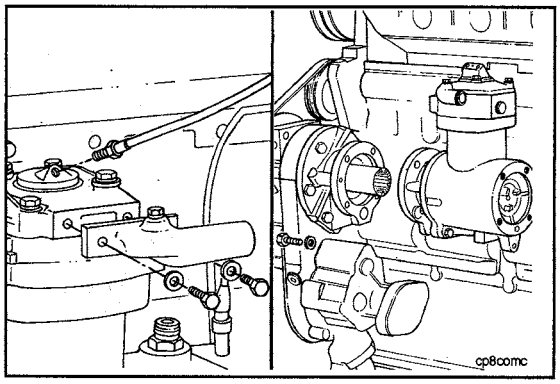
Remove the fuel pump. Refer to Procedure 005-016.

Drain the engine coolant. Refer to Procedure 008-018.

Remove the coolant lines from the air compressor.



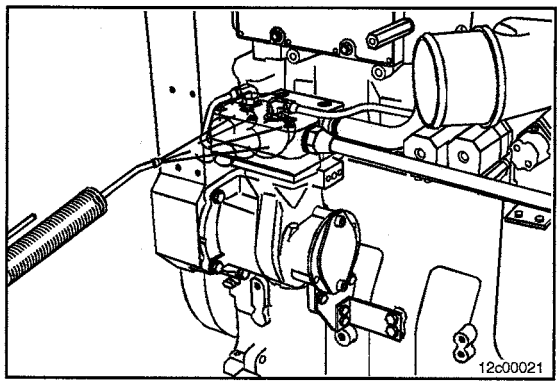




Remove the air connections from the air compressor.

Remove the air compressor support bracket and capscrews.

Remove the four capscrews, the air compressor, and splined coupling.

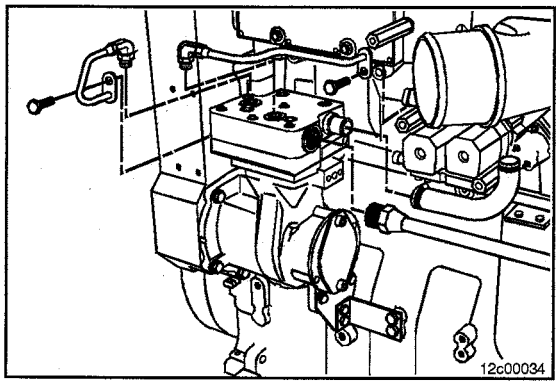


Cummins

⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam can cause serious personal injury.

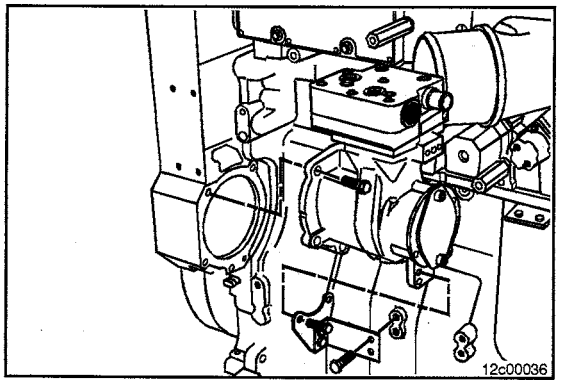
Use steam to clean the air compressor. Dry with compressed air.



Drain the engine coolant. Refer to Procedure 008-018-005.

Remove the coolant lines from the air compressor.

Remove the air connections from the air compressor.



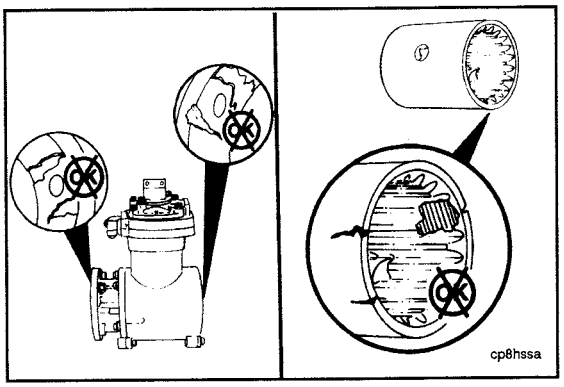
Remove the air compressor support bracket and capscrews.

Remove the four capscrews and the air compressor.

Inspect for Reuse (012-014-007)

Inspect the compressor housing for cracks or damage.

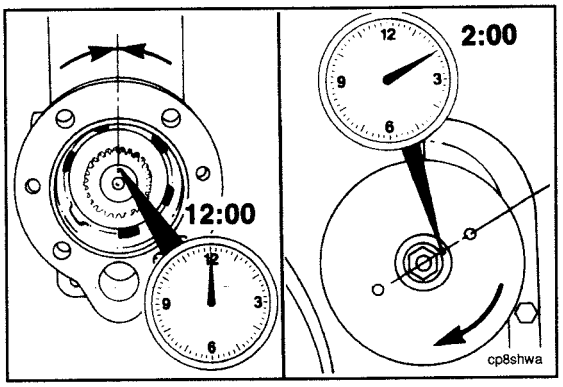
Inspect the splined coupling for cracks or damage.



Install (012-014-026)

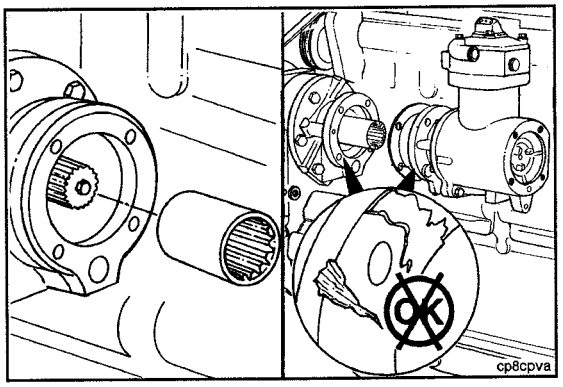
Position the timing mark on the air compressor crankshaft at the 12:00 o'clock position.

Position the accessory drive shaft dowel pin at the 2:00 o'clock position as viewed from the front of the engine.



Install the splined coupling on the accessory drive shaft.

Be sure the gasket surfaces of the accessory drive and air compressor are clean and **not** damaged.



Use a new gasket to install the air compressor and four capscrews to the accessory drive.

Holset

Torque Value: 68 N•m [50 ft-lb]

Cummins

Torque Value: 44 N•m [33 ft-lb]

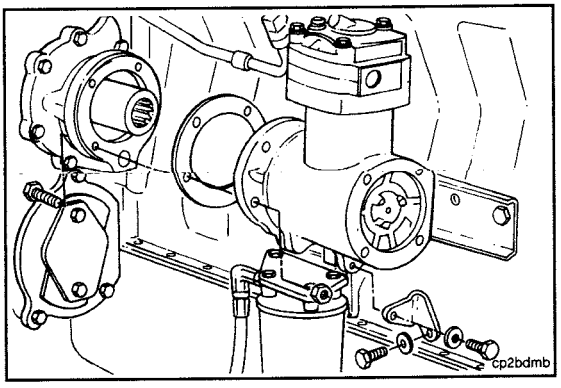
Install the air compressor support bracket.

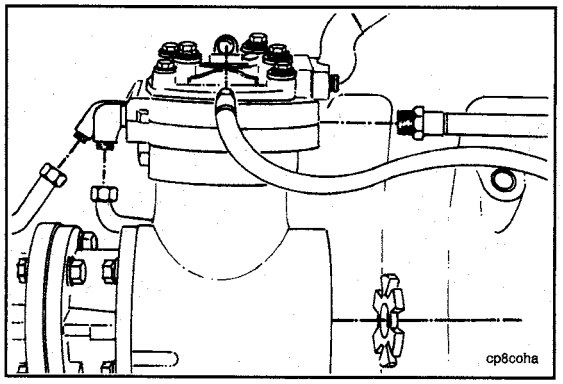
Holset

Torque Value: 47 N•m [35 ft-lb]

Cummins

Torque Value: 44 N•m [33 ft-lb]

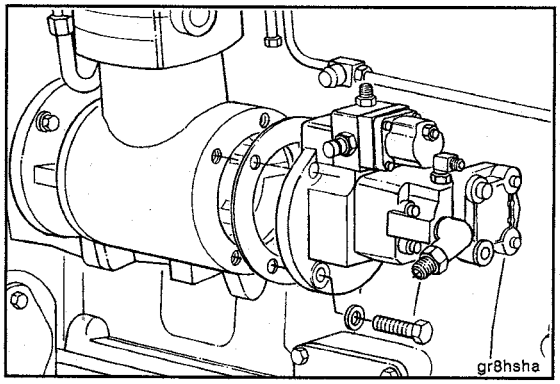




NOTE: If rubber grommets are used on the coolant lines, be sure they are installed carefully to prevent cuts or tears to the grommets which will cause coolant leaks. When flexible tubing is used make sure that it does **not** rub any other surfaces.

Install the coolant and air lines to the air compressor and tighten.

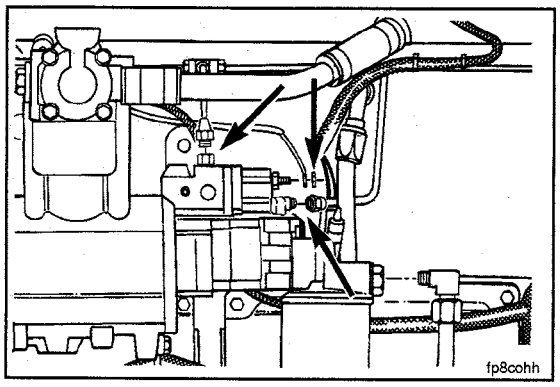
Install the fuel pump drive coupling on the air compressor.



Be sure the gasket surfaces of the air compressor and fuel pump are clean and **not** damaged.

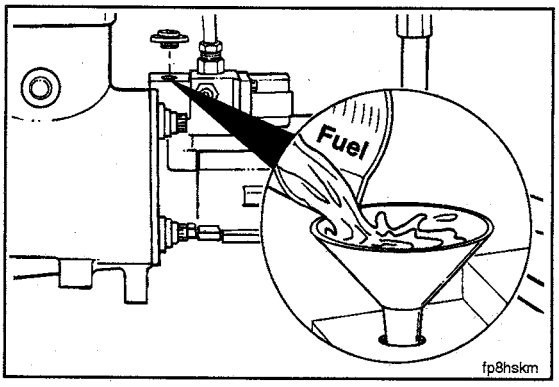
Use a new gasket when installing the fuel pump to the air compressor.

Install the fuel pump. Refer to Procedure 005-016.



Install all fuel tubing to the fuel pump and tighten.

Connect the electrical wiring to the fuel pump.



Whenever the fuel pump is removed, it is necessary to prime the pump after installing it on the engine to remove any trapped air.

NOTE: If the fuel pump is dirty, clean the outside of the pump.

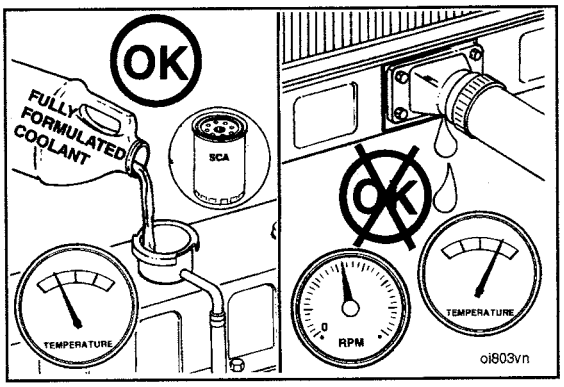
Remove the filter cap from the top of the front support.

Fill the housing with clean fuel. Install and tighten the filter cap.

Torque Value: 18 N•m [13 ft-lb]

Fill the engine cooling system. Refer to Procedure 008-018.

Operate the engine and check for leaks.

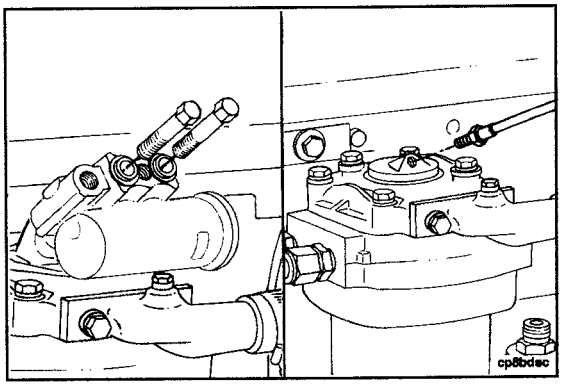


Air Governor (Air Compressor Will Not Pump) (012-017)

Initial Check (012-017-001)

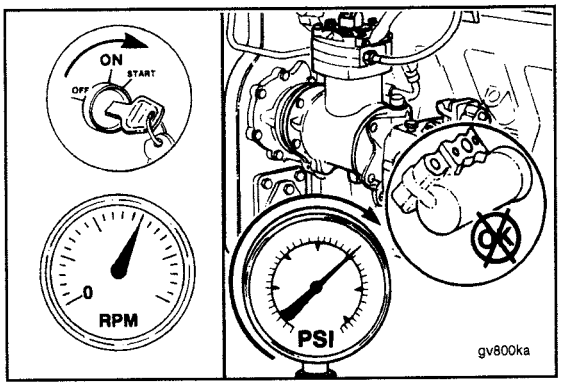
NOTE: The illustrations shown will be of the SS model single cylinder air compressor. Differences in procedures for Holset® models SS, QE, ST, and Cummins air compressors will be shown where necessary.

Remove the air governor or air governor line from the air compressor unloader body.



Operate the engine to activate the air compressor.

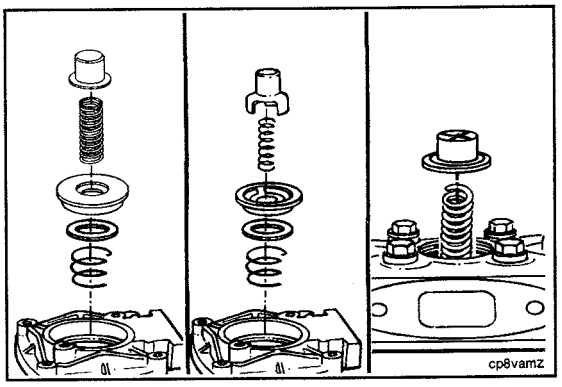
If the air compressor is pumping, the air governor is malfunctioning and **must** be repaired or replaced. Refer to the manufacturer's instructions.

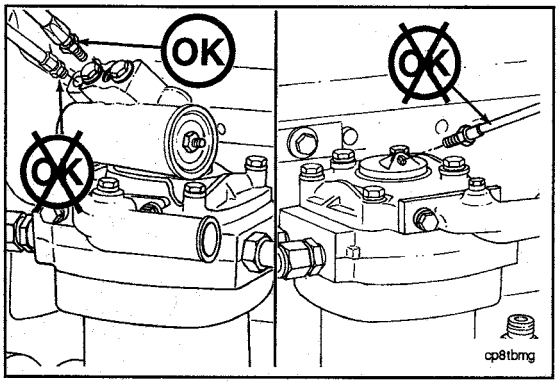


If the air compressor does **not** pump, remove, clean, and inspect the air compressor unloader valve assembly. Refer to Air Compressor Unloader Valve. Refer to the Holset® Air Compressor Master Repair Manual, Bulletin No. 3666121.

If the unloader valve assembly is okay, clean and inspect the exhaust valve assembly. Refer to the Holset® Master Repair Manual, Bulletin No. 3666121.

NOTE: Not all air compressors referenced may be used on your engine or application.



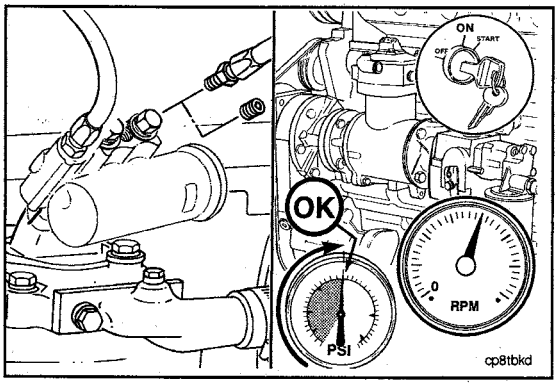


Air Governor (Air Compressor Pumps Continuously) (012-018)

Initial Check (012-018-001)

NOTE: The illustrations shown will be of the SS model single cylinder air compressor. Differences in procedures for Holset® models SS, QE, ST, and Cummins air compressors will be shown where necessary.

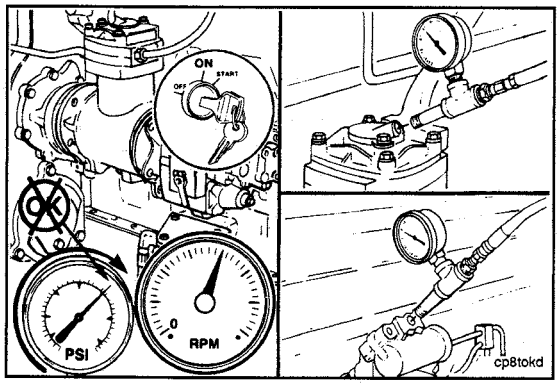
Remove the air accessory air lines from the air compressor governor.



Install pipe plugs in the air governor unloader ports where accessory air lines were removed.

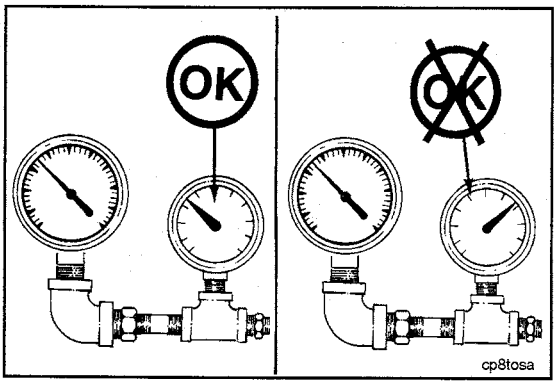
Operate the engine to activate the air compressor.

If the air compressor stops pumping (air pressure stops rising) at the governed air pressure, there is a leak in an accessory or an accessory air line. Refer to the equipment manufacturer's instructions for troubleshooting and repair.



If the air compressor does **not** stop pumping (air pressure continues to rise) at the governed air pressure, connect a regulated shop air pressure line to one of the following:

- The air compressor unloader valve port
- One of the air governor unloader valve ports.

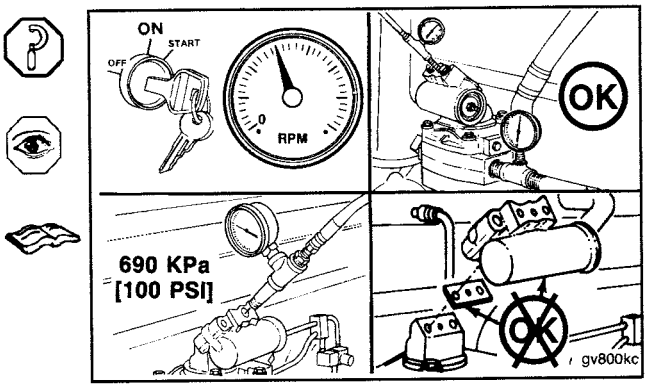


NOTE: Be sure the air pressure gauge is accurate, and the supply lines and fittings are in good condition before performing any air pressure checks.

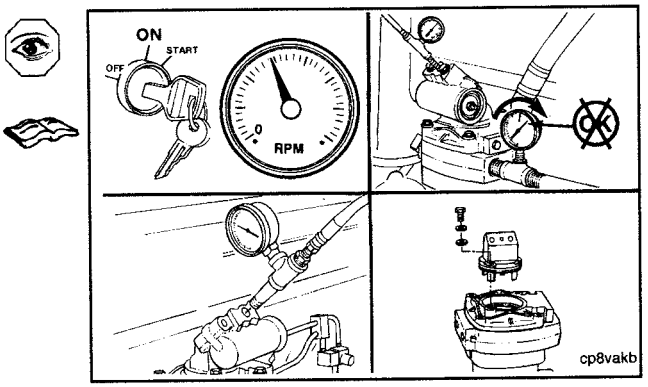
Use a master gauge of known accuracy to check the air pressure gauge.

Apply 690 kPa [100 psi] air pressure to the unloader port.

If the air compressor stops pumping (air pressure stops rising), the air governor is malfunctioning and **must** be repaired or replaced, or the air governor mounting gasket is leaking. Refer to the manufacturer's instructions.



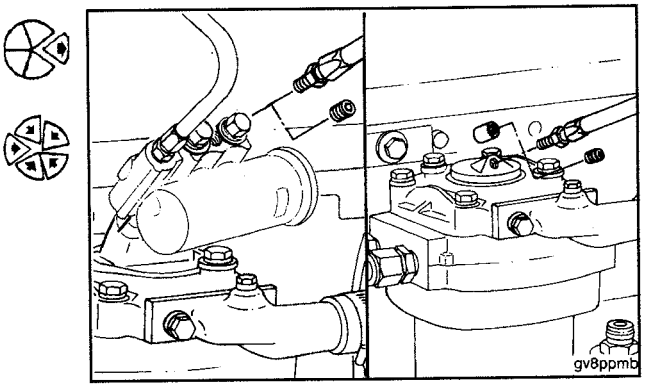
If the air compressor continues to pump (air pressure continues to rise), the unloader valve is malfunctioning and **must** be repaired or replaced. Refer to Air Compressor Unloader Valve, Procedure 012-013.



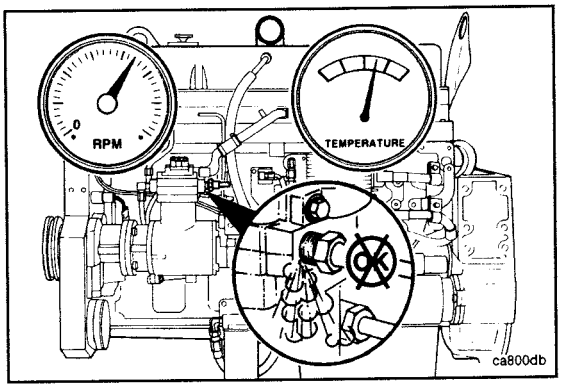
Remove the pipe plugs from the unloader ports used for accessory air lines.

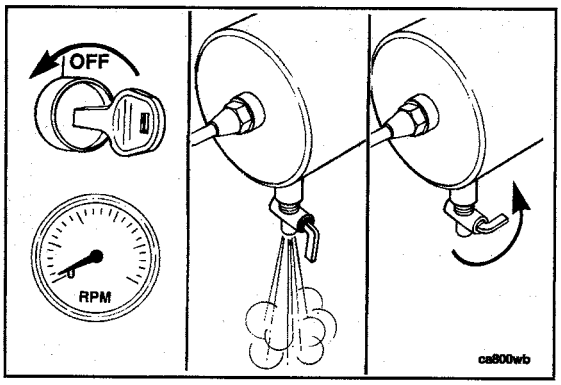
Install and tighten the accessory air lines.

Connect the line to the unloader valve.



Operate the engine and check for air leaks.





Air Leaks, Compressed Air System (012-019)

Initial Check (012-019-001)

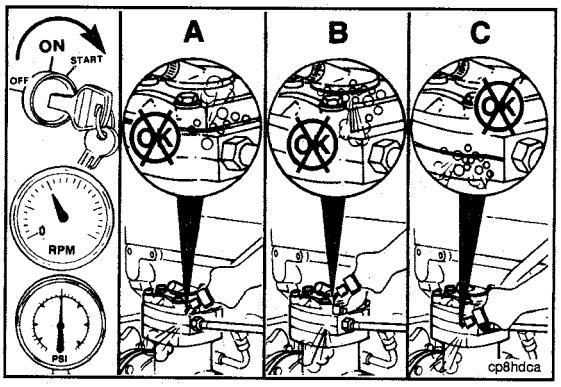
⚠ WARNING ⚠

Compressed air can propel debris into eyes and ears. Keep head away and wear protective eyewear.

NOTE: The illustrations shown will be of the single cylinder air compressor. Differences in procedures for Holset® models SS, QE, ST, and Cummins air compressors will be shown where necessary.

Shut off the engine.

Open the drain cock on the wet tank to release air from the system. Close the drain cock after the pressure is released.



Operate the engine to activate the air compressor.

With the air compressor pumping between 550 to 690 kPa [80 to 100 psi], use a solution of soapy water to check for air leaks in the following areas:

- Air compressor cover gasket
- Unloader body o-ring (Holset® **only**)
- Air compressor head gasket
- Air compressor valve plate gasket (Holset® QE models **only**)
- Hose and fitting leaks

If air leaks are found, replace the leaking gasket or o-ring. Refer to the Holset® Air Compressor Master Repair Manual, Bulletin No. 3666121.

NOTE: Not all air compressors referenced can be used on your engine or application.

Section 13 - Electrical Equipment - Group 13

Section Contents

Page

Alternator 13-4
Initial Check 13-4
Install 13-5
Remove 13-5

Batteries 13-9
Initial Check 13-9

Battery Cables and Connections 13-10
Initial Check 13-10

Drive Belt, Alternator 13-6
Adjust 13-8
Install 13-6
Remove 13-6

Electrical Equipment - General Information 13-1
General Information 13-1

Service Tools 13-3
Electrical Equipment 13-3

Specifications 13-2
Electrical System 13-2

Starter Magnetic Switch 13-10
Current Check 13-10

Starter Solenoid 13-13
Voltage Check 13-13

Starter Switch 13-12
Voltage Check 13-12

Starting Motor 13-15
Install 13-16
Remove 13-15

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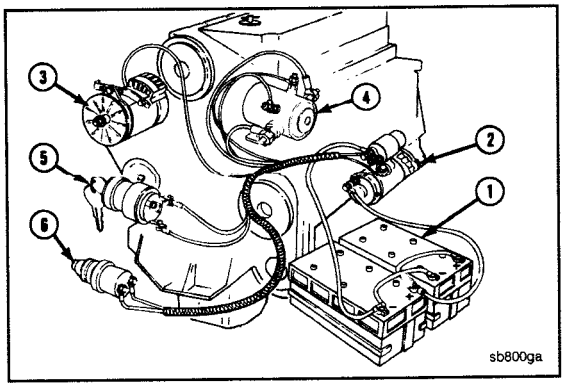
Electrical Equipment - General Information

General Information

The basic heavy-duty electrical system consists of:

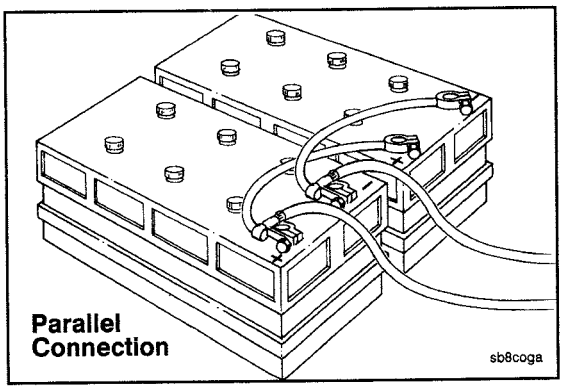
- Batteries (1) (usually three or four connected in parallel)
- A starting motor (2)
- An alternator (3)
- A magnetic switch (4)
- An ignition switch (5)
- A push-button switch (6)
- All necessary wiring.



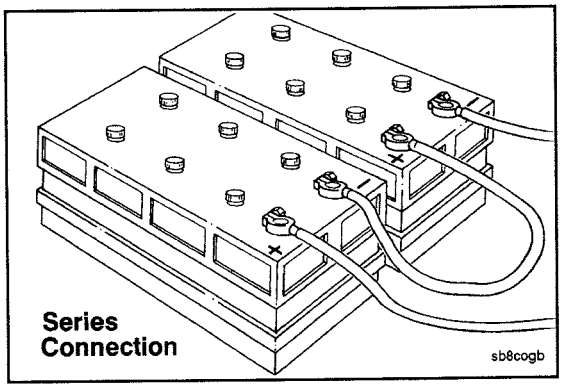
All components **must** be carefully matched.

The accompanying illustrations show typical parallel and series battery connections:

- Parallel connection



- Series connection.



Specifications

Electrical System

Minimum recommended battery capacity:

System Voltage	Ambient Temperature -18°C [0°F]		Ambient Temperature 0°C [32°F]	
	Cold Cranking Amperes	Reserve Capacity [1] Amperes	Cold Cranking Amperes	Reserve Capacity [1] Amperes
12 VDC	1800	640	1280	480
24 VDC [2]	900	320	640	240

1. The number of plates within a given battery size determines reserve capacity. Reserve capacity determines the length of time during that sustained cranking can occur.
2. Cold Cranking Amperes ratings are based on two 12-VDC batteries in series.

A minimum of 6.5 VDC at the power connector is required to power up the ECM.

Minimum Battery Capacity @ -18 to 0°C [0 to 32°F] ambient temperature
- 12-VDC starter ..... 640 Reserve Capacity Amperes - 1800 cold cranking amps @ -18°C [0°F]
- 24-VDC starter ..... 320 Reserve Capacity Amperes - 900 cold cranking amps @ -18°C [0°F]

Minimum Battery Capacity above 0°C [32°F] ambient temperature
- 12-VDC starter ..... 480 Reserve Capacity Amperes - 1280 cold cranking amps @ -18°C [0°F]
- 24-VDC starter ..... 240 Reserve Capacity Amperes - 640 cold cranking amps @ -18°C [0°F]

Maximum Starting Circuit Resistance
- 12-VDC starter ..... 0.00075 OHMS
- 24-VDC starter ..... 0.00200 OHMS

Battery Cable Sizes - American Wire Gauge (maximum length in cranking motor circuit)
- 12-VDC
  - No. 00 ..... 3.7 m [12 ft]
  - No. 000 ..... 4.9 m [16 ft]
  - No. 0000 or Two No. 0* ..... 6.1 m [20 ft]
  - Two No. 00 ..... 7.6 m [25 ft]
- 12-VDC High Output
  - No. 00 ..... 2.1 m [7 ft]
  - No. 000 ..... 2.7 m [9 ft]
  - No. 0000 or Two No. 0* ..... 3.7 m [12 ft]
  - Two No. 00 ..... 4.3 m [14 ft]
- 24 to 32-VDC
  - No. 00 ..... 6.1 m [20 ft]
  - No. 000 ..... 8.2 m [27 ft]
  - No. 0000 or Two No. 0* ..... 10.7 m [35 ft]
  - Two No. 00 ..... 13.7 m [45 ft]

Minimum ambient temperature without starting aid ..... -1°C [30°F]

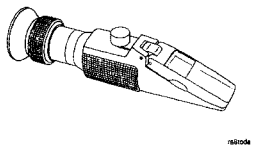
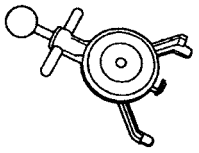
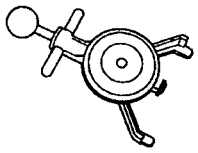
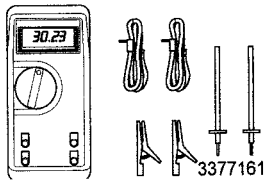
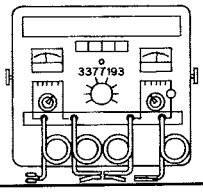
Minimum cranking speed without starting aid ..... 170 rpm

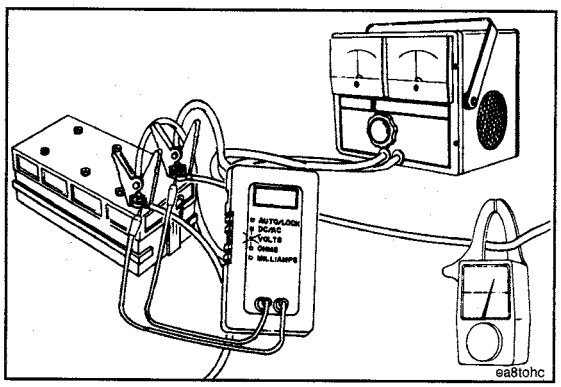
* Two strands of No. 0 cable can be used in place of one No. 0000 cable provided that all connections are carefully made to maintain equal current flow in each parallel cable.

Service Tools

Electrical Equipment

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
CC-2800	**Refractometer** The Fleetguard® refractometer is used to check the charge condition of a conventional battery.	
ST-1293	**Belt Tension Gauge** Used to measure belt tension on 'K' type v-ribbed belt with six to nine ribs.	
ST-1138	**Belt Tension Gauge** Used to check the alternator v-belt tension.	
3377161	**Digital Multimeter** Used to measure electrical circuits: Voltage (volts), resistantce (ohms), and current (amps). The digital multimeter is contained in compusave calibration kit, Part No. 3377151.	
3377193	**Inductive Charging - Cranking Systems Analyzer** Used to test generators, alternators, relays, starters, regulators, and batteries. Contains built-in voltmeter and ammeter.	

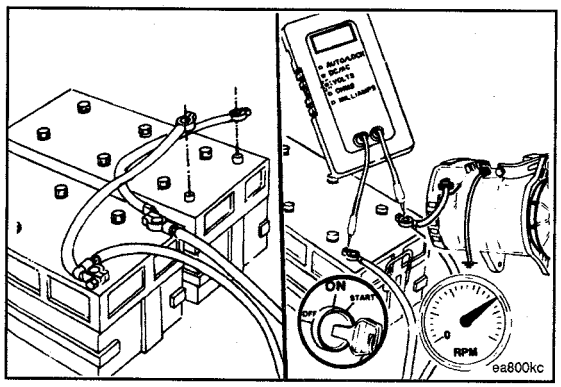


Alternator (013-001)

Initial Check (013-001-001)

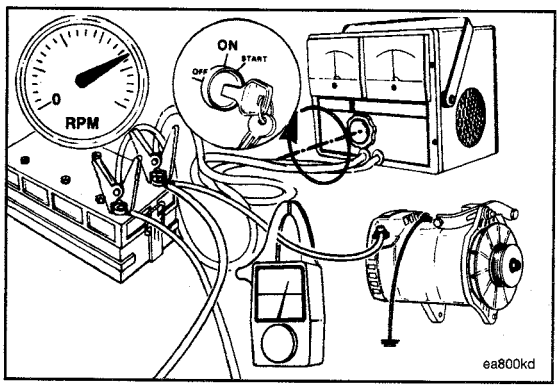
Connect a carbon pile load (battery tester) across the batteries in one of the battery boxes.

Clamp an induction pickup type ammeter around the battery cable, or use digital multimeter, Part No. 3377161, with clamp or current probe, Part No. 3823574.



Disconnect any cables that lead to any other battery boxes in the circuit.

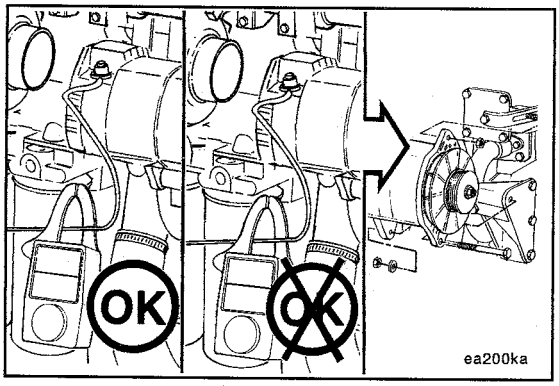
Operate the engine at high idle, and measure the alternator voltage output to the batteries with digital multimeter, Part No. 3377161. Refer to the equipment manufacturer's specifications.



Operate the engine at high idle and adjust the battery tester to apply the maximum rated amperage load to the alternator. Refer to the manufacturer's specifications.

NOTE: The alternator maximum rated amperage output is normally stamped or labeled on the alternator.

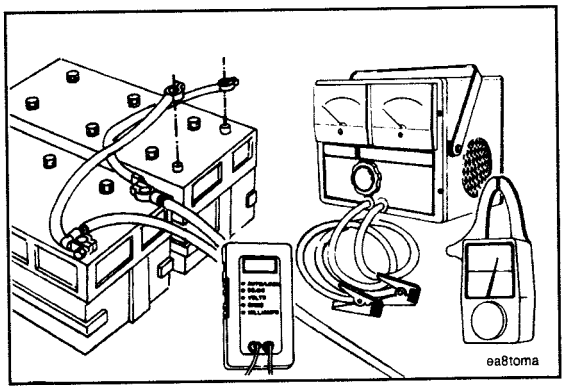
Measure the alternator amperage output. Refer to the alternator manufacturer's specifications.



If the gauge on the carbon pile load testing equipment does **not** indicate approximately the same output as the induction-type ammeter, determine which is defective and replace it. Refer to the equipment manufacturer instructions.

If the alternator output (amps) is **not** within 10 percent of rated output, repair or replace the alternator. Refer to the manufacturer's instructions for repair procedures.

Shut off the engine, and remove the test equipment.



Remove (013-001-002)

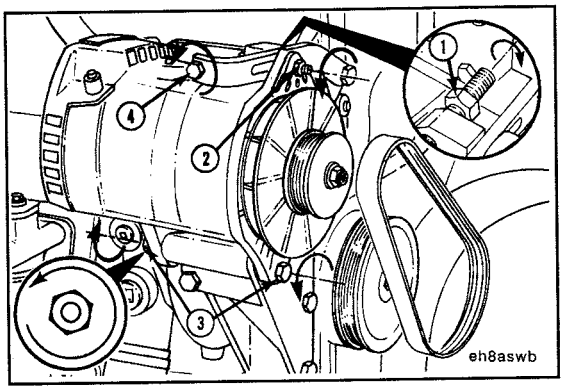
Loosen the adjusting screw locknut (1).

Loosen the retaining nut (2).

Loosen the alternator mounting capscrew (3).

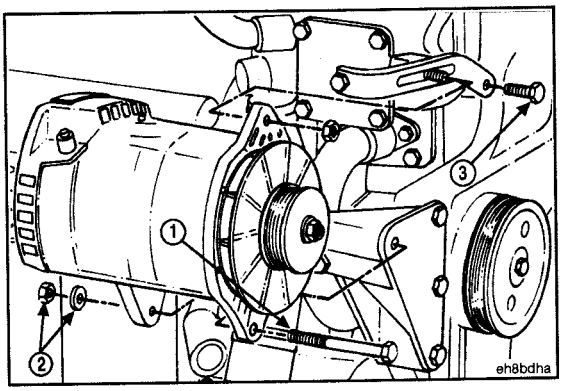
Turn the adjusting screw **counterclockwise** to release tension (4).

Remove the alternator belt.



Remove the adjusting link mounting capscrew(3) and the adjusting link.

Remove the alternator mounting capscrew(1), nut, washer(2), and alternator.



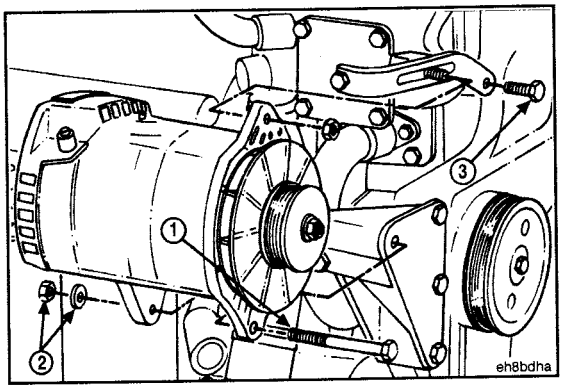
Install (013-001-026)

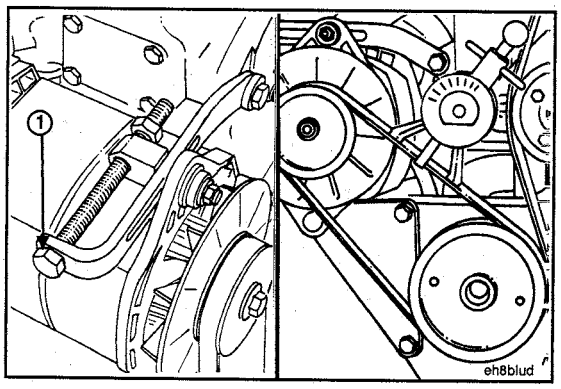
Install the adjusting link and mounting capscrew(3).

Torque Value: 47 N•m [35 ft-lb]

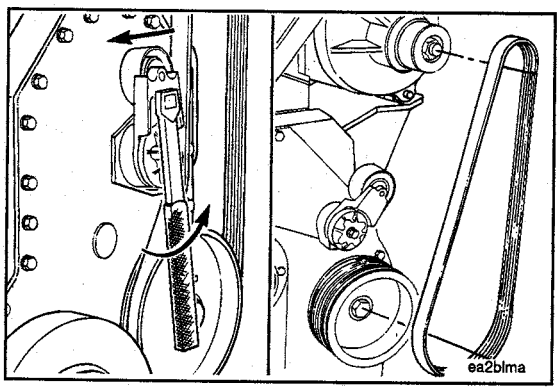
Install the alternator, capscrew(1), washer, and nut(2) to the mounting bracket and adjusting link.

NOTE: Do **not** tighten the capscrews and nuts until the alternator belt is installed and adjusted.





Install and adjust the alternator belt. Refer to Procedure 013-005.



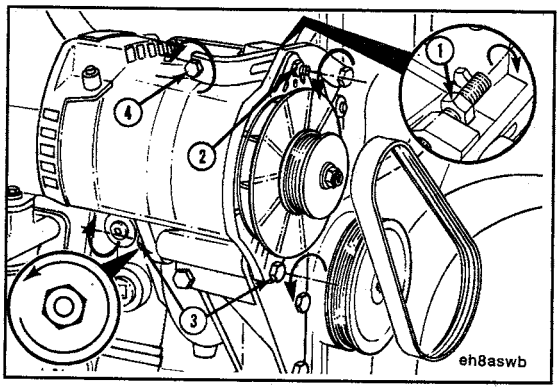
Drive Belt, Alternator (013-005)

Remove (013-005-002)

Insert a 3/8-inch breaker bar into the space provided on the tensioner.

Rotate the tensioner away from the belt until it stops.

Remove the alternator belt while holding the tensioner back.



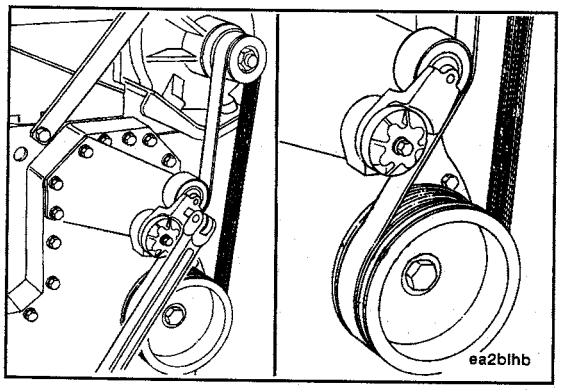
Loosen the adjusting screw locknut (1).

Loosen the adjustment link locking capscrew (2).

Loosen the alternator mounting capscrew (3).

Turn the adjusting screw (4) **counterclockwise** to release tension.

Remove the alternator belt.



Install (013-005-026)

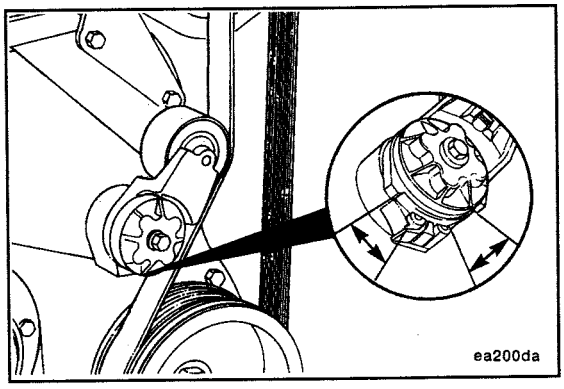
Install a new belt over the pulleys while holding the tensioner back. Be careful **not** to damage the belt while working it over the flanged pulleys.

Release the tensioner, and remove the breaker bar.

Belt drive systems equipped with an automatic belt tensioner can **not** be adjusted. A belt tension gauge will **not** give an accurate measure of the belt tension. The automatic belt tensioner is designed to maintain proper belt tension over the life of the belt. **Only** inspection of the tensioner is required.

The belt tensioner is designed to operate within the limit of arm movement provided by the cast stops when the belt length and geometry are correct.

If the tensioner is hitting either of the limits during operation, check the mounting brackets and the belt length. Loose brackets, bracket failure, alternator movement, incorrect belt length, or belt failure can cause the tensioner to hit the limits.

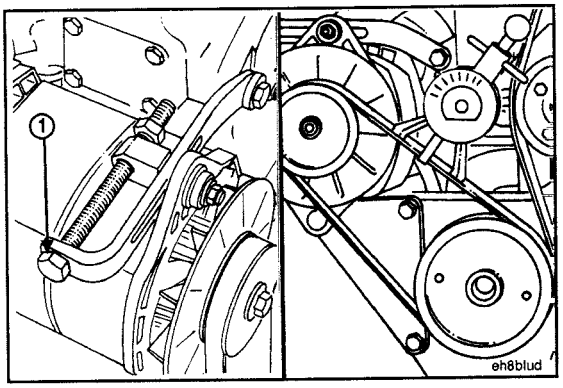


Install a new belt on the water pump and alternator pulleys. To prevent damage, do **not** roll a belt over the pulley or pry it on with a tool.

Turn the adjusting screw (1) **clockwise** to increase the belt tension.

Use belt tension gauge, Part No. ST-1293, to measure the belt tension. Refer to Drive Belt Tension in Section V for the correct tension value for the belt you are installing.

NOTE: A belt is considered used if it has been in operation for 10 minutes or longer.



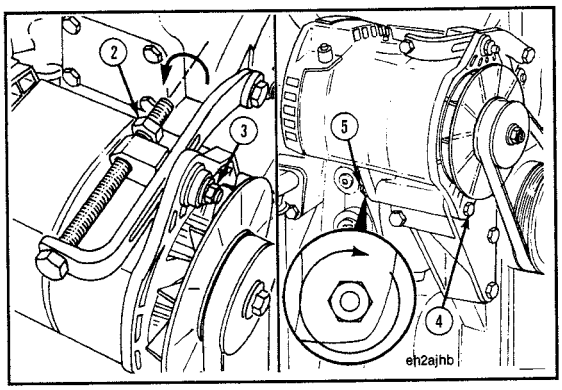
Tighten the adjusting screw locknut (2) against the retainer.

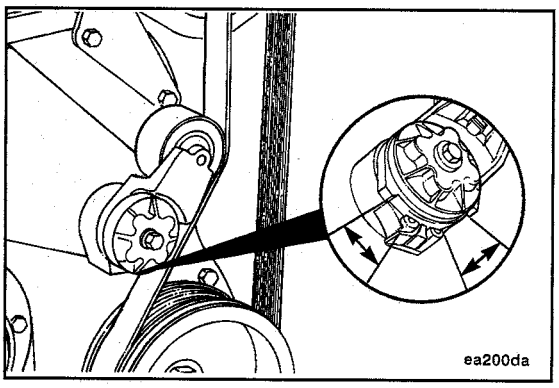
Tighten the adjustment link locking capscrew (3).

Torque Value: 80 N•m [60 ft-lb]

Tighten the pivot capscrew (4) and nut (5).

Torque Value: 47 N•m [35 ft-lb]





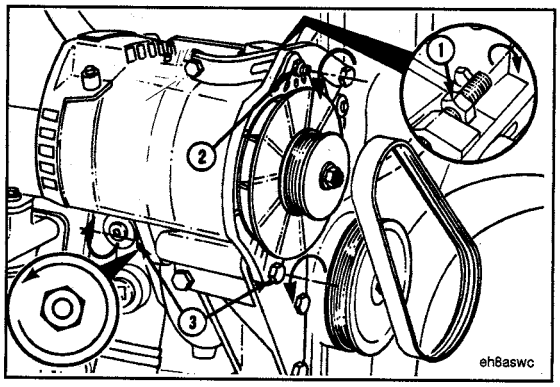
Adjust (013-005-029)

Belt drive systems equipped with an automatic belt tensioner can **not** be adjusted. A belt tension gauge will **not** give an accurate measure of the belt tension. The automatic belt tensioner is designed to maintain proper belt tension over the life of the belt. **Only** inspection of the tensioner is required.

The belt tensioner is designed to operate within the limit of arm movement provided by the cast stops when the belt length and geometry are correct.

If the tensioner is hitting either of the limits during operation, check the mounting brackets and the belt length. Loose brackets, bracket failure, alternator movement, incorrect belt length, or belt failure can cause the tensioner to hit the limits.

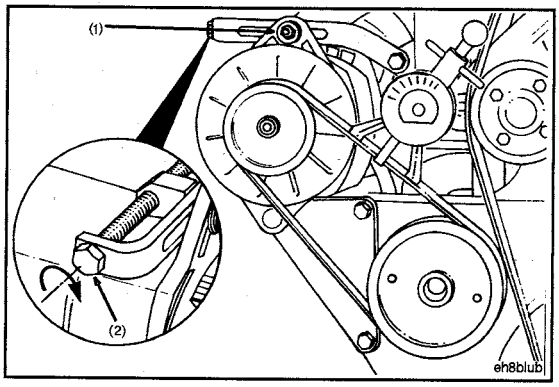
NOTE: If the engine is equipped with a secondary alternator, refer to the vehicle manufacturer for the secondary alternator belt adjustment procedure.



Loosen the adjusting screw locknut (1).

Loosen the adjustment link locking capscrew (2).

Loosen the pivot capscrew and nut (3).



Use belt tension gauge, Part No. ST-1293, to measure belt tension.

Turn the alternator adjusting screw(1) **clockwise** to tighten the belt. Refer to Drive Belt Tension in Section V for the correct belt tension for the belt you are adjusting.

NOTE: A belt is considered used if it has been in operation for 10 minutes or longer.

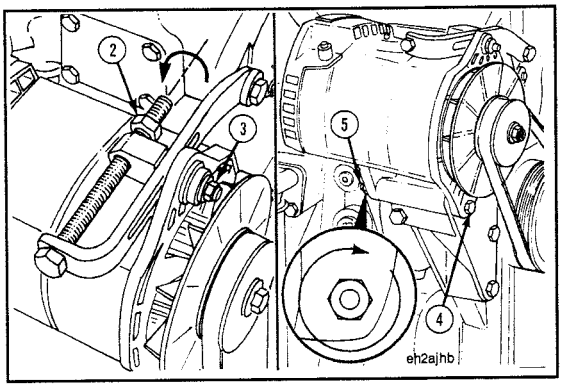
Tighten the adjusting screw locknut (2) against the retainer.

Tighten the adjustment link locking capscrew (3).

Torque Value: 80 N•m [60 ft-lb]

Tighten the pivot capscrew (4) and nut (5).

Torque Value: 47 N•m [35 ft-lb]



Batteries (013-007)

Initial Check (013-007-001)

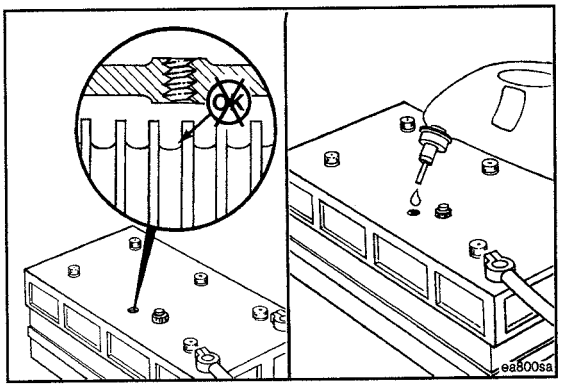
⚠ WARNING ⚠

Acid in extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to avoid serious bodily injury.

If conventional batteries are used, remove the cell caps or covers, and check the electrolyte level.

NOTE: Maintenance-free batteries are sealed and do **not** require the addition of water.

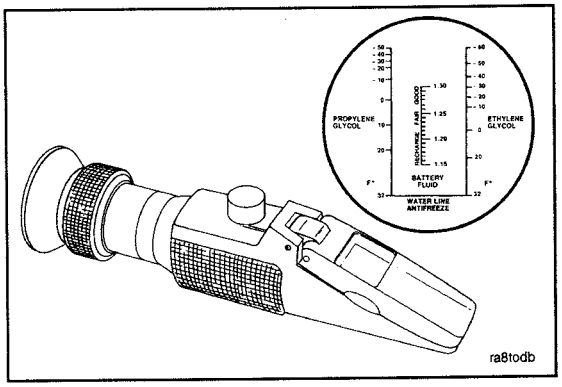
Fill each battery cell with distilled water. Refer to the manufacturer specifications.

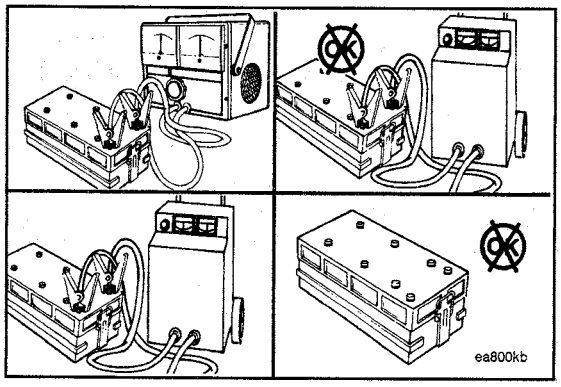


Use the Fleetguard® refractometer, Part No. CC-2800, to check the specific gravity of the battery electrolyte.

Refer to the battery fluid column in the refractometer to determine the state-of-charge of each battery cell.

If water has been added to a dry cell, recharge the battery to mix the added water with the existing battery electrolyte to prevent incorrect readings.





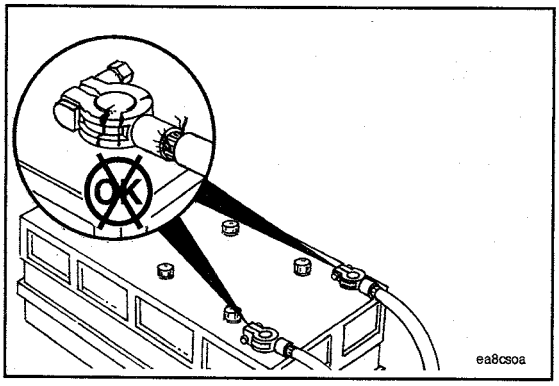
⚠ CAUTION ⚠

Disconnect all electrical connections at batteries prior to charging to prevent possible damage to engine electrical components.

Use battery tester, Part No. 3885845, to test the output amperage of maintenance-free or conventional vent cap batteries.

If the output amperage is low, use a battery charger to charge the battery. Refer to the manufacturer instructions.

Replace the battery if it will **not** charge to the manufacturer specifications or will **not** maintain a charge.

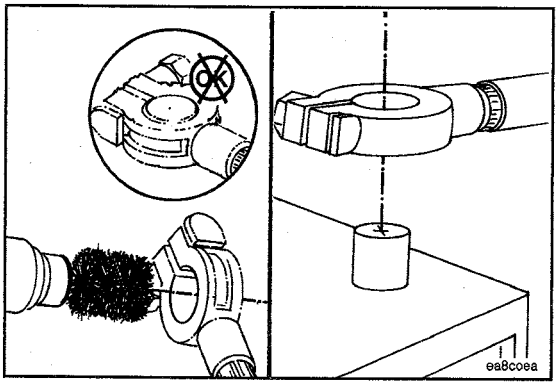


Battery Cables and Connections (013-009)

Initial Check (013-009-001)

Inspect the battery terminals for loose, broken, or corroded connections.

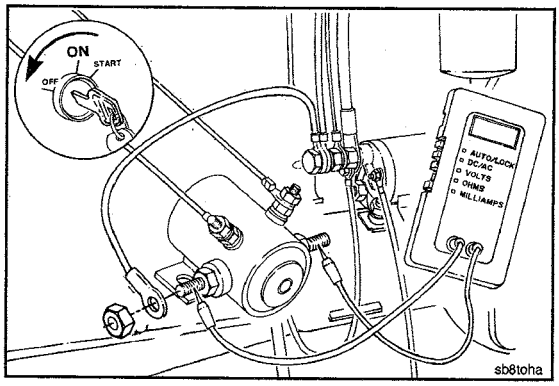
Repair or replace broken cables or terminals.



If the connections are corroded, remove the cables and use a battery brush to clean the cable and battery terminals.

Install and tighten the battery cables.

Use grease to coat the battery terminals to prevent corrosion.



Starter Magnetic Switch (013-017)

Current Check (013-017-042)

⚠ WARNING ⚠

Be sure the starter switch is in the OFF position to prevent electrical shock.

Remove the cable connecting the magnetic switch to the starter solenoid from the magnetic switch terminal.

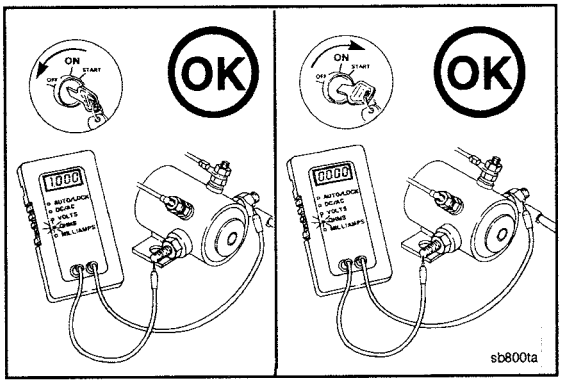
Connect the leads of the digital multimeter, Part No. 3377161, to the two large-switch terminals.

Set the multimeter to measure resistance (ohms).

With the starter switch off, the multimeter **must** indicate resistance at infinity, open circuit.

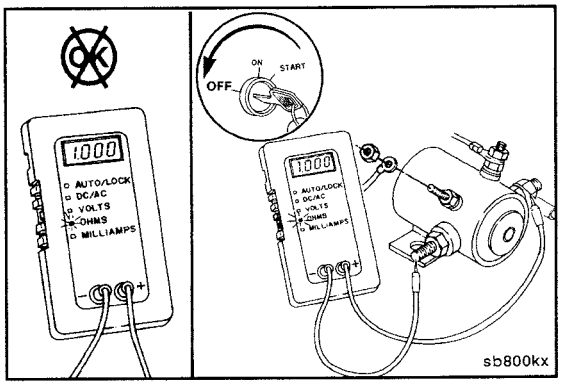
Turn the starter switch to the START position.

The multimeter **must** indicate zero resistance, closed circuit.

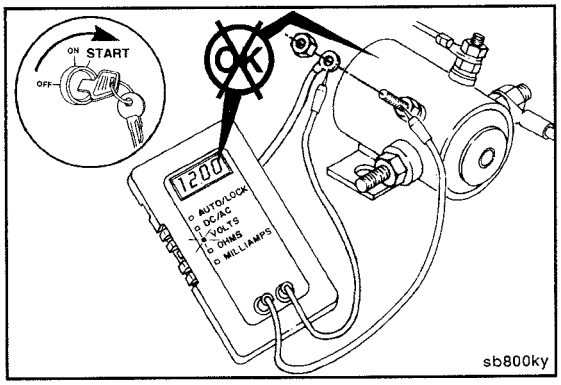


If the multimeter indicates resistance at infinity with the starter switch in the START position:

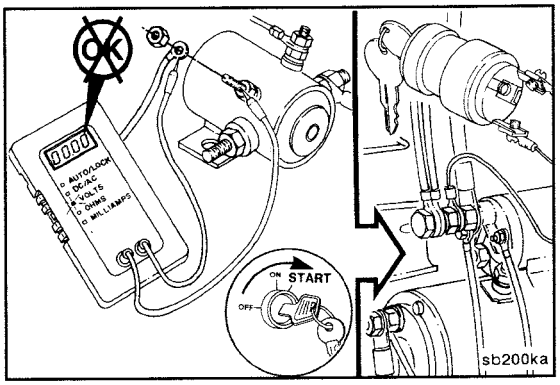
- Turn the starter switch off
- Remove the ground wire that is connected to one of the small magnetic switch terminals.

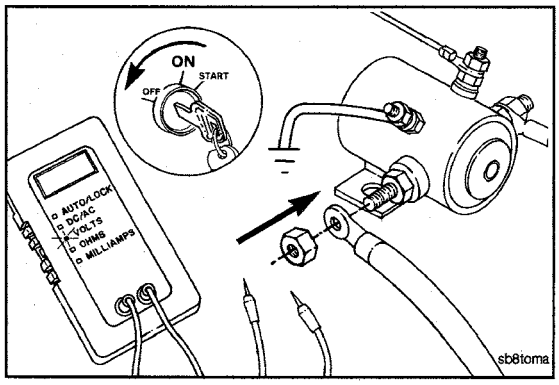


- Set the multimeter scale to indicate volts, 24 VDC or more.
- Connect the positive + lead of the multimeter to the magnetic switch ground terminal and the other lead to the ground wire.
- Turn the starter switch to the START position.
- The multimeter **must** indicate vehicle electrical system voltage.

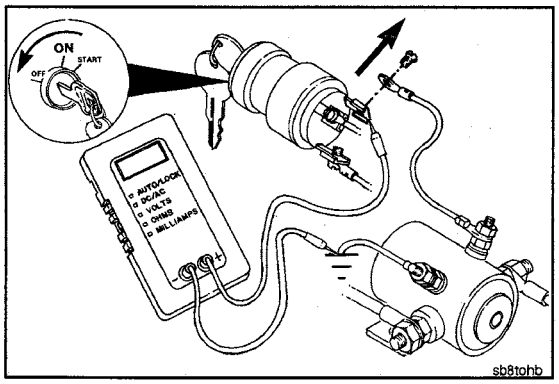


- If the multimeter does **not** indicate voltage, refer to Starter Switch - Check in this section.





- Turn the starter switch to the OFF position.
- Remove the multimeter leads.
- Connect the starter solenoid cable to the magnetic switch terminal and the ground wire to its corresponding terminal on the magnetic switch.



Starter Switch (013-018)

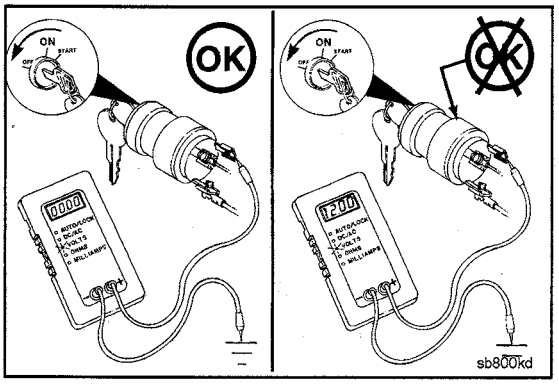
Voltage Check (013-018-041)

⚠ WARNING ⚠

Be sure the starter switch is in the OFF position to prevent electrical shock.

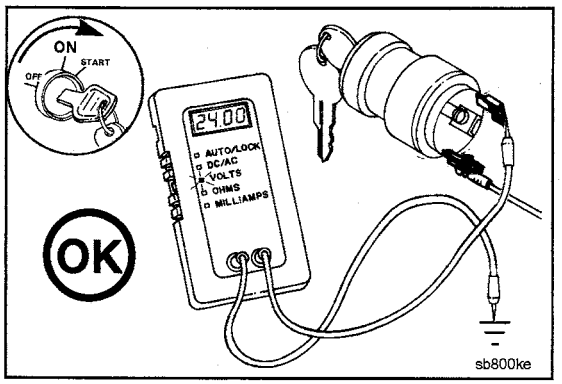
Remove the wire connecting the starter switch to the magnetic switch from the starter switch terminal.

Connect the positive (+) lead of digital multimeter, Part No. 3377161, to the starter switch terminal and the negative (-) lead to the chassis or an engine ground location.



- Set the multimeter to indicate D.C. volts.

With the starter switch in the OFF position, there **must not** be a voltage reading. If the meter indicates a voltage, the starter switch is malfunctioning and **must** be replaced.

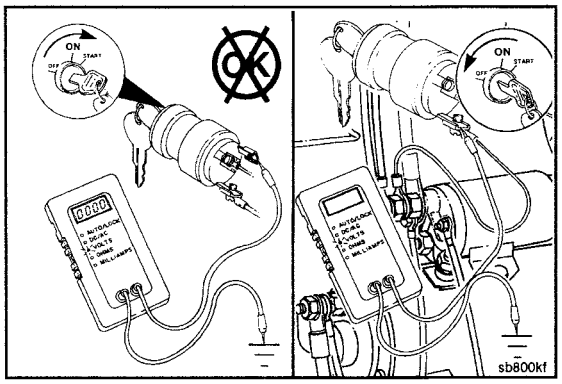


Turn the starter switch to the START position.

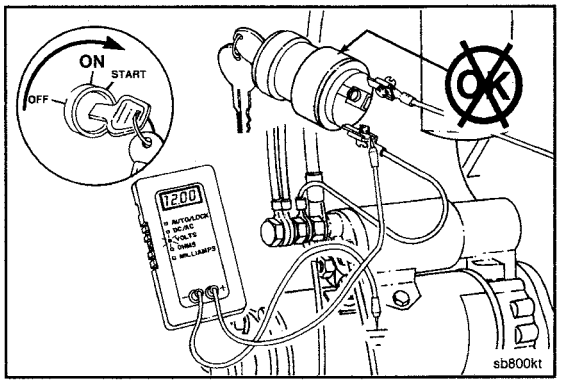
The multimeter **must** indicate a voltage in order for this check to be normal.

If there is **not** a voltage:

- Turn the starter switch to the OFF position
- Check the cable from the positive (+) voltage terminal of the starter solenoid to the starter switch for breaks. Also, check for loose or corroded connections.



- If the cable is good and the connections are clean and tight, the starter switch is malfunctioning and **must** be replaced.



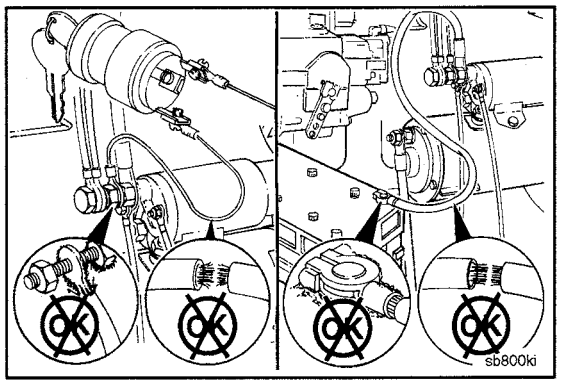
Starter Solenoid (013-019)

Voltage Check (013-019-041)

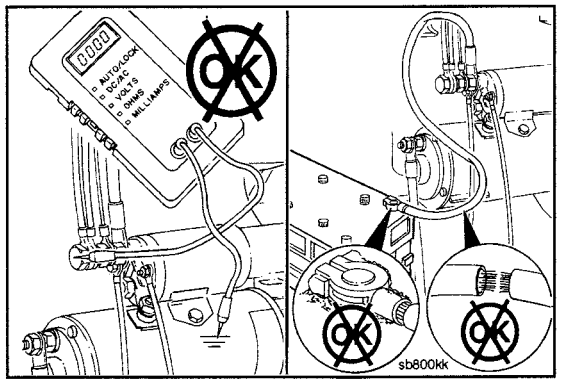
Use digital multimeter, Part No. 3377161, with the switch set to indicate D.C. volts.

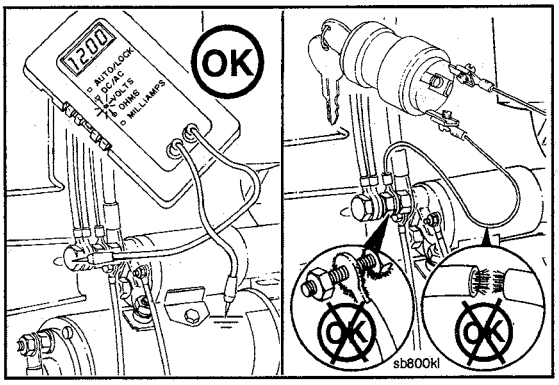
Connect the multimeter positive (+) lead to the starter solenoid positive (+)cable terminal and the negative (-) lead to a chassis or engine ground location.

The multimeter **must** show a voltage with the starter switch off to be normal.

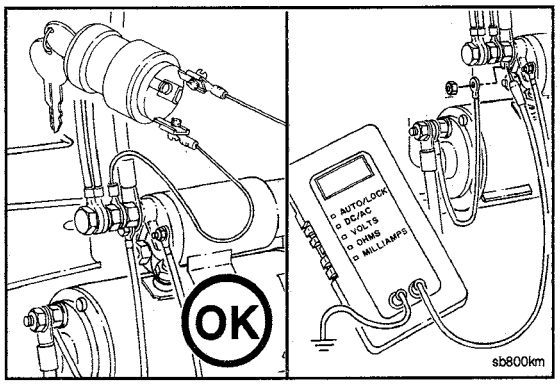


If the multimeter does **not** indicate a voltage, check the cable connecting the starter solenoid and battery for breaks. Also, check for loose or corroded connections.



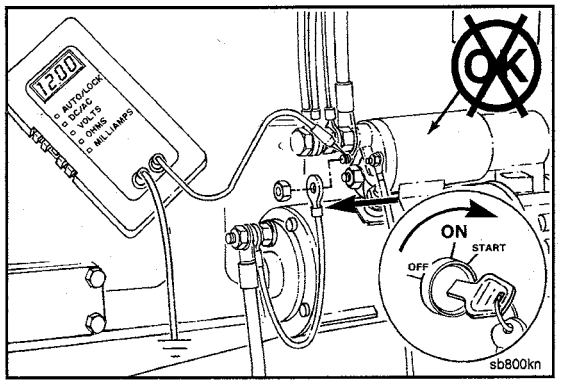


If the multimeter indicates a voltage but the starter will **not** operate, check the wire connecting the starter solenoid to the starter switch for breaks, and also check for loose or corroded connections.

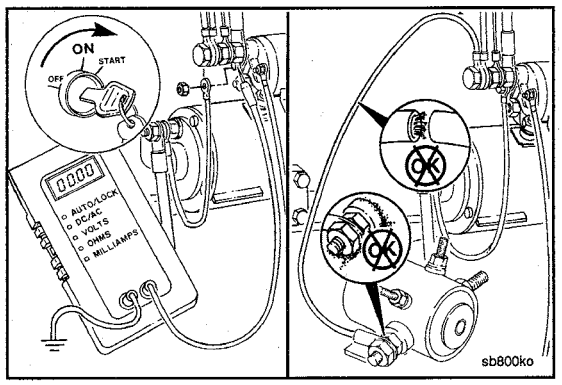


If the wire connecting the starter solenoid and starter switch is **not** loose or damaged, and the starter will **not** operate:

- Remove the cable connecting the starter and starter solenoid from the solenoid terminal.
- Connect the multimeter positive (+) lead to the solenoid positive (+) terminal and the negative (-) lead to the chassis or an engine ground location



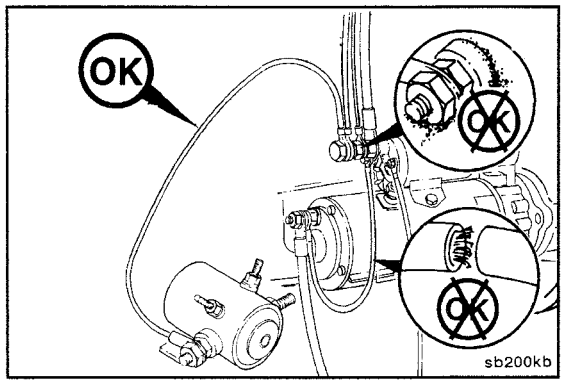
- Turn the starter switch to the START position
- If the multimeter indicates a voltage, the starter solenoid is malfunctioning and **must** be replaced.



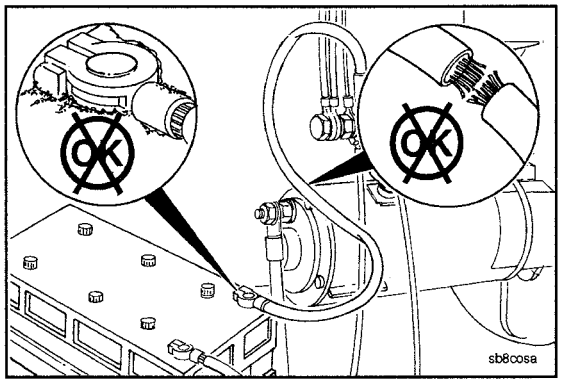
- If the multimeter does **not** indicate a voltage, check the wire connecting the starter solenoid to the magnetic switch for breaks and for loose or corroded connections.

If the wire connecting the starter solenoid to the magnetic switch is **not** loose or damaged, and the starter will **not** operate:

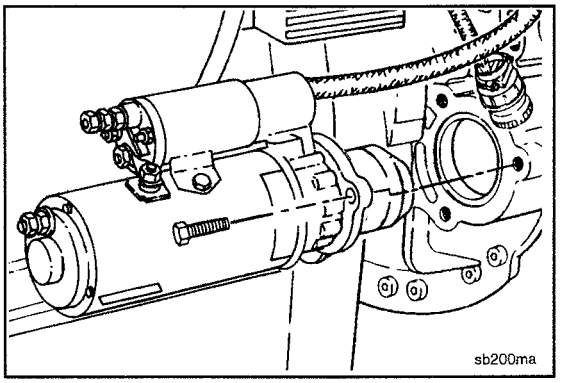
- Check the cable connecting the starter solenoid to the starting motor for breaks and for loose or corroded connections.



- Check the cable connecting the starting motor to the battery for breaks and for loose or corroded connections.



- If the cables are **not** loose or damaged, the starting motor is defective and **must** be replaced.

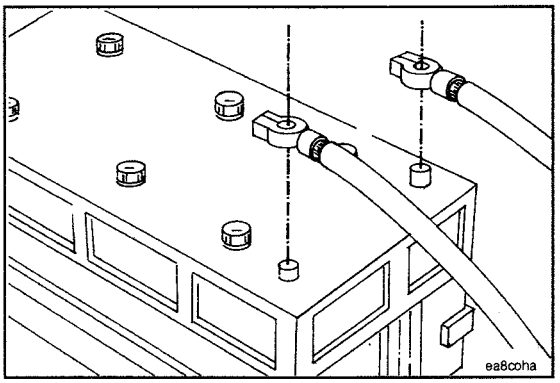


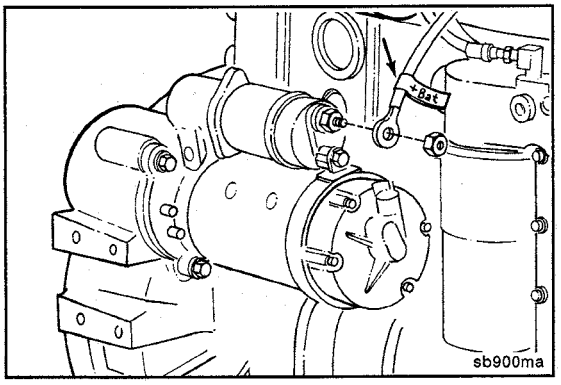
Starting Motor (013-020)

Remove (013-020-002)

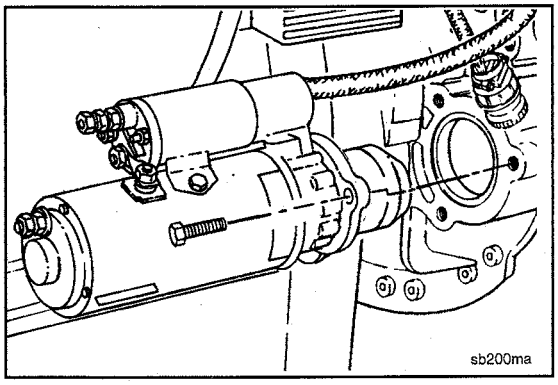
NOTE: The starting motor mounting capscrews can be metric or standard thread sizes. Make sure to install the same size capscrews that were removed.

Remove the electrical connections from the batteries.

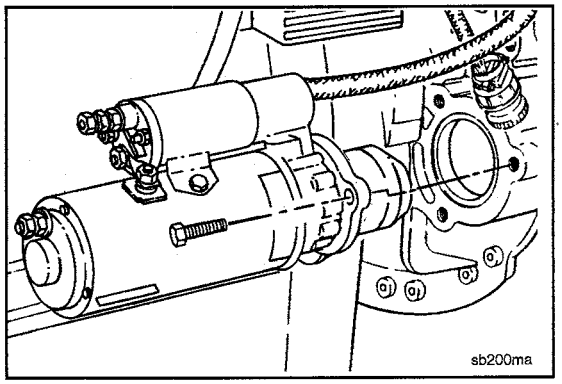




Tag and remove the electrical connections from the starting motor.



Remove the three capscrews and the starting motor.



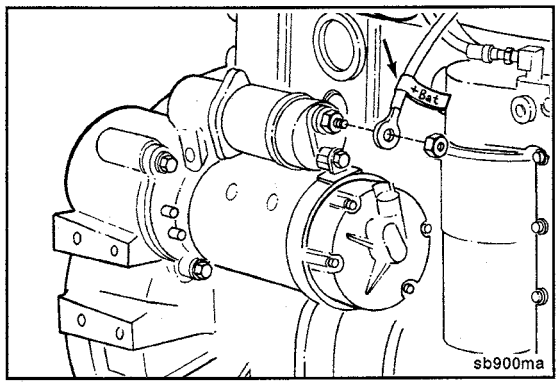
Install (013-020-026)

Before installing the starting motor, make sure the capscrews are the correct size and grade.

Install the starting motor and the three mounting capscrews.

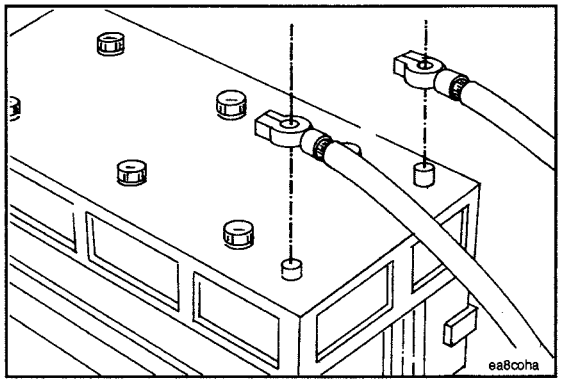
Tighten the capscrews.

Torque Value: 90 N•m [140 ft-lb]



Install and tighten the electrical connection to the starting motor.

Install and tighten the battery electrical connections.



NOTES

Section 14 - Engine Testing - Group 14

Section Contents

Page

Dynamometer Worksheet 14-10
Worksheet 14-10

Engine Run-in (Chassis Dynamometer) 14-20
Run-In Instructions 14-20

Engine Run-in (Without Dynamometer) 14-23
Run-In Instructions 14-23
Off-Highway Applications 14-24
On-Highway Applications 14-23

Engine Testing - General Information 14-1
Fuel Flow Measurement on Engine or Chassis Dynamometer 14-4
General Information 14-1

Engine Testing (Chassis Dynamometer) 14-11
Setup 14-11
Test 14-13

Service Tools 14-8
Engine Testing 14-8

Specifications 14-6
Engine Testing 14-6

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Engine Testing - General Information

General Information

This section outlines engine testing and engine run-in recommendations for M series engines. All engines **must** be run-in after a rebuild or a repair involving the replacement of one or more piston ring sets, cylinder liners, or cylinder kits.

Incorrect or insufficient break-in of the piston rings will lead to early oil consumption or high blowby complaints. Adherence to these run-in guidelines will allow the full durability of new pistons, liners, and rings to be realized.

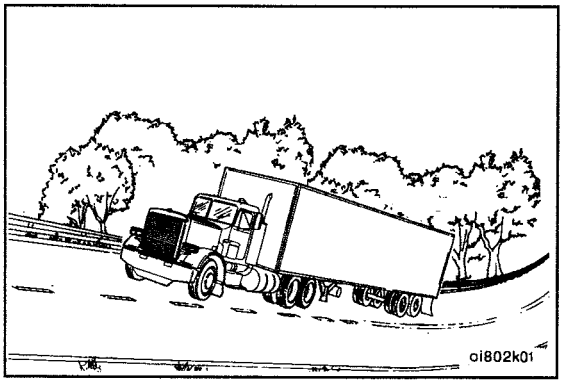
Before running the engine, make sure the engine is filled with the proper coolant. Also, be sure the lubricating oil system is filled and primed.

In-Service Run-in

The majority of heavy-duty diesel applications will provide sufficient run-in under normally **loaded** operations. However, light-load/high-rpm operation **must** be avoided during the run-in period. The following in-service run-in guidelines are recommended for M series engines after a repair involving replacement of one or more of the piston ring sets, cylinder liners, or cylinder kits where engine or an engine dynamometer and/or chassis dynamometer run-in can **not** be performed.

Engine Dynamometer Run-in

This is the preferred method of run-in for engines that have been rebuilt **out of chassis.** It is neither practical nor recommended that an engine be removed from the application to conduct the run-in after a rebuild or cylinder repair has been performed in-chassis. It is neither required nor recommended that an engine, which has been run-in and tested on a dynamometer, be run-in again after having been reinstalled in the vehicle.



DEFINITION OF TERMS ON ENGINE PERFORMANCE CURVE

Cummins M Series Heavy-Duty Engine Operating Curve Definitions:

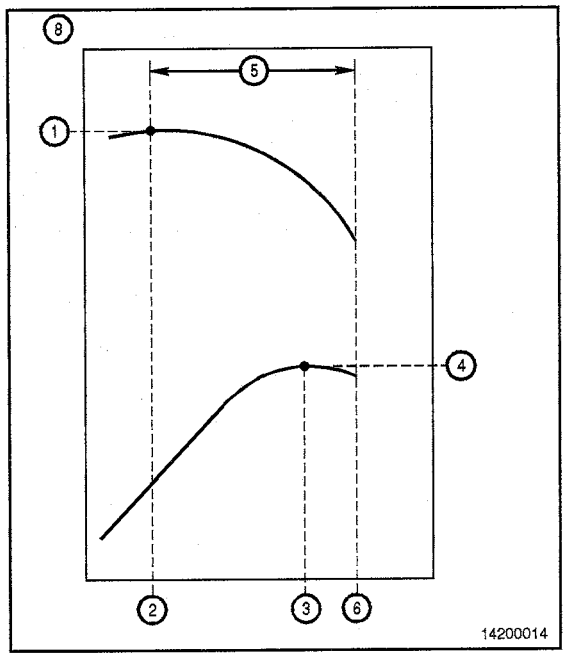


Fig. 1

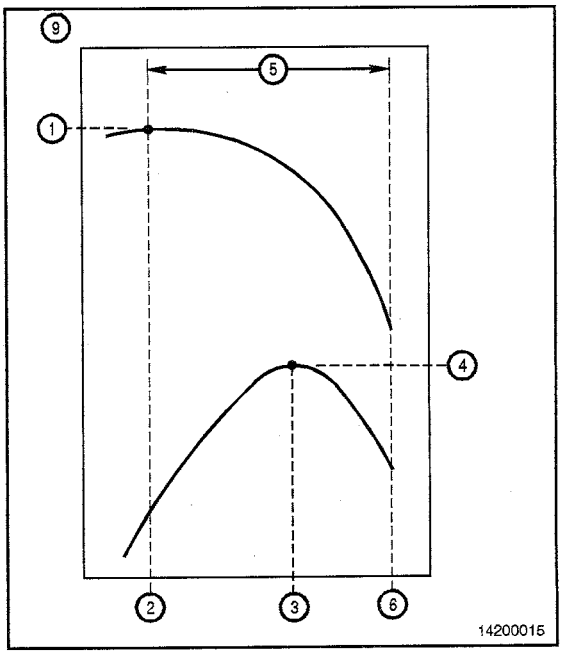


Fig. 2

1. **Peak Torque (N•m [ft-lb])** - Maximum torque that the engine will produce. This is listed on the engine dataplate.

2. **Peak Torque rpm** - Engine speed at which peak torque is generated. This is listed on the engine dataplate.

3. **Maximum hp rpm** - Engine speed at which maximum power is developed. This is listed with advertised horsepower on the engine dataplate.

4. **Advertised Horsepower (hp)** - Maximum power that the engine will develop. This is provided on the engine dataplate with its corresponding engine speed.

5. **Operating Range** - The engine's operating range from peak torque up to the engine's governed speed.

6. **Full-Load Governed Speed** - Defined as the upper end of the engine's full-load operating range. This is listed on the engine dataplate.

7. **No-Load Governed Speed** - (**not** shown) Maximum unloaded engine speed. This value is listed on the engine data sheet and in the FPEPS publications.

8. **Line Haul Rating** - An engine that has a line haul rating has a narrow operating range (rpm). A line haul rating is typically used for on-highway applications. These engines are used with larger (more gears, 13 speed, and so forth) transmissions with close ratio splits between gear shifts.

9. **Vocational Rating** - A vocational-rated engine has a wider operating range (rpm). This rating is typically used for on and off, or off-highway applications. These engines are used with smaller (fewer gears, 9 speeds, and so forth) transmissions with large ratio splits between gear shifts.

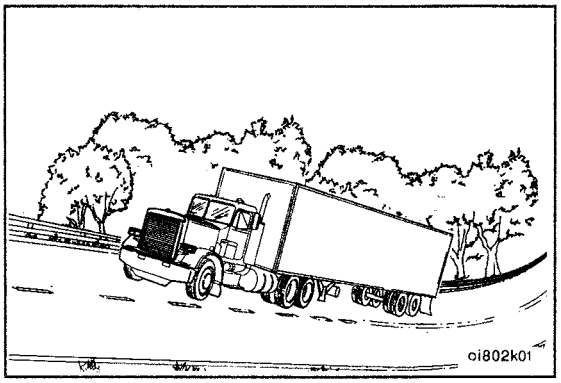
General Run-in Procedures

⚠ CAUTION ⚠

Refer to General Engine Test Specifications in this section before operating the engine to avoid internal component damage.

The amount of time specified for the following engine run-in phases are minimums.

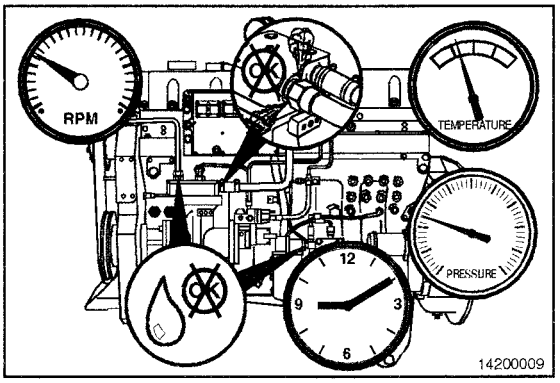
The engine can be operated for longer periods of time at each operating range or phase with the exception of engine idling, which **must** be kept to 5 minutes or less.



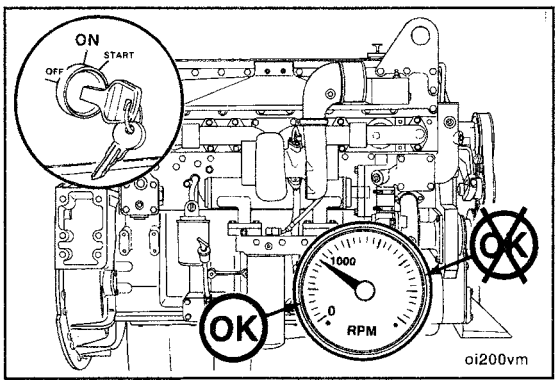
Start the engine and idle for initial check.

Avoid long idle periods. Operate the engine at low idle **only** long enough (5 minutes maximum) to check for correct oil pressure and any fuel, oil, water, or air leaks.

Do **not** operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation will occur and cause damage to the engine.

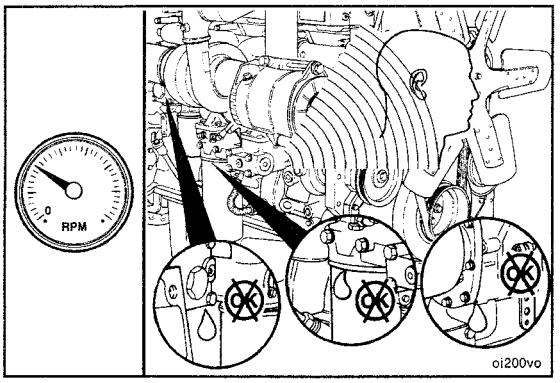


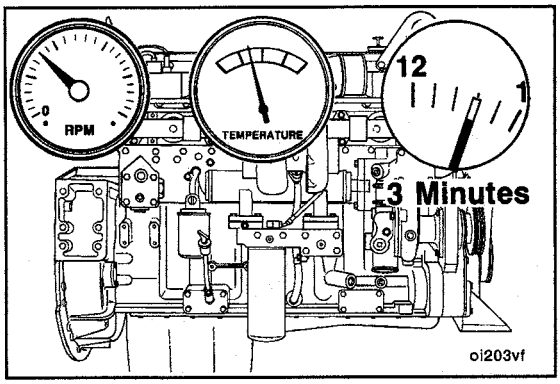
To avoid internal component damage, do **not** allow the engine speed to exceed 1000 rpm before run-in.



While the engine is idling, listen for unusual noises; watch for coolant, fuel, and lubricating oil leaks; and check for correct engine operation in general.

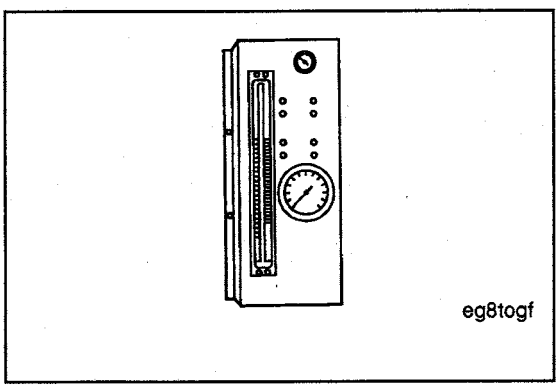
Repair all leaks or component problems before continuing the engine run-in.





⚠ CAUTION ⚠

Do not shut off the engine immediately after the run-in is completed. Allow the engine to cool by operating at low idle for a minimum of 3 minutes to avoid internal component damage.



Fuel Flow Measurement on Engine or Chassis Dynamometer

Accurate fuel flow measurement is important for evaluation of engine performance and troubleshooting on an engine or chassis dynamometer. The **only** way accurate fuel flow measurement can be obtained is through proper use of the available equipment. Below is a description of the fuel measuring device, available from Cummins Engine Company, along with installation and operation recommendations. The fuel measuring device, Part No. 3376375, can be used with either a chassis or engine dynamometer.

Installation

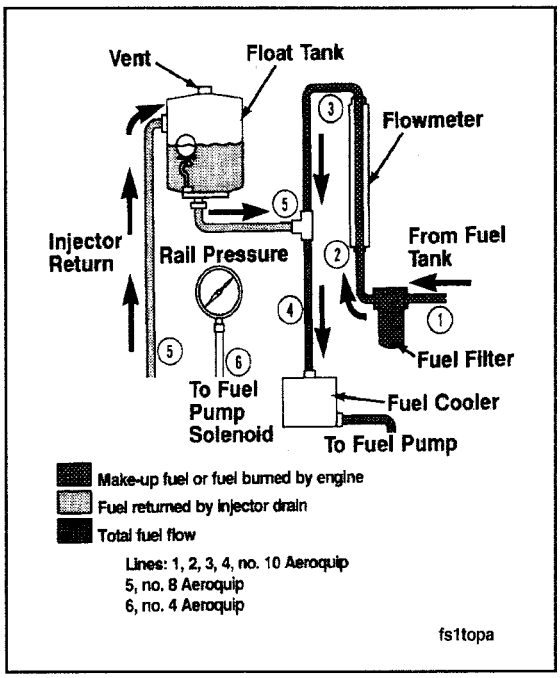
When installing the fuel measuring device, it is important to reduce the amount of air that can be introduced into the system when the device is **not** in use. Therefore, the plumbing used **must** include nonrestrictive shutoff valves, such as ballcock valves, to contain fuel in the device after each use. Additional installation considerations are:

- The fuel measuring device, Part No. 3376375, **must** be mounted vertically to maintain accuracy and proper operation.
- A separate fuel supply for use on the dynamometer is recommended. All fuel used in the measuring device **must** be clean for consistent operation.
- Care **must** be taken to reduce fuel line restriction to and from the engine. Minimum recommended hose sizes are No. 10 for the engine fuel inlet and No. 8 for the engine fuel drain. The length of either hose **must not** exceed 15 feet.
- For accurate fuel consumption or flow measurement while testing on a chassis dynamometer, it is recommended to use a fuel cooler to maintain inlet temperature to the fuel gear pump at 49°C [120°F] or below.

Operation

This is a schematic of the fuel measuring device, Part No. 3376375. The device consists of the following components:

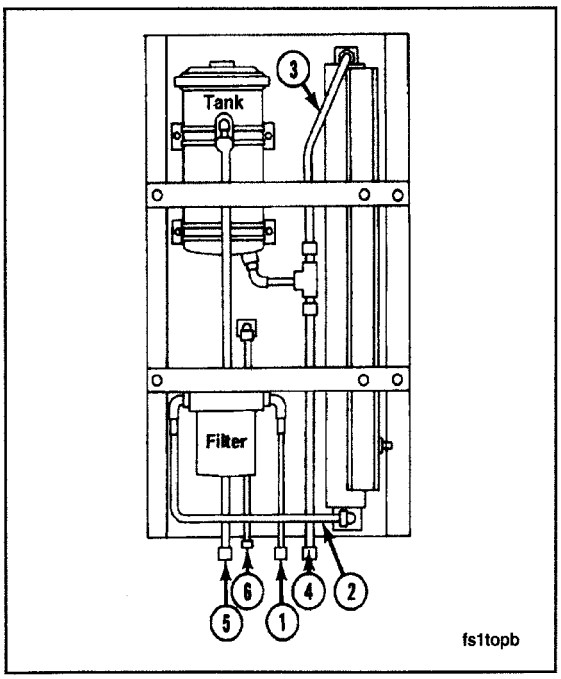
- Fuel filter
- Flow meter
- Float tank
- Fuel rail pressure gauge
- Fuel cooler is **not** a part of fuel measuring device, Part No. 3376375; however, it **must** be used when conducting a test with the flow meter.

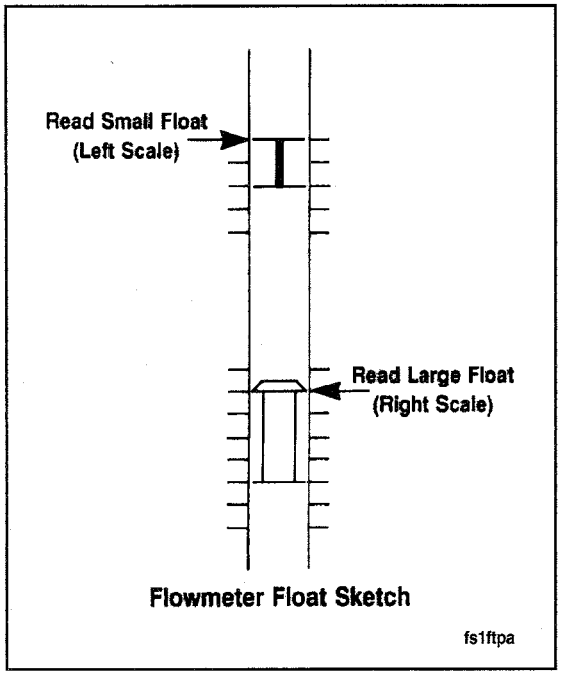


The fuel measuring device recirculates return fuel to the engine fuel inlet by routing the return fuel to the top side of the float tank. The fuel is de-aerated as it passes through the baffling in the float tank. A ball float valve at the bottom of the float tank maintains an adequate volume in the tank for de-aeration. The fuel is then returned to the engine fuel inlet. Refer to the sketch for fuel line connection points on the fuel measuring device.

1. Fuel supply from tank
2. Fuel flow to fuel meter
3. Fuel flow from fuel meter
4. Fuel flow to fuel cooler
5. Injector return fuel
6. Fuel rail pressure.

NOTE: The fuel supply tank **must** be below the level of the fuel measuring device to prevent overflow of the float tank. If an overhead fuel supply tank is used, a float-controlled reservoir **must** be installed between the fuel supply tank and the fuel measuring device, and below the level of the device.





The fuel measuring device is installed in series between the fuel supply tank and the engine fuel inlet. The quantity of fuel being drawn through the flow meter is know as "makeup" fuel, or the amount of fuel being burned by the engine.

The flow meter is graduated to read fuel flow in pounds per hour. The flow meter contains two floats with respective scales on either side of the flow meter. The small float is used to measure lower flows and **must** be read on the left scale, as shown. The larger float is for measuring higher flows and **must** be read on the right scale.

To obtain an accurate fuel rate measurement, the flow meter reading **must** be corrected based on the fuel temperature. There is a fuel temperature gauge on the front panel of the fuel measuring device. The gauge is graduated in percent of error by which the reading requires correction. An example is: The fuel of an engine reads 125 lbs/hr on the flow meter, and the temperature gauge reads +2 percent; the corrected fuel flow rate will be 125 plus 2 percent, or 127.5 lbs/hr.

Specifications

Engine Testing

Maintain the following limits during the engine test/run-in procedures:

Due to variations in ratings of different engine models, refer to the specific Engine Data Sheet for the particular engine model being tested.

Charge Air Cooler Restriction (Maximum):
- Mercury ..... 152 mm Hg [6 in Hg]
- Pounds Force ..... 21 kPa [3 psi]

Intake Restriction (maximum at advertised horsepower)
- Clean Air Filter ..... 254 mm H_20 [10 in H_20]
- Dirty Air Filter ..... 635 mm H_20 [25 in H_20]

Maximum Exhaust Back Pressure ..... 75 mm Hg [3 in Hg]

Oil Pressure:
- Low Idle (minimum allowable) ..... 69 kPa [10 psi]
- At 1200 rpm or Torque Peak (minimum allowable) ..... 207 kPa [30 psi]

Maximum Cylinder Block Coolant Pressure (closed thermostat) ..... 275 kPa [40 psi]

Maximum Allowable Coolant Operating Temperature ..... 100°C [212°F]

Maximum Allowable Fuel Inlet Temperature ..... 71°C [160°F]

Fuel Inlet Maximum Restriction:
- Clean Fuel Filter ..... 152 mm [6 in Hg]
- Dirty Fuel Filter ..... 254 mm [10 in Hg]

Fuel Drain Line Maximum Restriction ..... 89 mm Hg [3.5 in Hg]

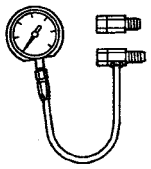
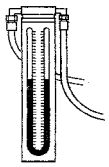
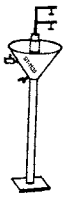
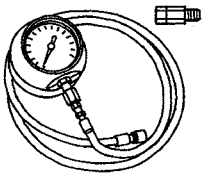
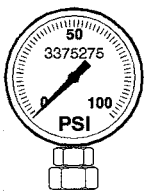
Blowby* (maximum at advertised horsepower):
- New or Rebuilt Engines (maximum)
  - (less than 160,000 km [100,000 mi] or 3600 hours) ..... 305 mm H_20 [12 in. H_20]
- Used Engines (maximum)
  - (over 160,000 km [100,000 mi] or 3600 hours) ..... 460 mm H_2 0 [18 in H_20]

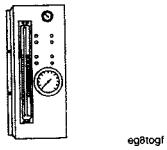
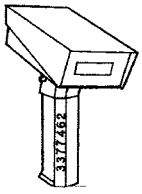
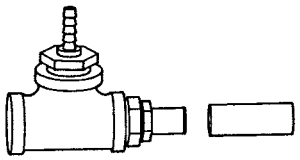
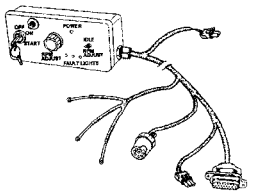
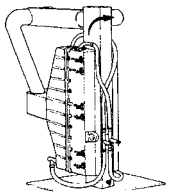
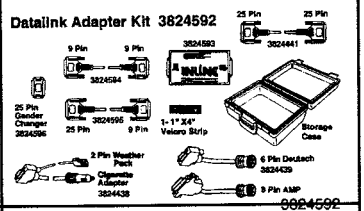
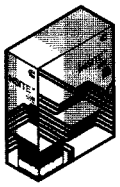
Blowby checking tool, Part No. 3822566, has a special 7.67 mm [0.302 in] orifice that **must** be used to be certain an accurate reading is obtained.

Service Tools

Engine Testing

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-434	**Vacuum Gauge** Used to check fuel filter or intake air restriction.	 eg8togc
ST-1111-3	**Manometer** Used with tool, Part No. 3375150, for measuring blowby.	 eg10oja
ST-1135	**Lubricating Oil Sampling Filter** Used to monitor oil contamination.	 st-1135
ST-1273	**Pressure Gauge** Used to measure intake manifold pressure. The pressure gauge is not needed if INSITE™ is available.	 eg8togi
3375275	**Pressure Gauge (0 to 160 psi)** Used to measure lubricating oil pressure. The pressure gauge is not needed in INSITE™ is available.	 3375275
3375932	**Pressure Gauge (0 to 300 psi)** Used to measure fuel pressure. Includes necessary hoses and hardware to attach to a fuel pump. Part No. ST-435-1 is the hose and Part No. ST-435-6 is the pressure gauge.	 eg8togh

Tool No.	Tool Description	Tool Illustration
3376375	**Fuel Measuring Device** Measure the rate of fuel consumption of a Cummins diesel engine.	
3377462	**Digital Optical Tachometer** Used to measure engine speed (rpm). The digital optical tachometer is not needed if Insite is available.	
3822566	**Blowby Check Tool** Used with manometer, Part No. ST-1111-3, to measure the engine crankcase pressure.	
3823948	**CELECT™/CELECT™ Plus Engine Dyno Control** Used on an engine dyno to control the CELECT™/CELECT™ Plus engine.	
3823978	**Dyno-Room Charge Air Cooler** Used to cool intake air when an air-to-air engine is used on an engine dyno.	
3162844	**Data link Adapter Kit** INLinE2 adapter and associated cables are used to connect a computer to an engine datalink.	
3886206	**INSITE™ software kit** This kit contains INSITE™ software kit, Part No. 3885790, for use with interact system engines. Each software kit can also be ordered separately. The kits are used to troubleshoot, program, and adjust the electronic system.	

Dynamometer Worksheet (014-001)

Worksheet (014-001-056)

Date:	Repair Order No:	Operator:
ESN:	CPL:	Fuel Pump Code:
Complaint:		SC Code:

PARAMETER	CODE SPECIFICATIONS	ACTUAL READING
Fuel Pressure (psi @ rpm)	Refer to Specifications - Engine Testing	
Fuel Rate (lb/hr)		
Intake Mfd. Pressure (in Hg)	See Fuel Pump Code	
Intake Mfd. Temperature		
*Intake Air Restriction	25 in H_20, Maximum	
*Exhaust Air Restriction	3 in Hg, Maximum	
*Fuel Inlet Restriction	Refer to Specifications - Engine Testing	
*Fuel Drain Line Restriction	3.5 in. Hg	
Engine Blowby	12 in H_2O New Engines, Max. 18 in H_20 Used Engines, Max.	
* Recorded at maximum horsepower speed and full load		

Road Speed Limit				Engine High Speed Limit		
Check Oil Level	Low	High	OK	**Fuel Quality**	OK	**Not** OK

Engine Speed	Fuel *Rate/Press		Fuel Temp	Turbo Inlet Air Temp	Intake Manifold Temp/Press		Coolant Temp/Press		Engine Blowby	Lube Oil Press	hp or Torque

* Be sure that the fuel rate is corrected for temperature.

Fuel Temperature	Correction for Flow Rate
Less than 7°C[45°F]	Flow meter **not** accurate
7 to 13°C[45 to 55°F]	Subtract 2% from flow rate reading
13.0 to 20.0°C[55 to 68°F]	Subtract 1% from flow rate reading
20.0 to 29°C[68 to 85°F]	No Correction
29 to 42°C[85 to 108°F]	Add 1% to flow rate reading
42 to 56°C[108 to 132°F]	Add 2% to flow rate reading
56°C above [132°F]	Flow meter **not** accurate

Pressure Conversions

1 in H_20 = 0.074 in Hg = 0.036 psi
1 in Hg = 13.514 in H_2 0 = 0.491 psi
1 psi = 2.036 in Hg = 27.7 in H_20

This Page Can Be Copied For Your Convenience.

Engine Testing (Chassis Dynamometer) (014-002)

Setup (014-002-011)

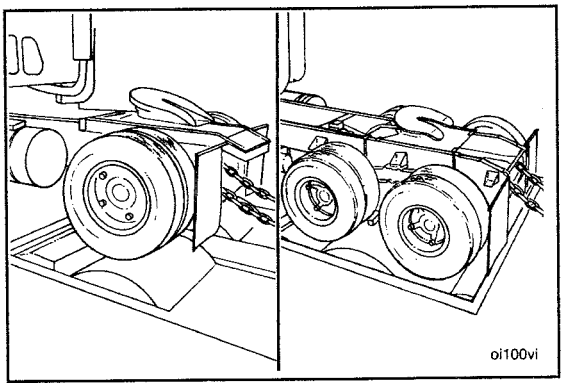
The performance of an engine installed in "on-highway" vehicles can be tested on a chassis dynamometer.

NOTE: Due to driveline inefficiencies and engine-driven accessories, the rated horsepower will be reduced by approximately:

- 20 percent for single-axle vehicles
- 25 percent for tandem-axle vehicles.

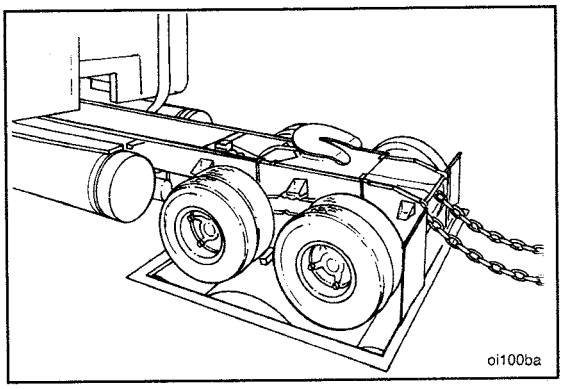
The net horsepower available is called wheel horsepower (WHP).

NOTE: These percentages are used for engine run-in **only** and are **not** to be used as absolute figures.



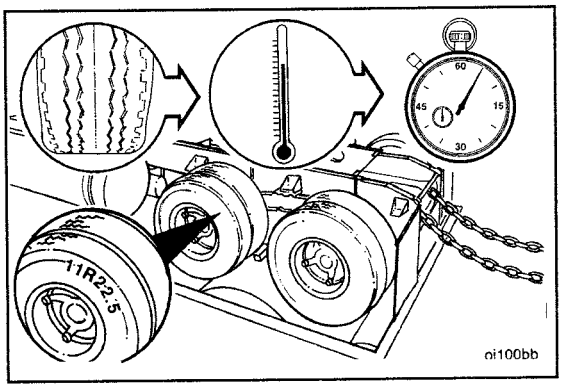
⚠ CAUTION ⚠

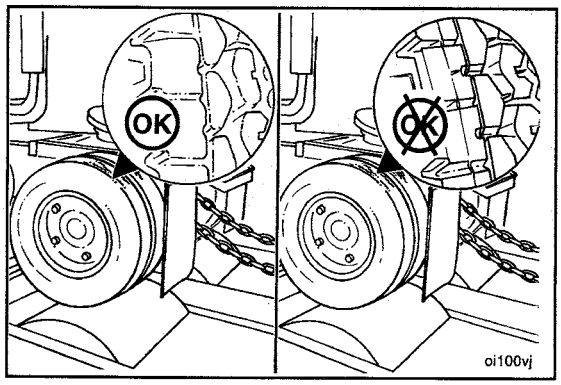
Before installing or operating a vehicle on a chassis dynamometer, follow all the vehicle manufacturer's safety precautions.



⚠ CAUTION ⚠

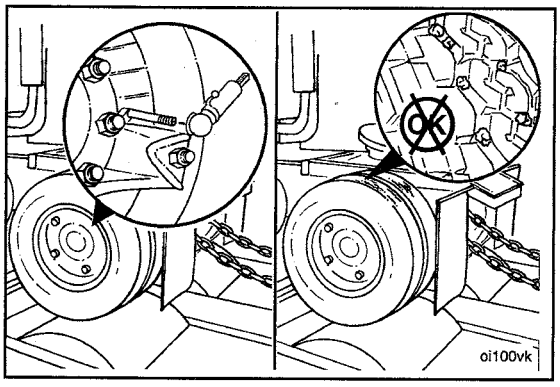
Low-profile radial tires are more sensitive to heat than bias ply tires. Excessive operating time at full load can damage tires due to overheating. Check the tire manufacturer's recommendations for the maximum allowable chassis dynamometer operating time.



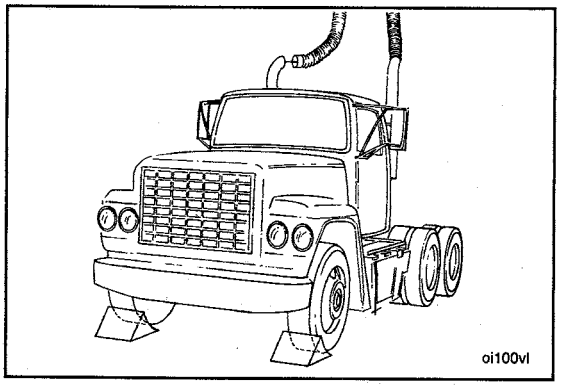


The following are general safety precautions to be observed while operating the chassis dynamometer.

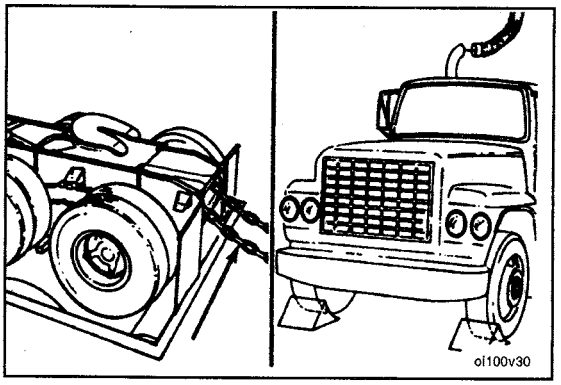
- Use tires that have more than 160 km [100 mi] on them. Do **not** use new tires.
- Do **not** use recapped tires or tires of different sizes or designs.



- Make sure the tires are inflated to the manufacturer's specifications.
- Remove all rocks or other material from the tread of all tires that will be rotating on the dynamometer rollers.



- Make sure there is correct overhead clearance for exhaust stacks, air deflectors, or other attachments above the cab.

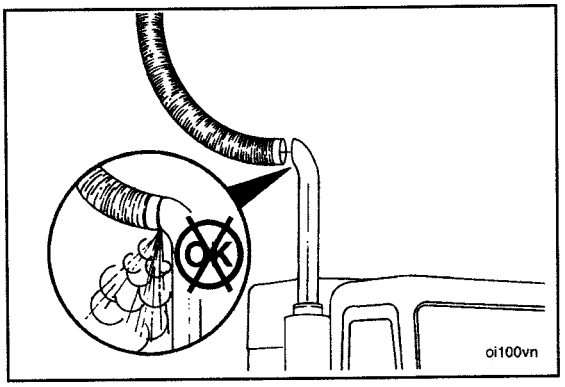


△ CAUTION △

The "tie-down" chains must have slack to prevent damage to the chassis dynamometer.

- Carefully position the vehicle on the rollers.
- Attach the "tie-down" chains to the rear of the vehicle, and put wheel chocks in front of the front wheels.

- Adjust the vehicle and dynamometer room exhaust system to make sure all exhaust gases are removed from the room.
- Refer to the chassis dynamometer and vehicle manufacturer's recommendations and specifications for testing procedures.



Test (014-002-012)

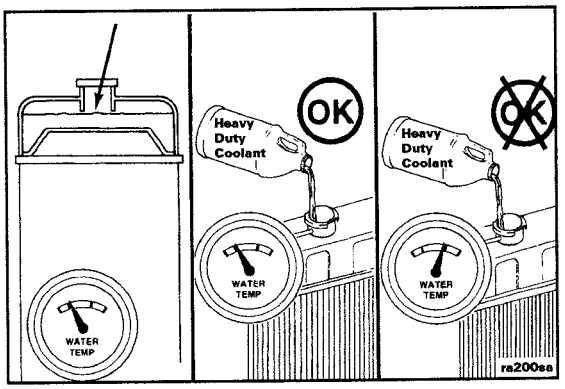
Check the engine coolant level to be sure it is filled to the proper level.

⚠ WARNING ⚠

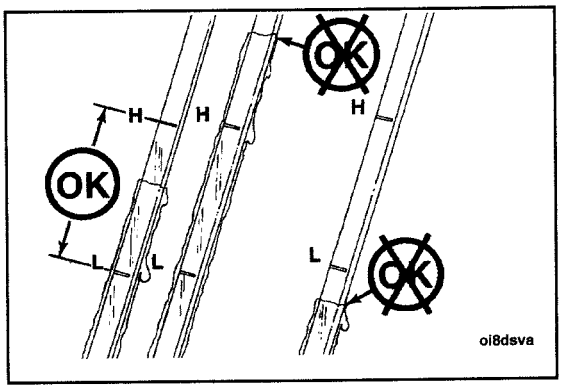
Check the coolant level only when the engine is stopped. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.

⚠ CAUTION ⚠

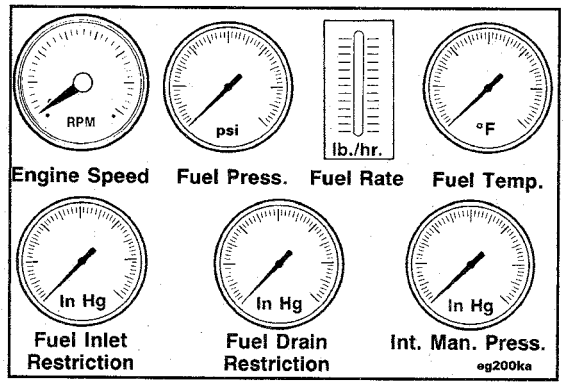
Do not add cold coolant to a hot engine. This can cause engine casting damage. Allow the engine to cool to below 50°C [120°F] before adding coolant.



Check the engine lubricating oil level to be sure it is filled to the proper level.

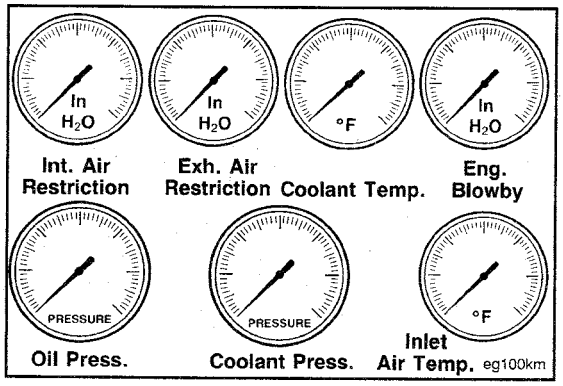


NOTE: Use good quality No. 2 diesel fuel. This is very important since No. 1 diesel fuels, along with most other alternate fuels, are lighter (lower specific gravity, higher API gravity) than No. 2 diesel fuel. The lighter the fuel, the lower the energy content (BTU) per gallon (liter, and so forth).

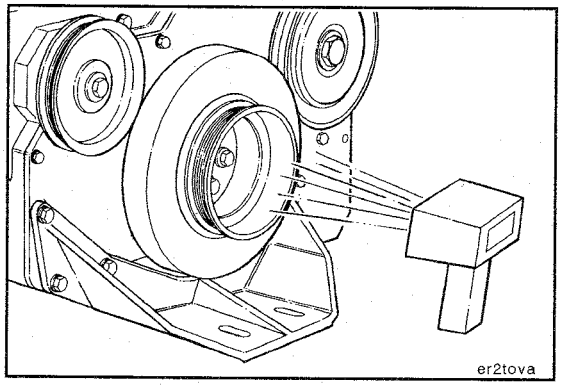


To monitor engine performance properly, record the following parameters. To limit dynamometer operating time, instrument the engine to make as many checks as possible. Refer to the dynamometer worksheet 14-001.

- Engine speed rpm with a verified tachometer
- Fuel pressure
- Fuel rate (use service tool, Part No. 3376375)
- Fuel temperature (if needed to correct fuel rate)
- Fuel inlet restriction
- Fuel drain line restriction
- Intake manifold pressure

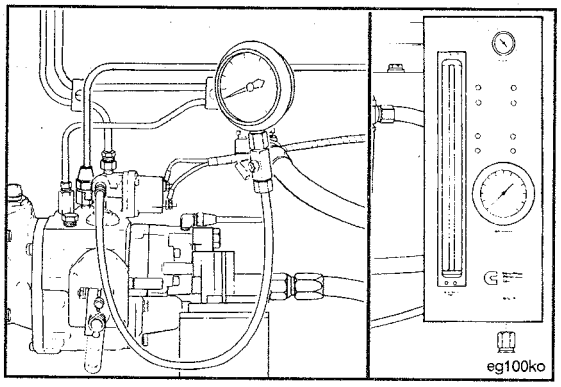


- Intake air restriction
- Exhaust air restriction
- Coolant temperature
- Engine blowby
- Lubricating oil pressure
- Coolant pressure
- Inlet manifold air temperature
- Turbocharger inlet air temperature
- Oil temperature
- Available on INSITE™.



Engine Speed (rpm) With a Verified Tachometer

Use INSITE™ to check and verify engine speed. If INSITE™ is not available, use a digital optical tachometer, Part No. 3377462.



Fuel Pressure

Measure the fuel pressure. Install the pressure gauge, Part No. ST-435-6, or the pressure gauge in the fuel measuring device, Part No. 3376375, to the fitting on the fuel shutoff valve.

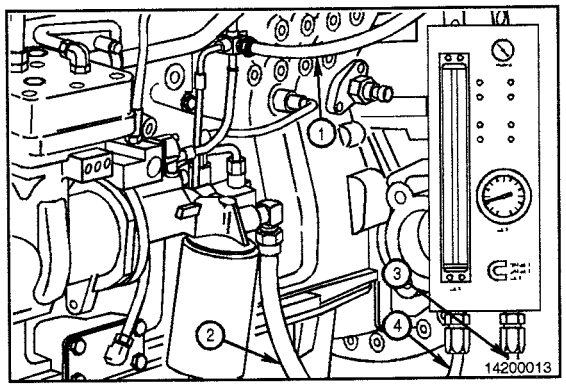
NOTE: Pressure gauge, Part No. ST-435-6, is included with snap rail pressure gauge, Part No. 3375932.

Fuel Rate

Use fuel measuring device, Part No. 3376375, to measure the rate of fuel consumption. For more information, refer to Engine Testing - General Information.

Install the fuel measuring device as follows:

- The fuel return hose from the engine to the fuel measuring device (1).
- The fuel inlet hose to the fuel filter inlet (2).
- The return hose from the device (3) to the fuel tank.
- The fuel inlet hose to the device from the fuel tank suction line (4).



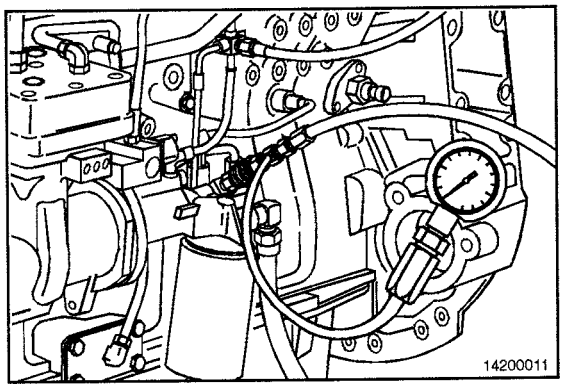
NOTE: Adjust the fuel rate to compensate for temperature variation, if required.

Inlet Fuel Temperature		
°C		°F
15.5	MIN	60
48.9	MAX	120

Fuel Inlet Restriction

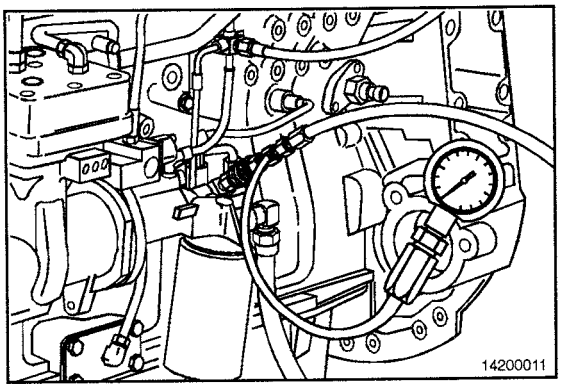
Measure the fuel inlet restriction. Install a vacuum gauge, Part No. ST-434, between the fuel filter and the gear pump inlet.

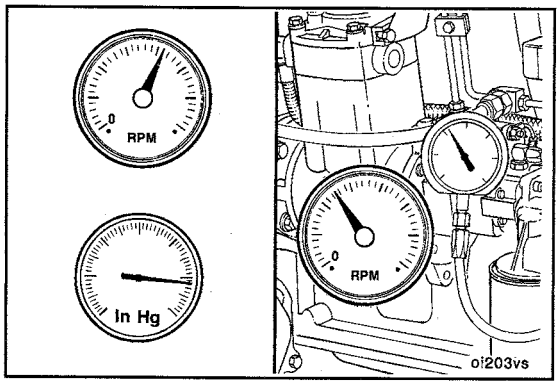
NOTE: Do **not** measure fuel inlet restriction with the fuel measuring device installed. This will **not** measure the inlet restriction of the vehicle's supply plumbing.



Hold the gauge at the same level as the gear pump.

NOTE: The gauge will **not** measure the correct vacuum if the gauge is **not** held at the same level as the gear pump.



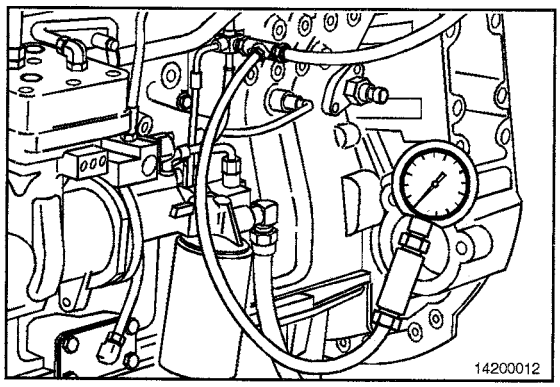


NOTE: On M series engines, it is **not** necessary to operate the engine to maximum horsepower, only high idle.

Observe the reading on the gauge.

Fuel Inlet Restriction			
	mm Hg		in Hg
Clean Filter	152	MIN	6
Dirty Filter	254	MAX	10

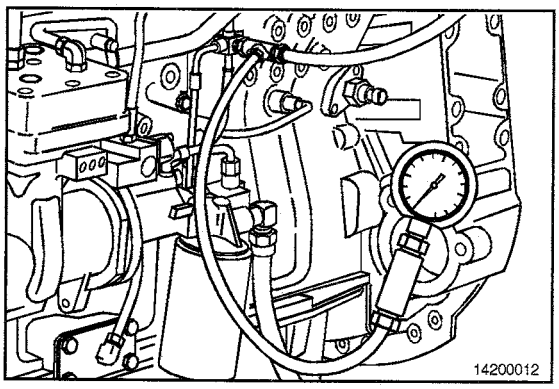
Correct the restriction, or replace the fuel filter.



Fuel Drain Line Restriction

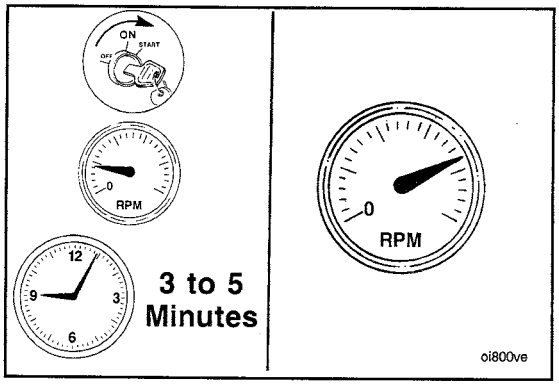
Use pressure gauge, Part No. ST-1273, to measure fuel drain line restriction.

NOTE: Do **not** measure fuel drain line restriction with the fuel measuring device installed. This will **not** measure the drain line restriction of the vehicle's return plumbing.



Hold the gauge at the same level as the connection.

NOTE: The gauge will **not** measure the correct pressure if the gauge is **not** held at the same level as the connection.



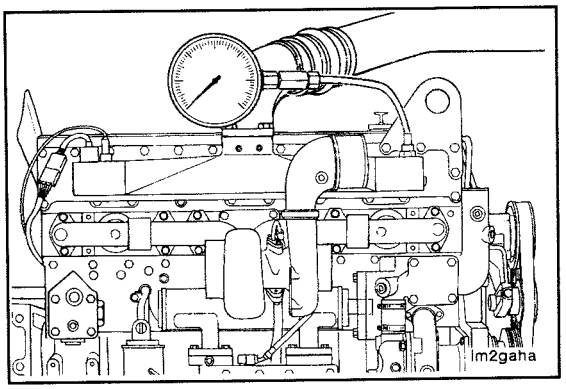
NOTE: On M series engines, it is **not** necessary to operate the engine to maximum horsepower, **only** to high idle.

Observe the reading on the gauge.

Fuel Drain Line Restriction		
mm Hg		in Hg
89	MAX	3.5

Intake Manifold Pressure

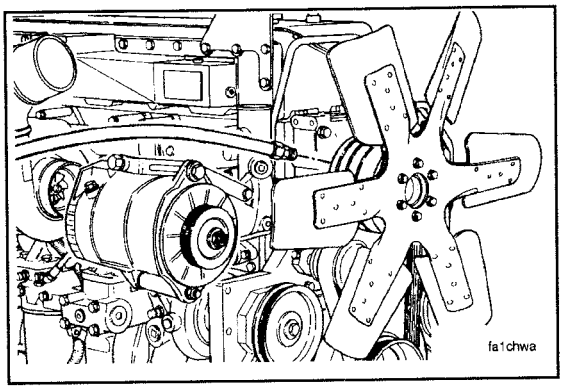
Use INSITE™ to measure the intake manifold pressure (turbocharger boost). If INSITE™ is not available install a pressure gauge, Part No. ST-1273, in the intake manifold as shown.



Intake Air Temperature Control - Chassis Dynamometer Test

When operating an engine on a chassis dynamometer, follow these steps for best results and safe operation.

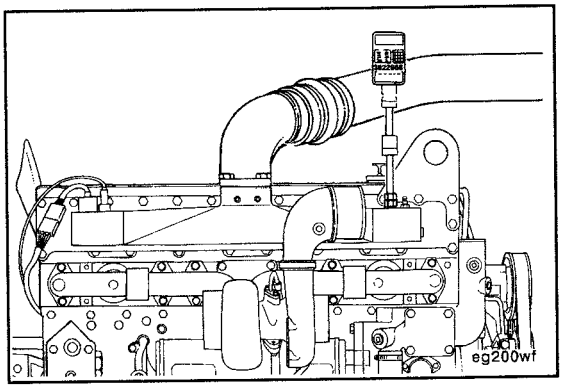
Lock the cooling fan in the ON mode. This can be done by installing a jumper across the temperature switch or by supplying shop air to the control valve. Refer to the fan drive manufacturer for the recommended procedure.



Monitor the intake manifold air temperature using INSITE™ in the monitor mode, or install Fluke digital thermometer, Part No. 3822666, and thermocouple wire kit, Part No. 3822988, into the intake manifold.

The intake manifold air temperature **must not** exceed the maximum allowable temperature. The engine protection system will disrupt performance if the temperatures exceed this level. Maintain intake manifold air temperature at the nominal level or below during chassis dynamometer operation.

Intake Manifold Air Temperature		
°C		°F
66	NOMINAL	150
77	MAX	170



If the intake manifold temperature exceeds 77°C [170°F], shut off the engine. Allow the engine to cool.

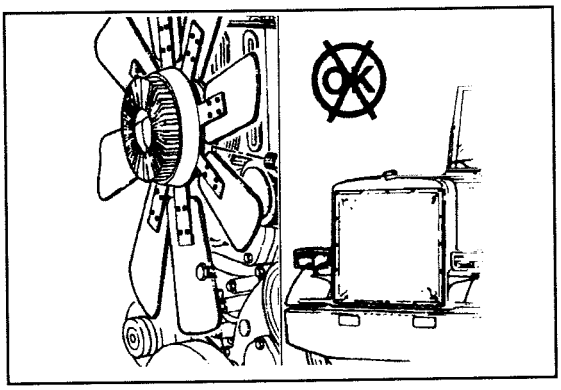
Inspect the CAC fins for obstructions to the airflow.

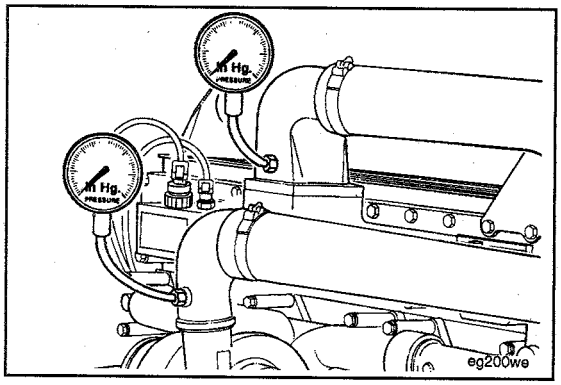
Check the fan drive. Make sure the fan is locked in the ON mode.

Remove any obstructions, such as a winterfront or debris. Manually lock the shutters in the OPEN position, if equipped.

Inspect the dynamometer room for adequate supply of suitably cool or outside air. Make sure that dynamometer room recirculation is **not** an issue.

Resume the test.





Charge Air Cooler Restriction

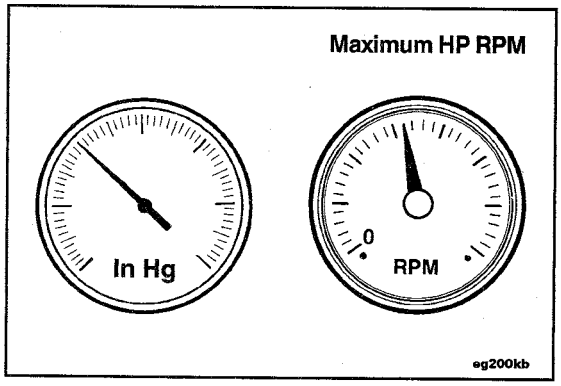
Measure the intake pressure drop across the charge air cooler, if applicable.

This test can be done with a mercury manometer or two separate gauges, Part No. ST-1273. If two gauges are being used, calibrate both gauges on a common pressure source to maintain consistency.

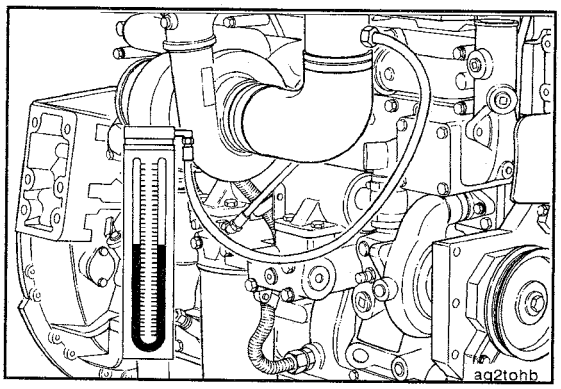
Install one pressure gauge, Part No. ST-1273, in the fitting in the turbocharger compressor outlet elbow. Install the other pressure gauge in the fitting in the intake manifold.

CAC Restriction

mm Hg		in Hg
152	MAX	6



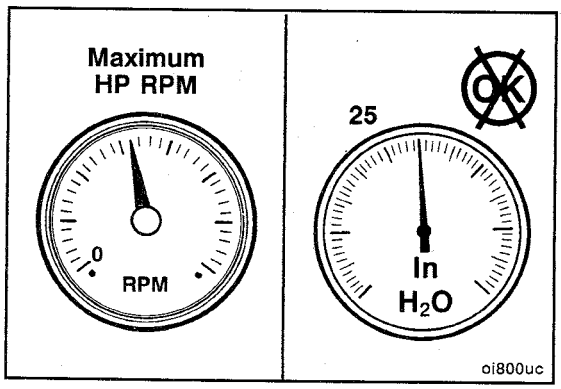
When measuring the pressure drop, operate a dynamometer at the rpm that delivers the maximum horsepower of the engine tested. Engine speed will be 1600 to 1700 rpm on most engines.



Intake Air Restriction

Measure the inlet air restriction. Install the vacuum gauge, Part No. ST-434, or a manometer in the intake air piping.

NOTE: The gauge adapter **must** be installed at a 90-degree angle to the airflow in a straight section of pipe at a minimum of one pipe diameter before the turbocharger.



Operate the engine at maximum horsepower rpm and advertised horsepower.

Observe the reading on the gauge or manometer.

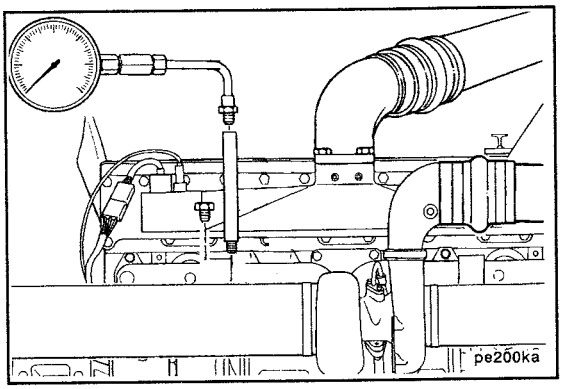
Intake Air Restriction

mm H_2O		in H_2O
635	MAX	25

Exhaust Air Restriction

Measure the exhaust air restriction. Install the pressure gauge, Part No. ST-1273, or a manometer in the exhaust air piping.

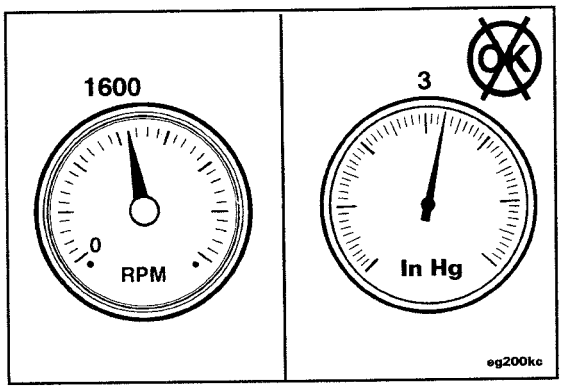
The gauge adapter **must** be installed near the turbocharger in a straight section of pipe at the turbine outlet.



Operate the engine at maximum horsepower rpm and advertised horsepower.

Observe the gauge or manometer.

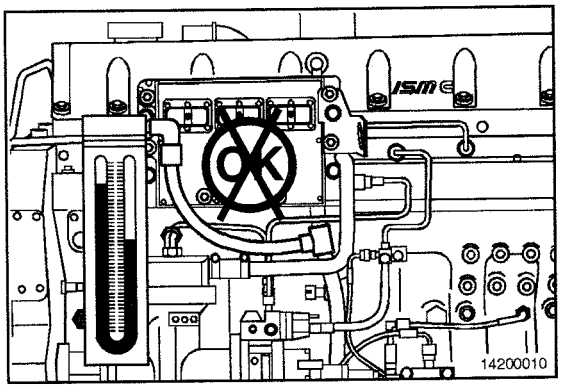
Exhaust Air Restriction		
mm Hg		in Hg
76	MAX	3.0



Engine Blowby

Measure the engine crankcase pressure.

Use blowby checking tool, Part No. 3375150, and water manometer, Part No. ST-1111-3 or 3824645.

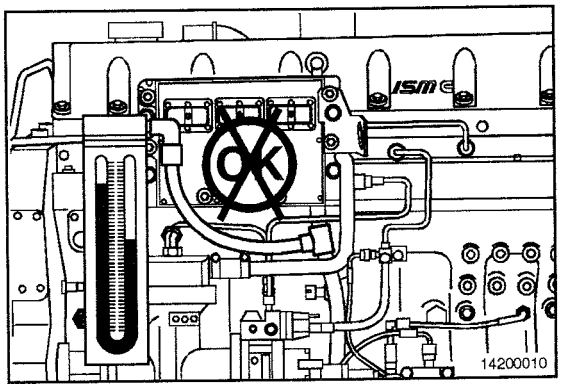


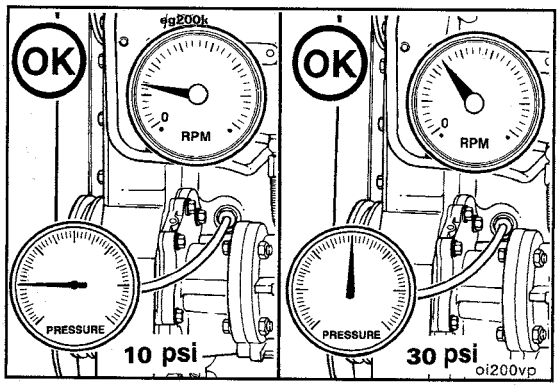
Install the water manometer to the blowby checking tool. Observe the engine blowby.

Engine blowby **must not** exceed the following specifications:

Blowby Specifications	
New, Rebuilt Engines*	30.5 cm H_2O [12.0 in H_2O]
Used Engines**	46.0 cm H_2O [18.0 in H_2O]

*Less than 160,000 km [100,000 mi] or 3600 hours.
**Over 160,000 km [100,000 mi] or 3600 hours.



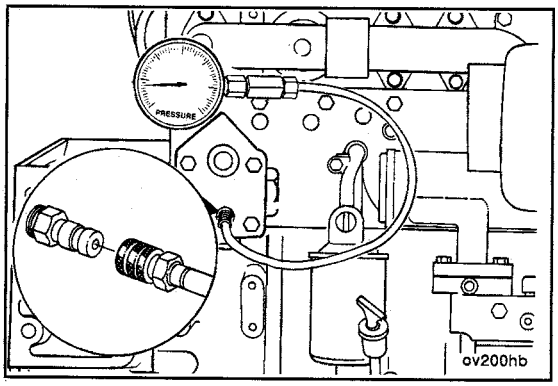


Lubricating Oil Pressure

Use INSITE™ to measure the lubricating oil pressure. If INSITE™ is not available, use pressure gauge Part No. 3375275.

Install the pressure gauge to the main oil rifle, and observe the oil pressure.

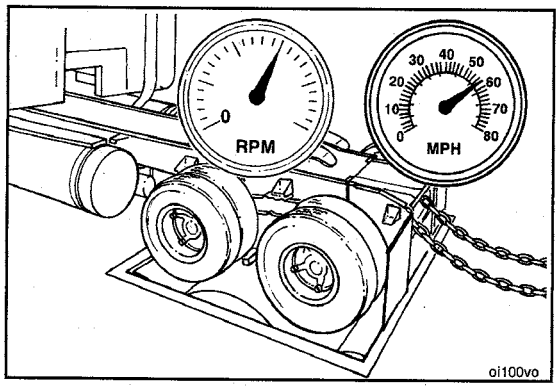
Lubricating Oil Pressure			
	kPa		psi
Low idle	70	MIN	10
At 1200 rpm	207	MIN	30



Coolant Pressure

Use coolant pressure/temperature/flow analyzer kit, Part No. 3822994, to measure engine coolant pressure.

Coolant Pressure		
kPa		psi
275	MAX	40

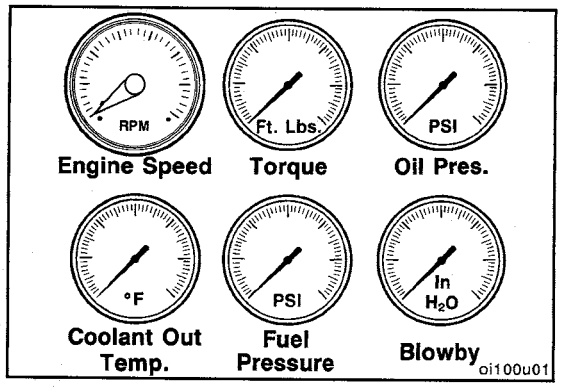


Engine Run-in (Chassis Dynamometer) (014-003)

Run-In Instructions (014-003-276)

Refer to Chassis Dynamometer - Operation, Procedure 014-002, for general operating procedures and safety precautions.

Operate the vehicle in a gear that produces a road speed of 90 to 100 km/h [55 to 60 mph] at maximum horsepower rpm.

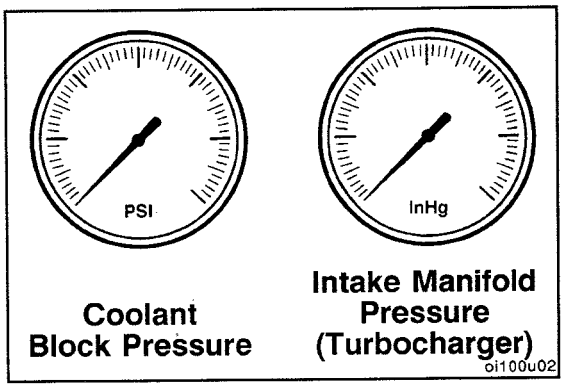


Monitor and record the following measurements during run-in:

- Lubricating oil pressure
- Coolant temperature
- Fuel pressure
- Wheel horsepower
- Crankcase blowby
- Engine speed (rpm)
- Fuel rate (use service tool, Part No. 3376375)
- Intake manifold air temperature
- Intake manifold pressure
- Turbocharger inlet air temperature
- Oil temperature
- INSITE™.

Refer to the Engine Dynamometer Worksheet in section 14-001.

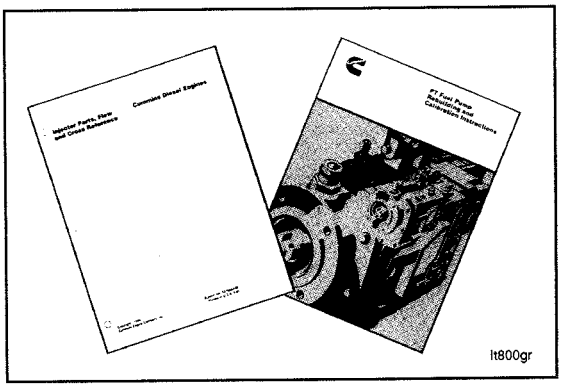
Cummins Engine Company, Inc. recommends monitoring block coolant pressure during run-in to aid in early indication of a cooling system problem.



NOTE: INSITE™ should be used to confirm the ECM code on the ECM is the same as the one installed in the ECM. There is an associated fuel pump code with all ECM codes.

Obtain the ECM code from the ECM dataplate and the fuel pump code from the fuel pump dataplate.

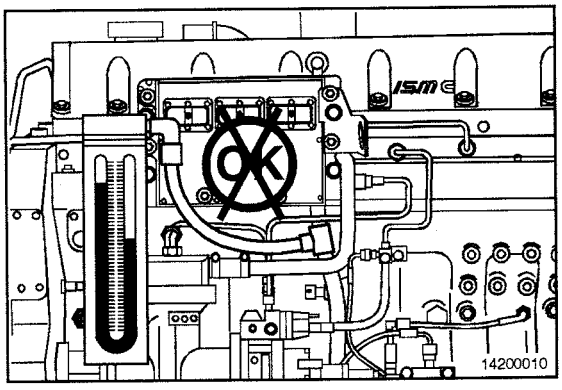
Engine performance specifications are listed for specific pump codes in the distributor information system menu.



During the test, if a sudden increase in blowby occurs or if blowby exceeds the maximum allowable limit during any run-in, return to the previous step of the test and continue the run-in. If blowby does **not** reach an acceptable level during the next step, discontinue the run-in and determine the cause.

Do **not** proceed to the next step until a steady, acceptable blowby reading is obtained.

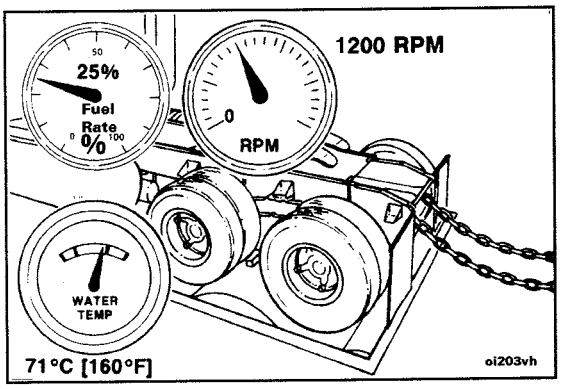
NOTE: Blowby **must** be measured by using service tool, Part No. 3375150 or 3822566 with manometer, Part No. ST-1111-3 or 3824645. Service tool, Part No. 3375150, as shown, utilizes a chamfered 7.67-mm [0.302-in] orifice.

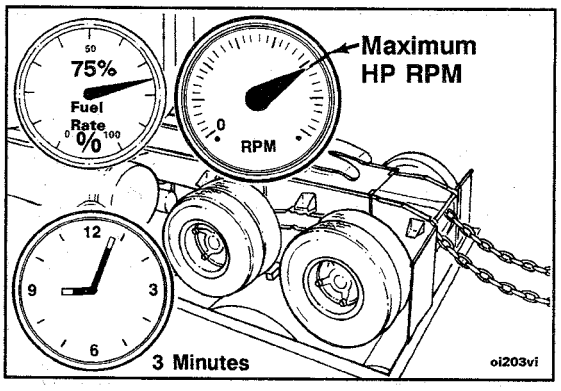


Move the throttle to obtain 1200-rpm engine speed, and apply a test load sufficient to develop 25-percent fuel rate on M series engines.

Operate the engine at this speed and load level until the coolant temperature reaches 71°C [160°F].

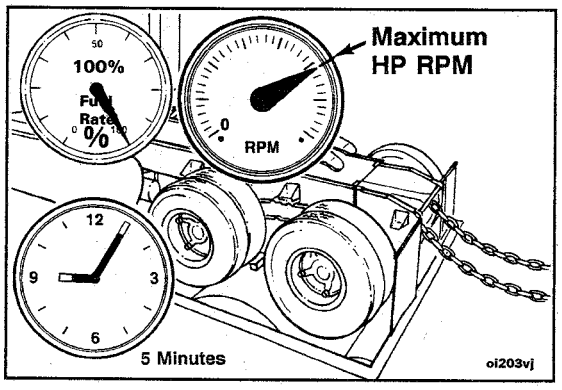
Check all gauges, and record the data.



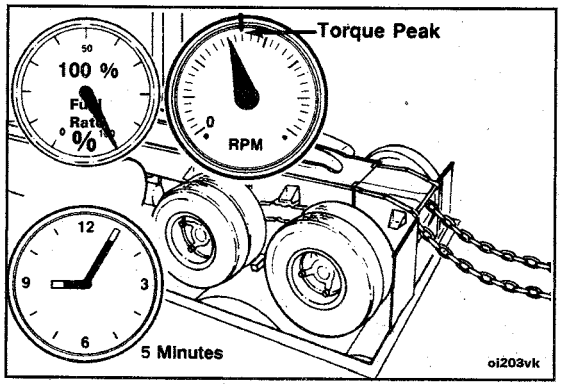


Operate the engine at maximum horsepower rpm and 75-percent fuel rate on M series engines for 3 minutes. Check the gauges, and record the readings.

Do **not** proceed to the next step until a steady, acceptable blowby reading is obtained.

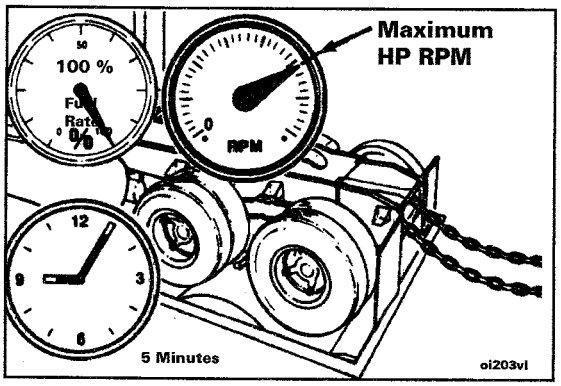


Operate the engine at maximum horsepower rpm and advertised horsepower with a wide-open throttle for 5 minutes. Check the gauges, and record the readings.



Operate the engine at nominal torque peak rpm, wide-open throttle, for 5 minutes. Check the gauges, and record the readings.

Refer to the engine "Data Plates" for the torque peak rpm of the engine model being tested.

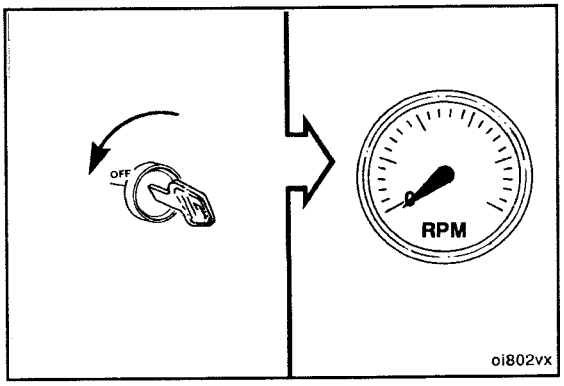


Operate the engine at maximum horsepower rpm with a wide open throttle for 5 minutes. Check the gauges, and record the readings. Compare the readings to those published on the appropriate engine "Data Sheet."

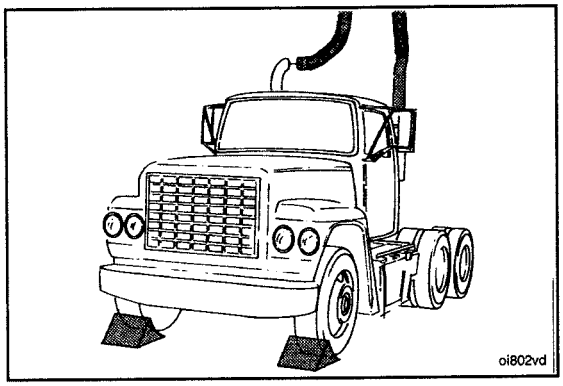
⚠ CAUTION ⚠

Do not shut off the engine immediately after the run-in is completed. Allow the engine to cool by operating it at 700 to 900 rpm for a minimum of 3 to 5 minutes to avoid internal component damage. This allows the turbocharger and other components to cool.

Shut off the engine.



Make sure all instrumentation is removed before removing the vehicle from the chassis dynamometer.



Engine Run-in (Without Dynamometer) (014-004)

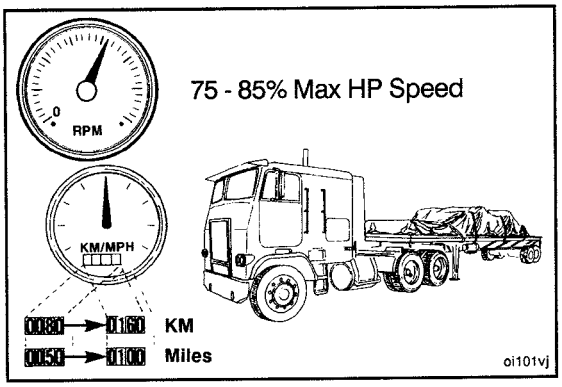
Run-In Instructions (014-004-276)

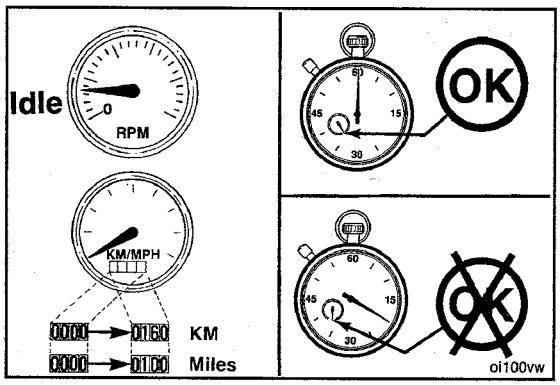
On-Highway Applications

⚠ CAUTION ⚠

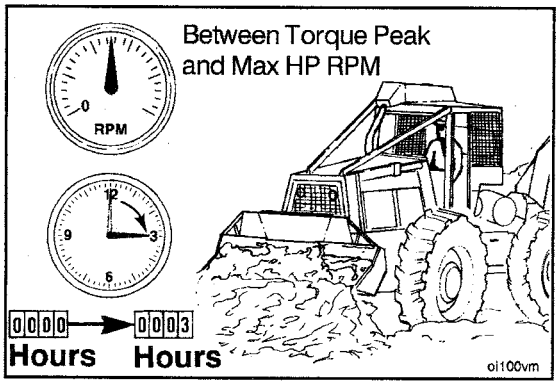
Refer to Engine Testing - General Information and Specifications - Engine Testing at the front of this section before operating the engine to avoid internal component damage.

Operate the vehicle pulling the heaviest available trailer allowed for the first 80 to 160 km [50 to 100 mi] after a rebuild. Operate the vehicle in the highest gear possible within the normal operating rpm range of the engine. It is necessary to operate the engine at or near full throttle at 75 percent to 85 percent of maximum horsepower rpm indicated on the dataplate.





Do **not** idle the engine for more than 5 minutes at any one time during the first 160 km [100 mi] of operation.

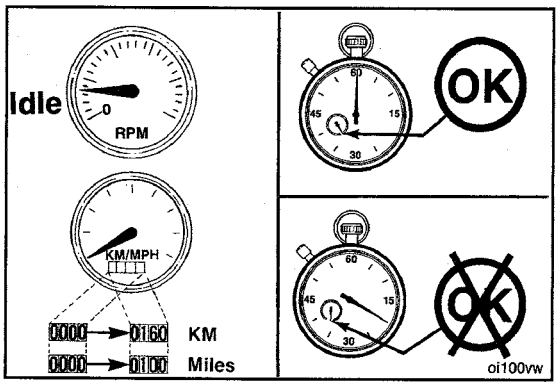


Off-Highway Applications

△ CAUTION △

Refer to Engine Testing - General Information and Specifications - Engine Testing at the front of this section before operating the engine to avoid internal component damage.

Operate the engine under the highest load possible at full throttle within the normal operating rpm range of the engine for the first 3 hours of operation after rebuild.



Do **not** idle the engine for more than 5 minutes at any one time during the first 3 hours of operation after a rebuild.

Section 16 - Mounting Adaptations - Group 16

Section Contents

Page

Engine Lifting Brackets 16-2
Clean 16-2
Inspect for Reuse 16-2
Install 16-2
Remove 16-2

Engine Mounts 16-28
Install 16-28

Engine Support Bracket, Front 16-3
Clean 16-3
Inspect for Reuse 16-3
Install 16-4
Remove 16-3

Flywheel 16-4
Clean 16-5
Inspect for Reuse 16-5
Install 16-6
Measure 16-7
Remove 16-4

Flywheel Housing 16-10
Clean 16-12
Inspect for Reuse 16-12
Install 16-13
Measure 16-13
Remove 16-10

Flywheel Housing, REPTO 16-16
Clean 16-19
Inspect for Reuse 16-20
Install 16-21
Measure 16-22
Remove 16-16

Flywheel Ring Gear 16-27
Install 16-28
Remove 16-27

Service Tools 16-1
Mounting Adaptations 16-1

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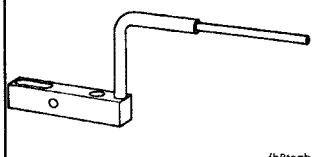
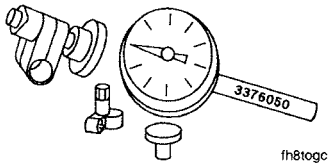
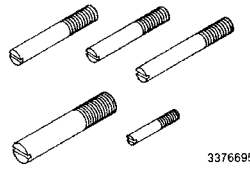
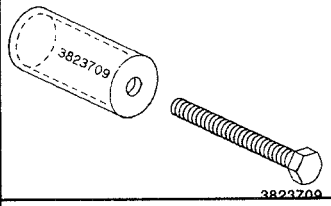
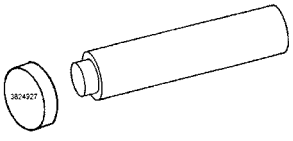
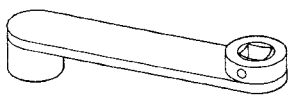
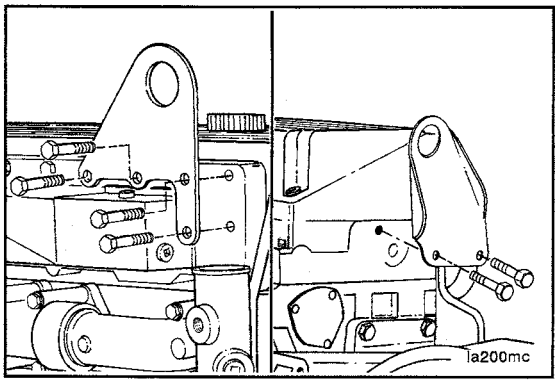
Service Tools

Mounting Adaptations

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-1325	**Dial Gauge Attachment** Attaches to crankshaft flange to provide measuring of flywheel and flywheel housing runout with dial bore gauge.	 fh8togb
3376050	**Dial Indicator and Sleeve Assembly** Use with Part No. ST-1325 dial gauge attachment, to measure flywheel and flywheel housing runout.	 fh8togc
3824926	**Guide Pin Kit** Aid during removal and installation of flywheel and flywheel housing.	 3376695
3823709	**Idler Shaft Puller and Capscrew** Used to remove the idler shaft from the idler gear and flywheel housing on engines equipped with a REPTO flywheel housing.	
3824927	**Cup Plug Driver** Used to install the cup plug in a REPTO flywheel housing. Requires a cup plug driver handle.	 3824927
3824928	**Offset Wrench** Used to loosen or tighten four hidden mounting capscrews on engines equipped with a REPTO flywheel housing.	 3823711

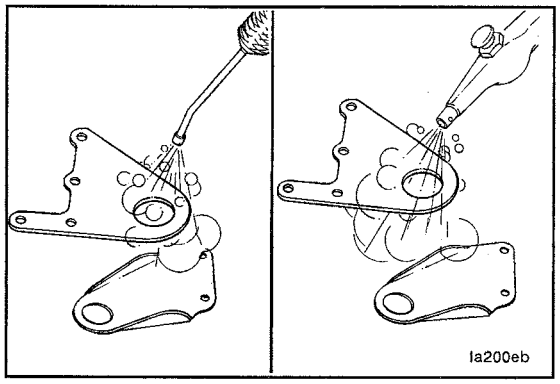


Engine Lifting Brackets (016-001)

Remove (016-001-002)

Remove the capscrews and the front lifting bracket.

Remove the capscrews and the rear lifting bracket.

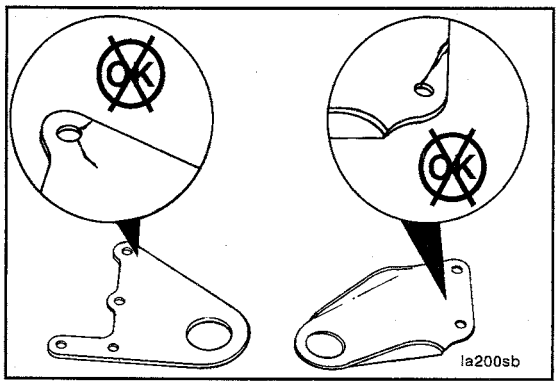


Clean (016-001-006)

⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

Use steam or solvent to clean the lifting brackets. Dry with compressed air.



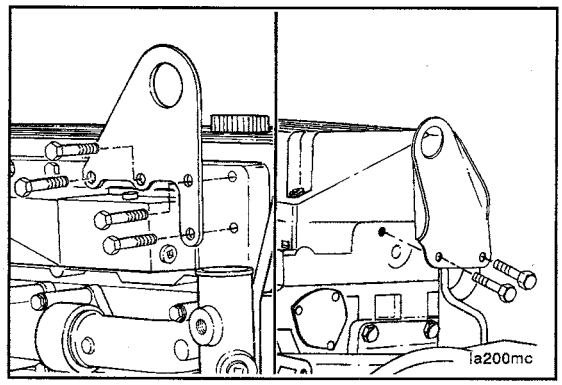
Inspect for Reuse (016-001-007)

△ CAUTION △

Do not use a cracked or damaged bracket. Do not weld a cracked bracket. Personal injury can result.

Inspect the brackets for cracks or damage.

Replace the bracket if it is cracked.



Install (016-001-026)

Install the front bracket and capscrews.

Torque Value: 47 N•m [35 ft-lb]

Install the rear bracket and capscrews.

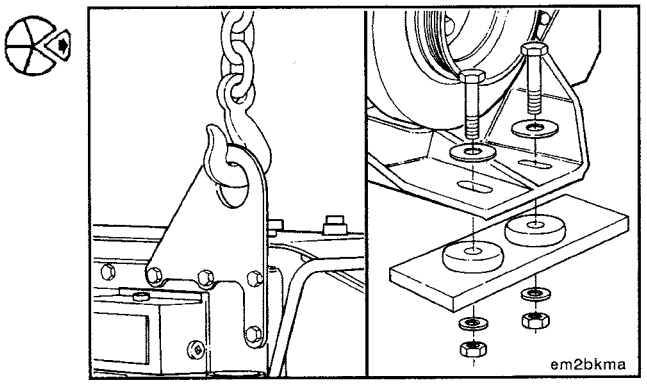
Torque Value: 81 N•m [60 ft-lb]

Engine Support Bracket, Front (016-002)

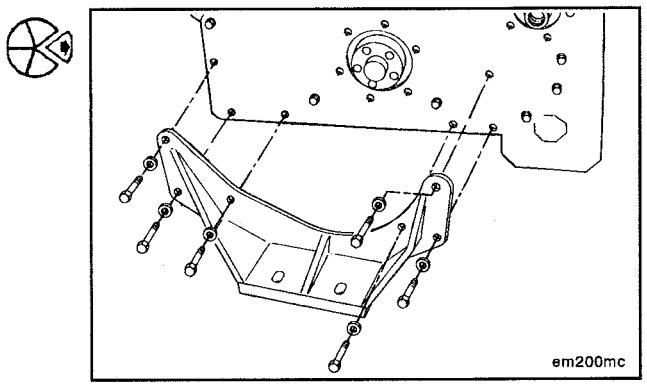
Remove (016-002-002)

Use a hoist or lifting fixture to support the front of the engine.

Remove the capscrews from the front engine mount.



Remove the six mounting capscrews and the front engine support.

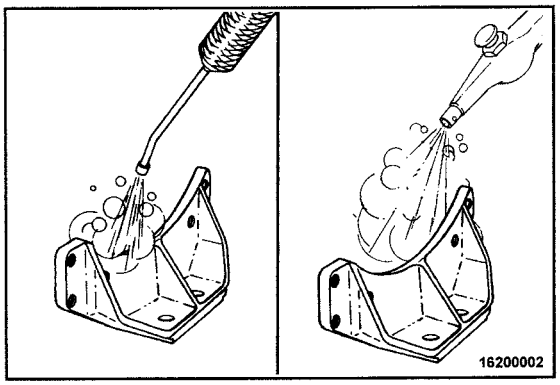


Clean (016-002-006)

⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

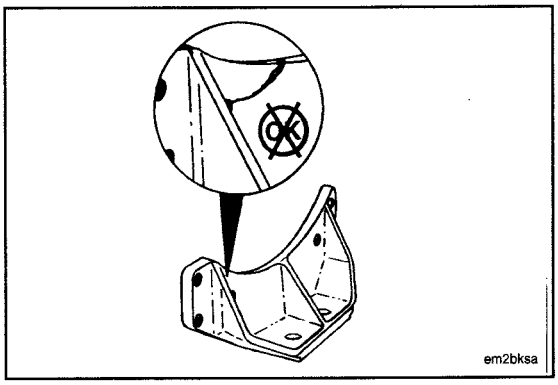
Use steam or solvent to clean the front engine support. Dry with compressed air.

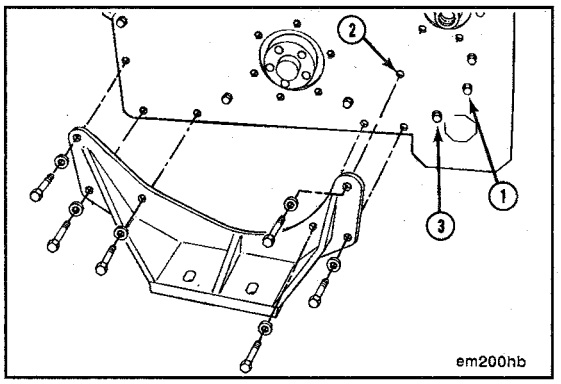


Inspect for Reuse (016-002-007)

Inspect the support for cracks or damage.

If the support is cracked, it **must** be replaced.



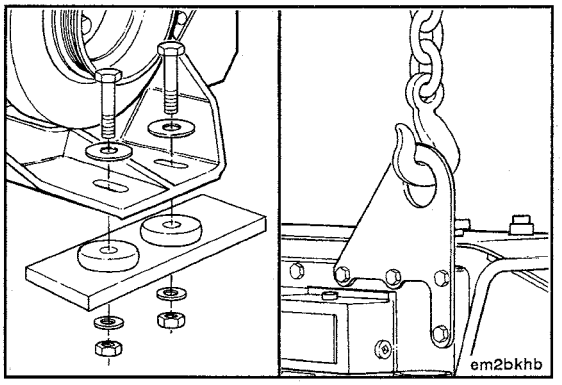


Install (016-002-026)

Apply a coating of thread sealant, Part No. 3823494, to the three capscrews at locations 1, 2 and 3.

Install the front support and mounting capscrews.

Torque Value: 68 N•m [50 ft-lb]

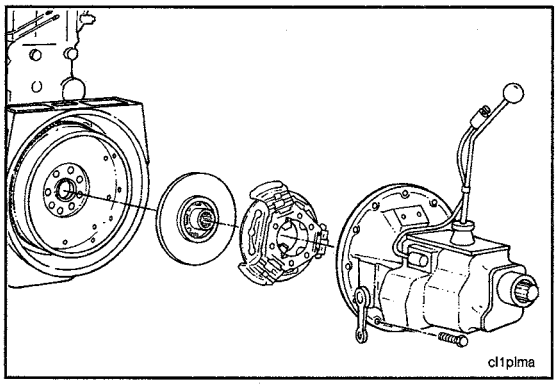


Lower the front of the engine.

Install the front engine mount capscrews.

Tighten the capscrews to the manufacturer's specifications.

Remove the lifting fixture or hoist from the front of the engine.



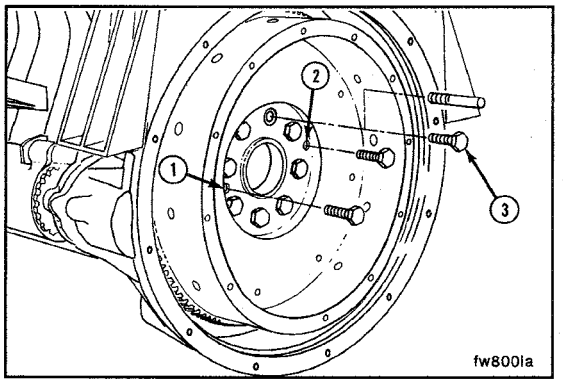
Flywheel (016-005)

Remove (016-005-002)

Remove the vehicle driveline and transmission. Refer to the manufacturer's instructions.

Remove the clutch discs and pressure plate.

Hold the flywheel to prevent rotation.



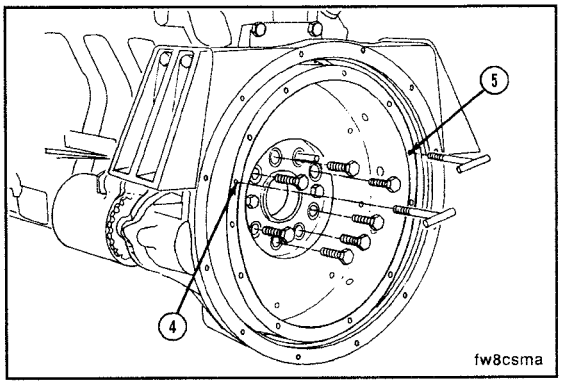
Install M10 - 1.50 x 40 puller capscrews (at points 1 and 2).

Remove capscrew (3) and install guide pin, Part No. 3376696.

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be sure to use the correct capscrews.

Determine the capscrew thread design and size, and install two "t-handles" in the flywheel (at points 4 and 5).

Remove the remaining seven flywheel mounting capscrews.

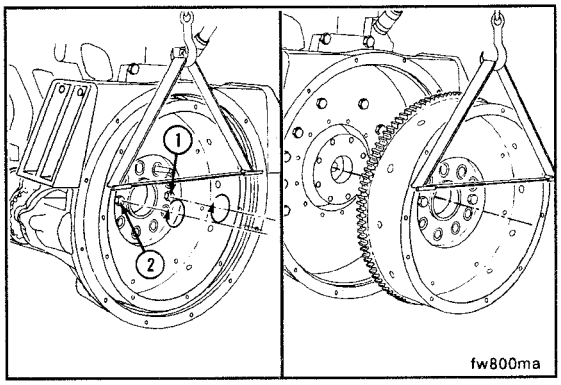


⚠ WARNING ⚠

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

Tighten capscrews (1 and 2) in alternating sequence to loosen the flywheel.

Remove the flywheel from the guide pin.



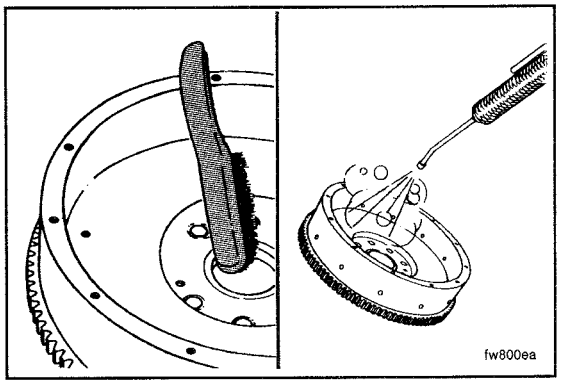
Clean (016-005-006)

⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

Use a wire brush to clean the crankshaft pilot bore.

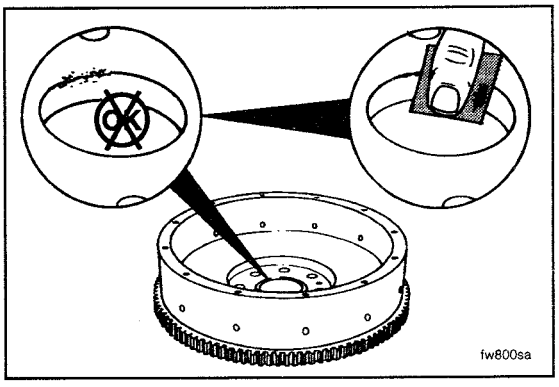
Use steam or solvent to clean the flywheel. Dry with compressed air.

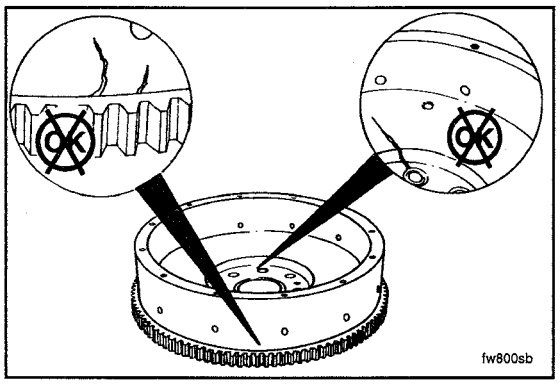


Inspect for Reuse (016-005-007)

Inspect for nicks or burrs.

Use Scotch-Brite™ 7448, Part No. 3823258 or equivalent, to remove small nicks and burrs.

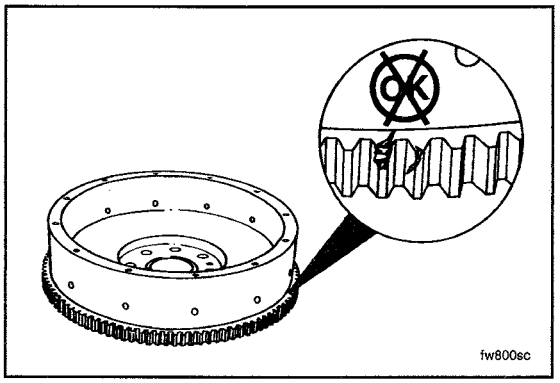




⚠ WARNING ⚠

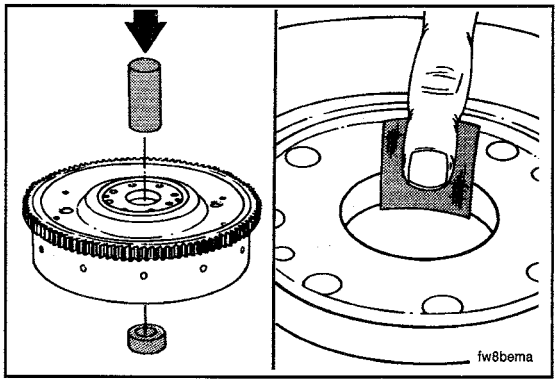
Do not use a cracked flywheel. A cracked flywheel can break and cause serious personal injury or property damage.

Inspect the flywheel for cracks.



Inspect the flywheel ring gear teeth for cracks and chips.

If the ring gear teeth are cracked or broken, the ring gear **must** be replaced.

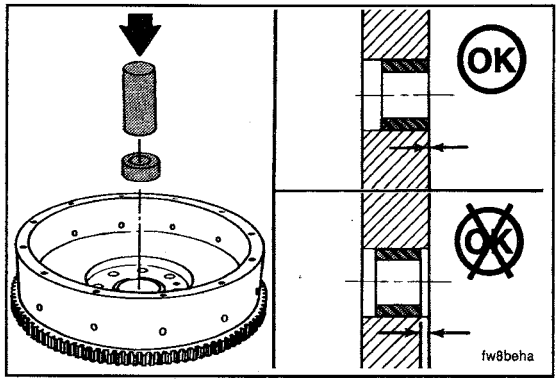


Install (016-005-026)

Use a new pilot bearing when installing a new or rebuilt clutch.

Remove the pilot bearing with a mandrel and hammer.

Clean the pilot bore with Scotch-Brite 7448, Part No. 3823258 or equivalent.



Install the pilot bearing with a mandrel and hammer.

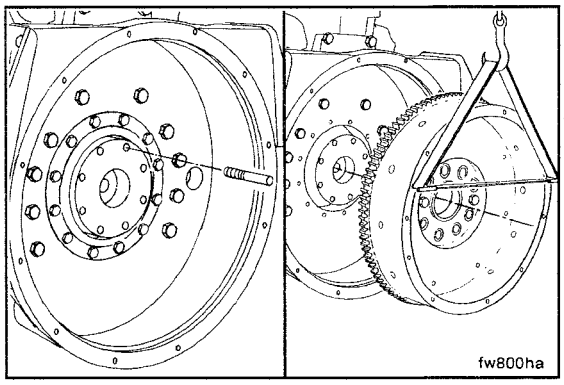
The pilot bearing **must** be installed flush with the pilot bore surface.

⚠ WARNING ⚠

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

Install guide pin, Part No. 3376696, in the crankshaft flange.

Install the flywheel on the guide pin.



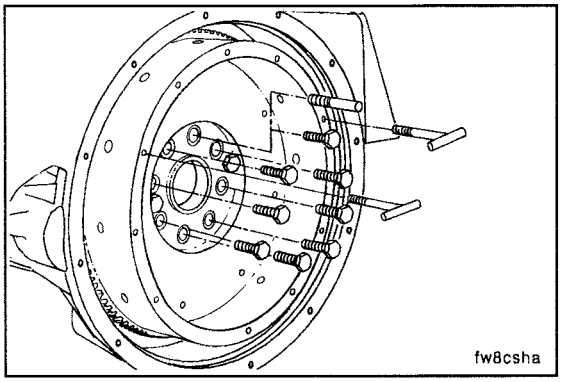
Install the seven capscrews.

Remove the "T-handles" and the guide pin.

Install the remaining capscrew in the hole.

Tighten the capscrews in a star pattern.

Torque Value: 183 N•m [135 ft-lb]



Measure (016-005-010)

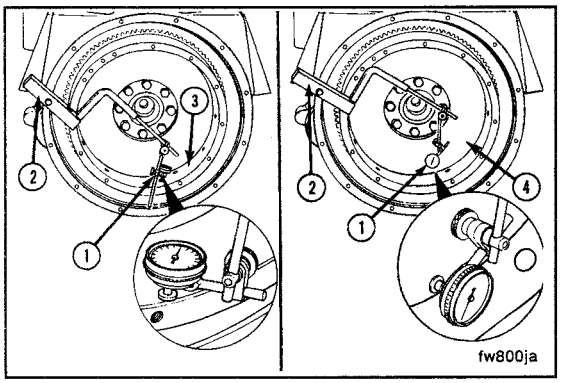
Bore Runout

Use dial indicator gauge (1), Part No. 3376050 or equivalent, and dial gauge attachment (2), Part No. ST-1325, to inspect the flywheel bore (3) and face (4) runout.

Install the attachment to the flywheel housing.

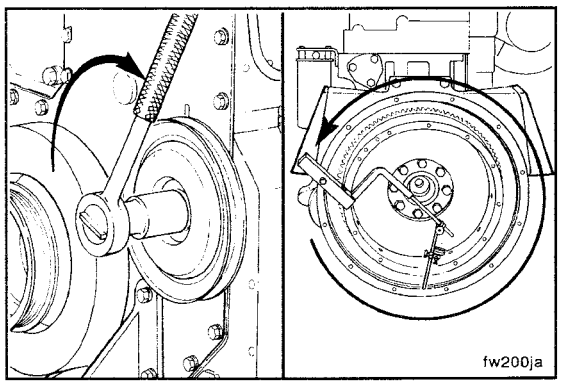
Install the gauge on the attachment.

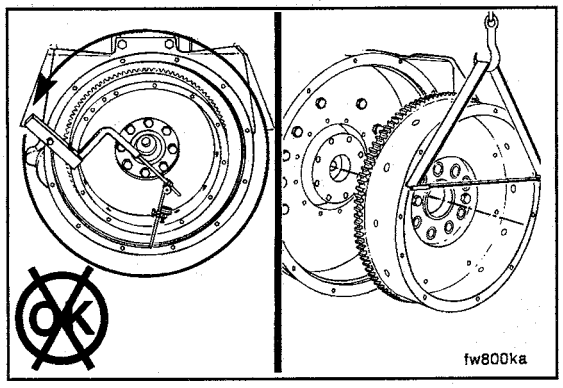
Install the contact tip of the indicator against the inside diameter of the flywheel bore.



Use the accessory driveshaft to rotate the crankshaft one complete revolution (360 degrees).

The total indicator reading **must not** exceed 0.127 mm [0.0050 in].



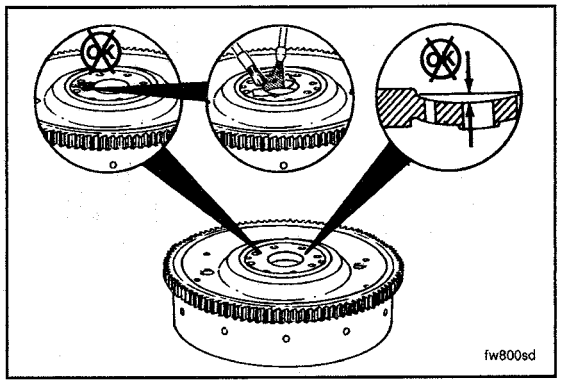


⚠ WARNING ⚠

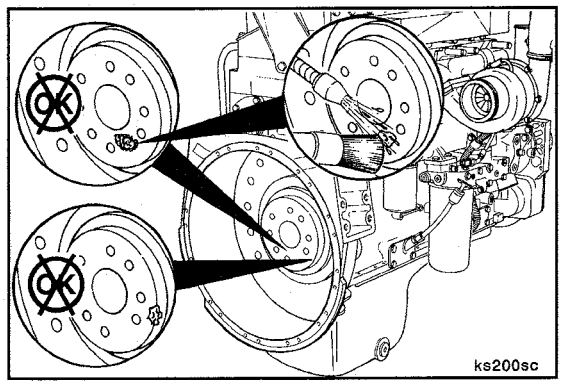
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

If the total indicator reading is greater than the specification:

- Remove the flywheel.

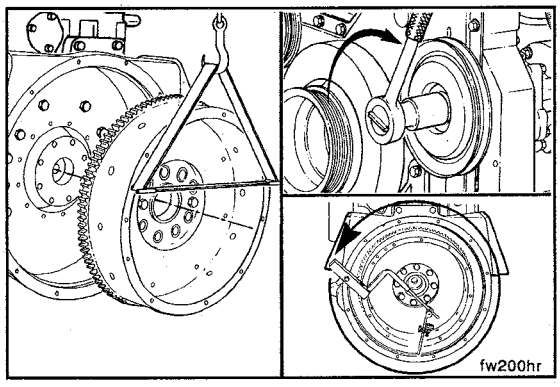


- Inspect the flywheel mounting surface for dirt or damage.



- Inspect the crankshaft for dirt or damage.

Refer to the M11 Series Engine Shop Manual, Bulletin No. 3666075, to replace the crankshaft.



⚠ WARNING ⚠

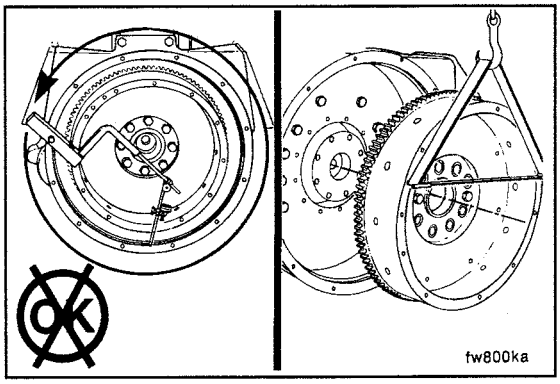
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

- Install the flywheel, and inspect the bore runout again.

⚠ WARNING ⚠

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

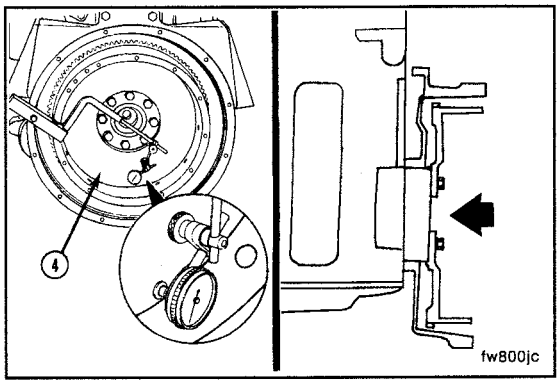
- Replace the flywheel if the runout does **not** meet specifications.



Face Runout

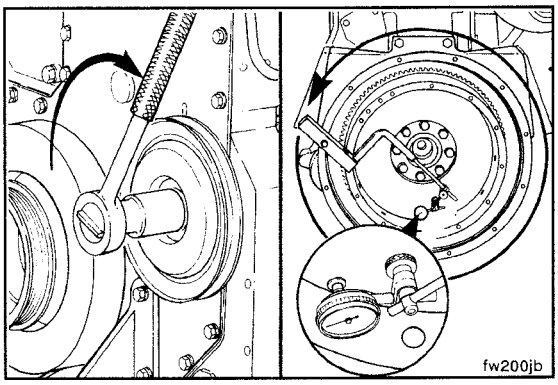
Install the contact tip of the indicator against the flywheel face as close to the outside diameter as possible to inspect the face (4) run out.

Push the flywheel forward to remove the crankshaft end thrust.



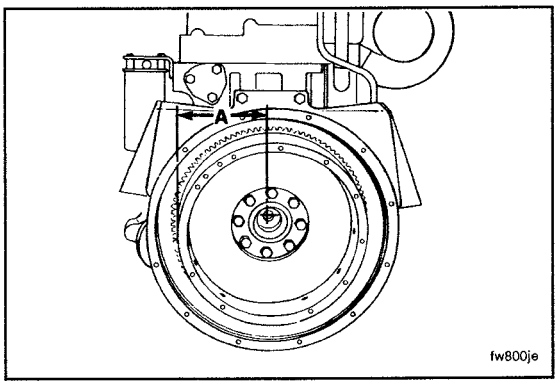
Use the accessory driveshaft to rotate the crankshaft one complete revolution (360 degrees) while keeping the crankshaft end thrust pushed forward.

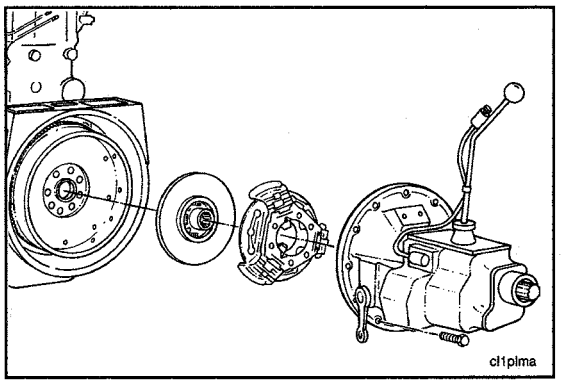
The total indicator reading **must not** exceed the following specifications.



Flywheel Face Runout Total Indicator Reading

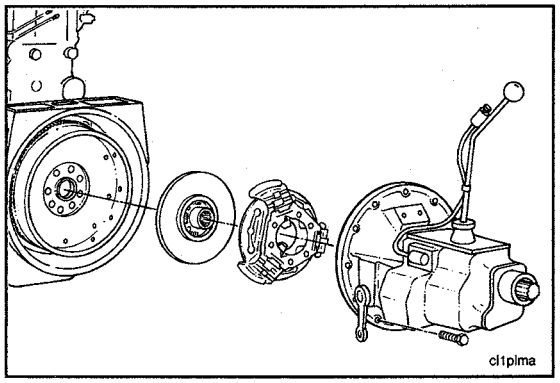
Flywheel Radius (A)		Maximum Total Indicator Reading of Flywheel Face	
mm	in	mm	in
203	8	0.203	0.008
254	10	0.254	0.010
305	12	0.305	0.012
356	14	0.356	0.014
406	16	0.406	0.016





Install the clutch discs, pressure plate, transmission, and driveline, if equipped, in reverse order of removal. Refer to the manufacturer's instructions.

Align the universal joints on each end of the driveshaft to prevent vibration.

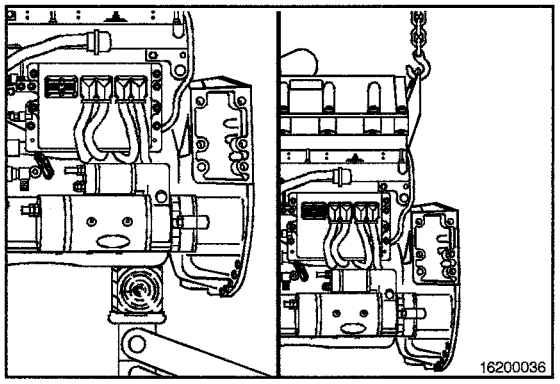


Flywheel Housing (016-006)

Remove (016-006-002)

Remove the transmission, clutch, and all related components, if equipped. Refer to the manufacturer's instructions.

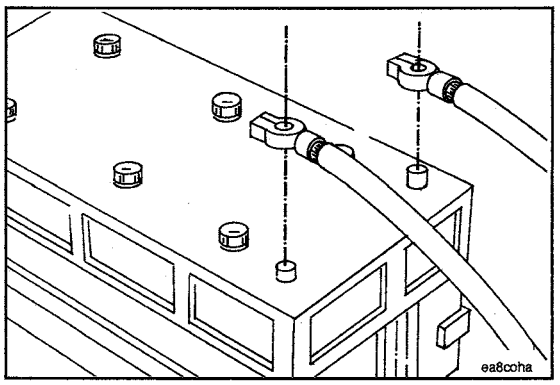
Remove the flywheel. Refer to Procedure 016-005.



⚠ CAUTION ⚠

Place a wooden block, the width of the oil pan, between the floor jack and oil pan to prevent damage to the engine.

Use a floor jack or a suitable lifting fixture to support the rear of the engine.

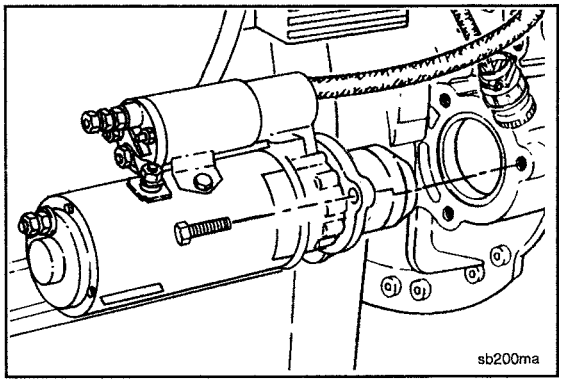


⚠ WARNING ⚠

Batteries can emit explosive gases. To avoid personal injury, always ventilate the compartment before servicing the batteries. To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

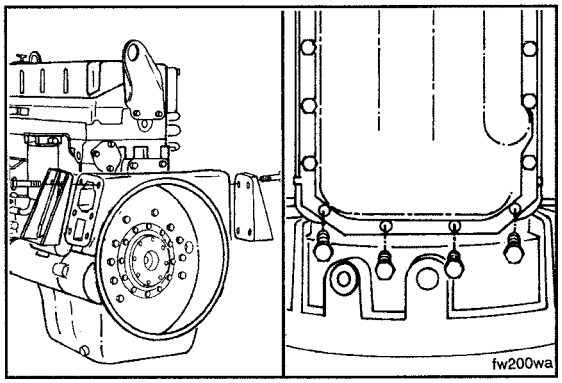
Disconnect the battery cables.

Remove the starting motor. Refer to Procedure 013-020.



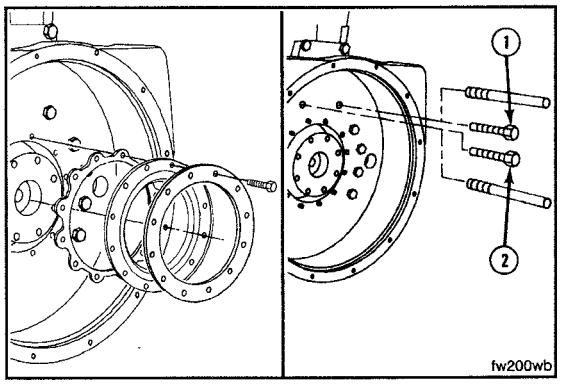
Remove the capscrews and both rear engine mounts.

Remove the four oil pan rear mounting capscrews.



Remove the rear crankshaft oil seal. Refer to Procedure 001-024.

Remove capscrews 1 and 2 and install two guide pins, Part No. 3376697.



⚠ WARNING ⚠

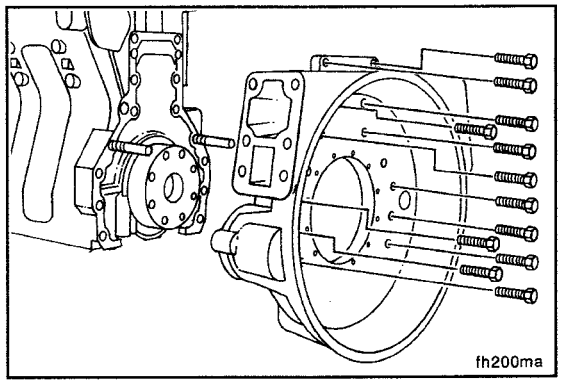
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

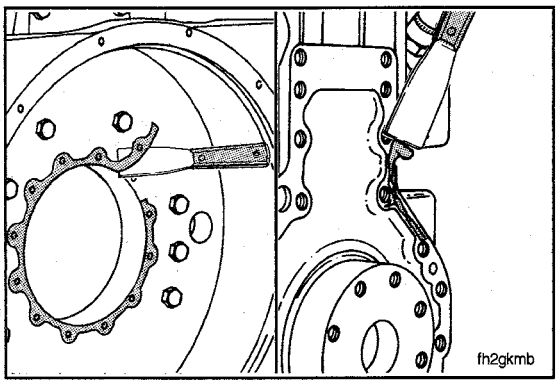
Remove the remaining capscrews.

Use a rubber hammer to loosen the flywheel housing.

NOTE: Do **not** damage the rear of the oil pan gasket when removing the flywheel housing.

Remove the flywheel housing.

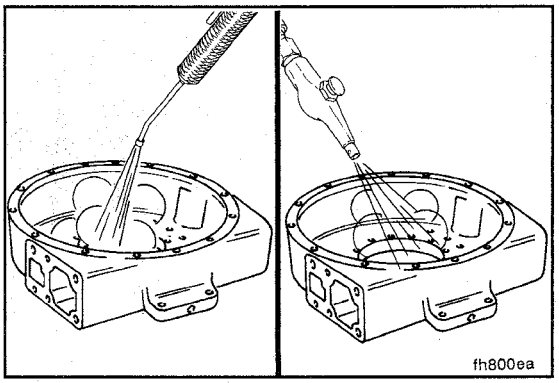




Clean (016-006-006)

Remove the gasket material from the flywheel housing oil seal gasket surface.

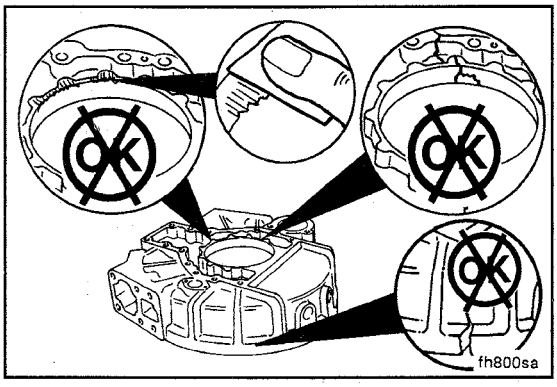
Clean the sealant from the cylinder block surface.



⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

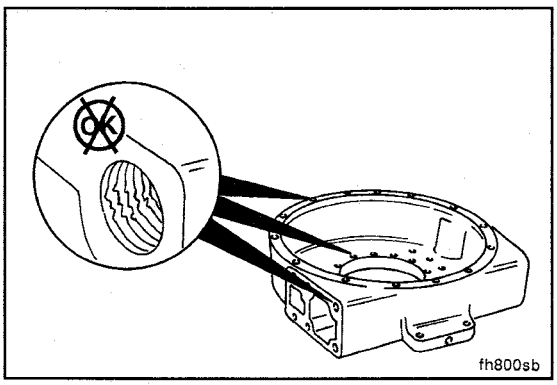
Use steam or solvent to clean the flywheel housing. Dry with compressed air.



Inspect for Reuse (016-006-007)

Inspect all surfaces for nicks, burrs, or cracks.

Use fine crocus cloth to remove small nicks and burrs.



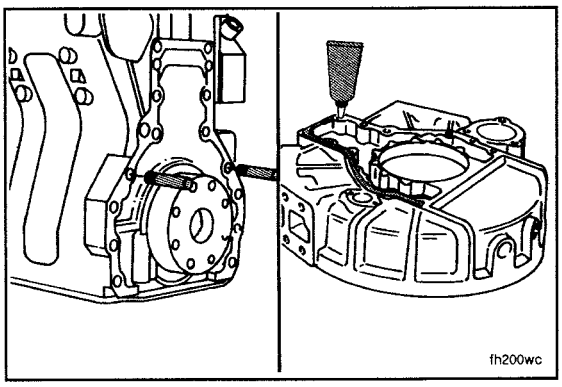
Inspect all threaded capscrew holes for damage.

Repair or replace the housing if the capscrew holes are damaged.

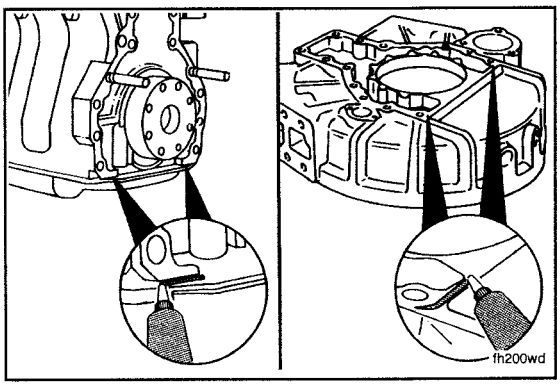
Install (016-006-026)

Install two guide pins, Part No. 3376697, in the cylinder block to help support and align the housing during installation.

Apply a 2 mm [1/16 in] bead of silicone sealant, Part No. 3823494, on the mounting surface of the housing and around each capscrew hole.



Apply silicone sealant to each rear corner of the oil pan gasket and flywheel housing mating surface.



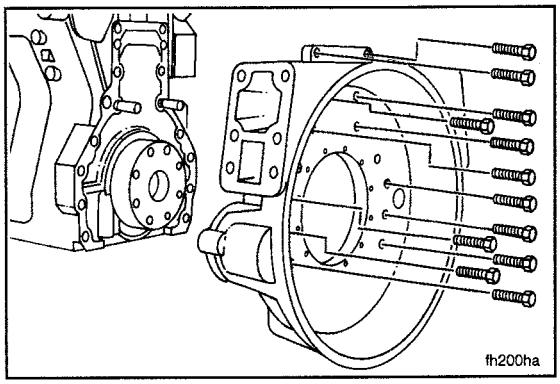
Install the flywheel housing over the guide pins.

NOTE: Do **not** damage the oil pan gasket when installing the flywheel housing.

The flywheel housing bore **must** be aligned with the crankshaft. Do **not** tighten the capscrews to the final torque value until the flywheel housing is aligned.

Install the capscrews. Remove the guide pins, and install the remaining two capscrews.

Torque Value: 7 N•m [60 in-lb]



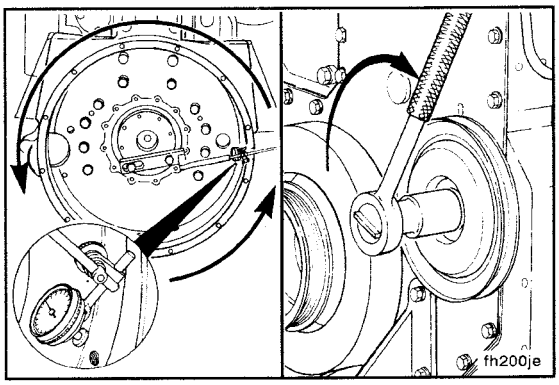
Measure (016-006-010)

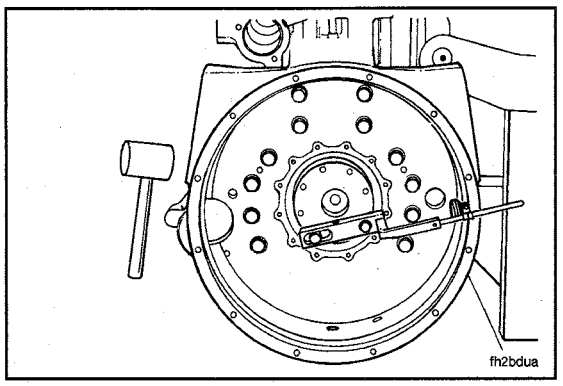
Bore Alignment

Use dial indicator gauge, Part No. 3376050, and dial gauge attachment, Part No. ST-1325, to measure the bore alignment.

Adjust the dial indicator gauge to zero "0."

Use the accessory driveshaft to rotate the crankshaft one complete revolution (360 degrees).



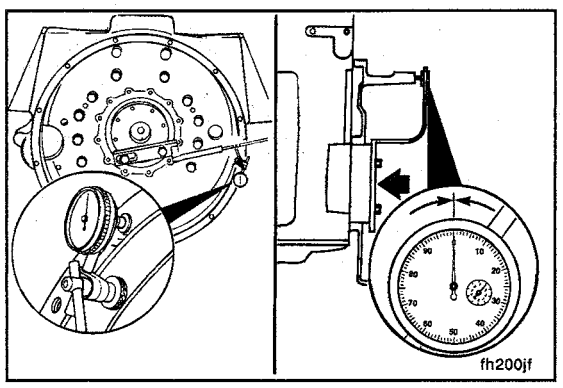


Flywheel Housing Bore Alignment Maximum Total Indicator Reading

mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008

If the maximum bore alignment does **not** meet the specifications, use a rubber hammer to move the housing in the necessary direction, and repeat the measurement procedure.

If the bore alignment will **not** meet the specifications or the bore is **not** round, the housing **must** be replaced.



Face Alignment

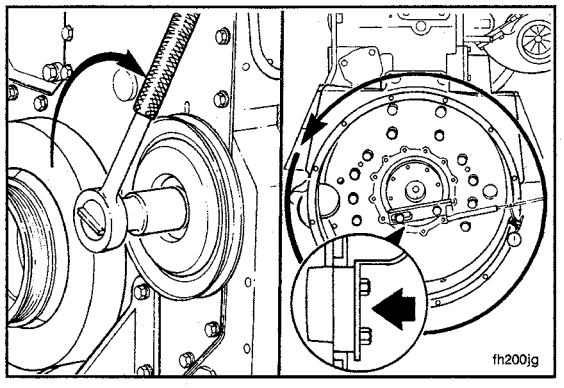
⚠ CAUTION ⚠

The tip of the gauge must not enter the capscrew holes or the gauge will be damaged.

Install the contact tip of the dial indicator gauge against the flywheel housing face.

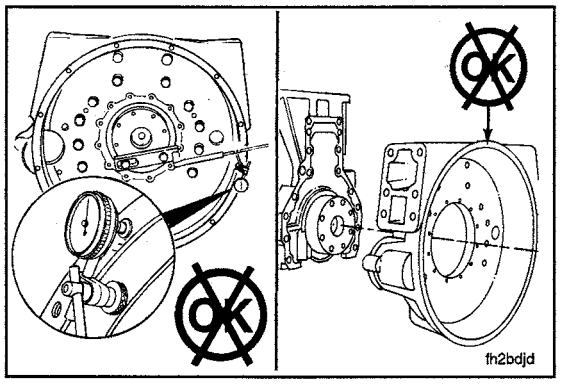
Push the crankshaft toward the front of the engine.

Adjust the dial indicator gauge to zero "0."



Monitor the dial indicator gauge while turning the crankshaft.

Use the accessory driveshaft to rotate the crankshaft one complete revolution (360 degrees) while keeping the crankshaft end thrust pushed forward.



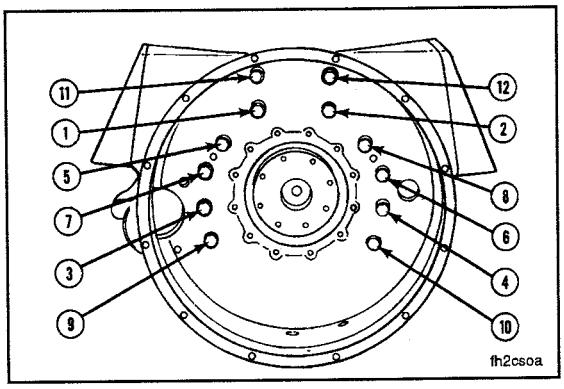
Flywheel Housing Face Alignment Maximum Total Indicator Reading

mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008

If the maximum face alignment does **not** meet the specifications, the flywheel housing **must** be replaced.

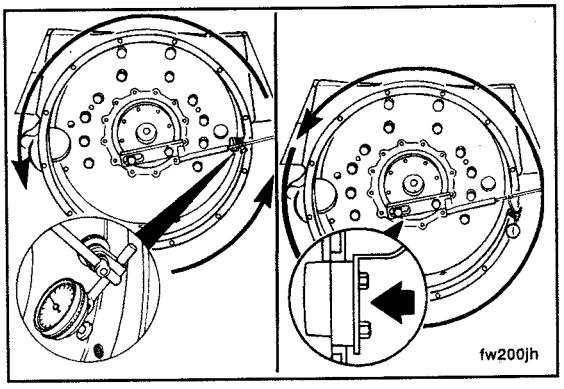
Tighten all capscrews in the sequence shown.

Torque Value: Step 1 68 N•m [50 ft-lb]
2 129 N•m [95 ft-lb]
3 197 N•m [145 ft-lb]



Measure the bore and face alignment again.

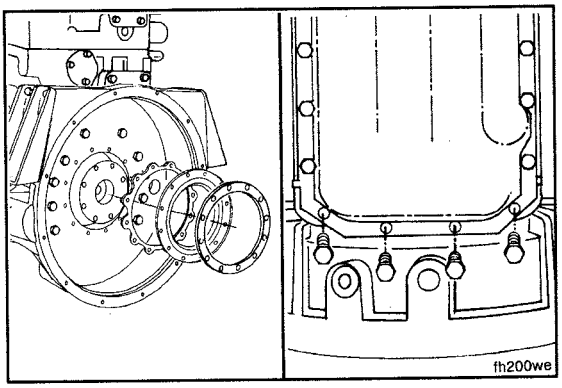
If bore and face alignment does **not** meet the specifications, loosen the housing capscrews. Tighten the capscrews, and measure the bore and face alignment again.



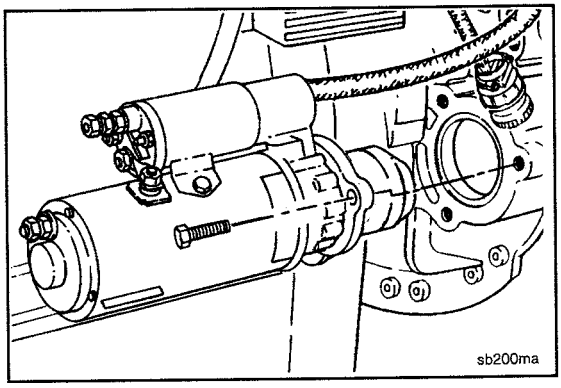
Install the rear crankshaft oil seal. Refer to Procedure 001-024.

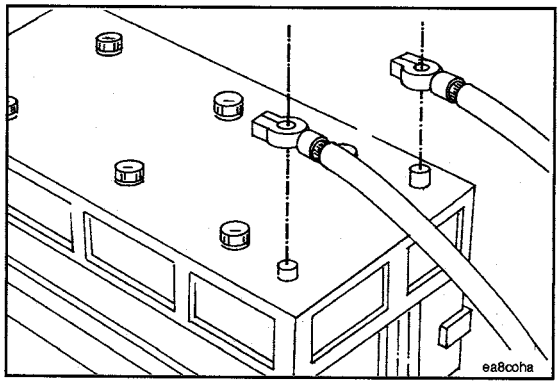
Install the four oil pan rear mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]



Install the starting motor. Refer to Procedure 013-020.

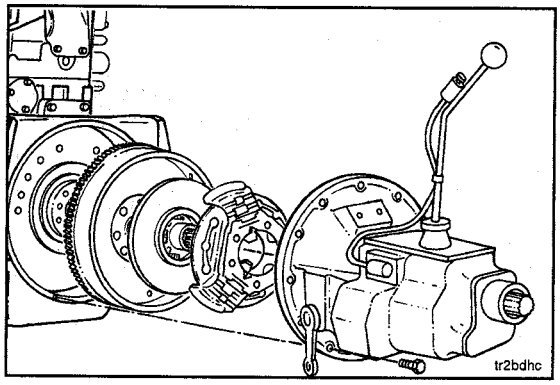




⚠ WARNING ⚠

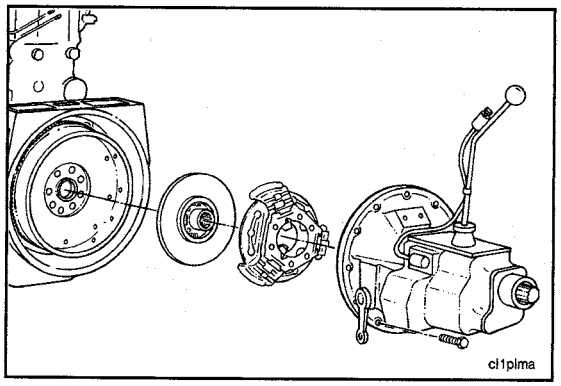
Batteries can emit explosive gases. To avoid personal injury, always ventilate the compartment before servicing the batteries. To avoid acrcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Connect the battery cables.



Install the flywheel and clutch, if equipped. Refer to Procedure 016-005.

Install the transmission and related components. Refer to the manufacturer's instructions.

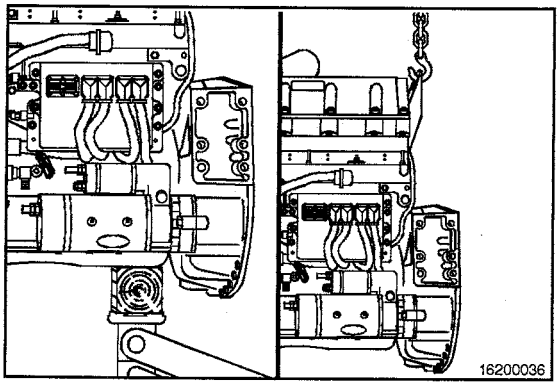


Flywheel Housing, REPTO (016-007)

Remove (016-007-002)

Remove the transmission, clutch, and all related components, if equipped. Refer to the manufacturer's instructions.

Remove the flywheel. Refer to Procedure 016-005.



△ CAUTION △

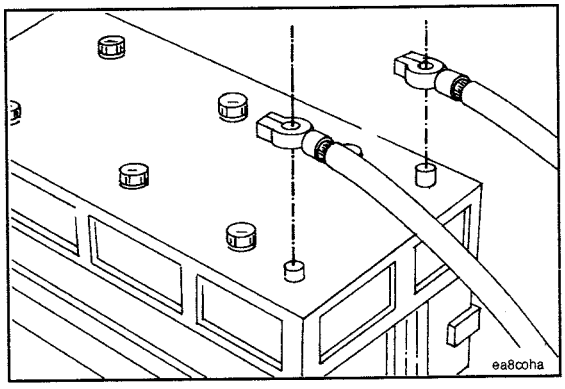
Place a wooden block, the width of the oil pan, between the floor jack and oil pan to prevent damage to the engine.

Use a floor jack or a suitable lifting fixture to support the rear of the engine.

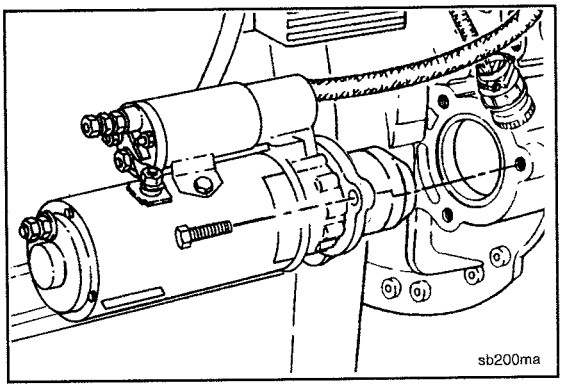
⚠ WARNING ⚠

Batteries can emit explosive gases. To avoid personal injury, always ventilate the compartment before servicing the batteries. To avoid acrcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the battery cables.



Remove the starting motor. Refer to Procedure 013-020.

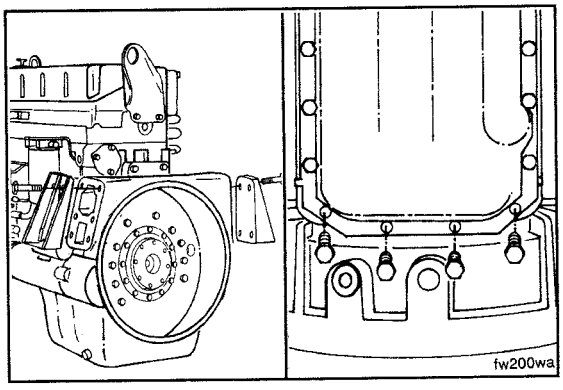


Remove the capscrews and both rear engine mounts.

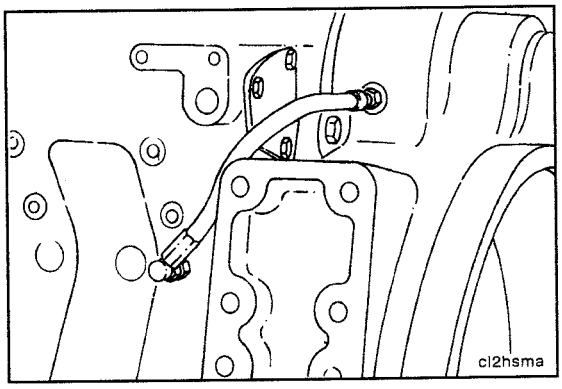
Remove the four oil pan rear mounting capscrews.

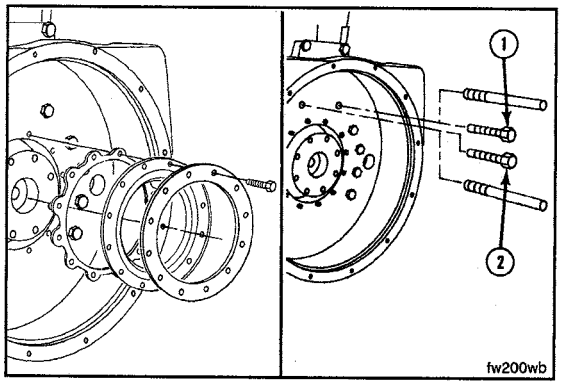
Loosen six capscrews on each side of the oil pan at the end closest to the flywheel housing. This will allow enough clearance to remove the flywheel housing.

NOTE: Be careful **not** to tear the oil pan gasket. If the oil pan gasket is damaged, the oil pan **must** be removed and the gasket replaced.



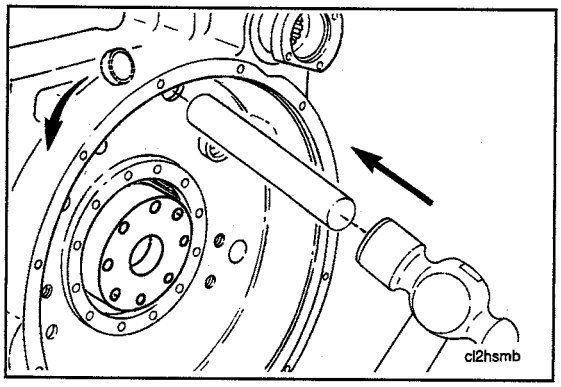
Remove the oil supply line from the flywheel housing.





Remove the rear crankshaft oil seal. Refer to Procedure 001-024.

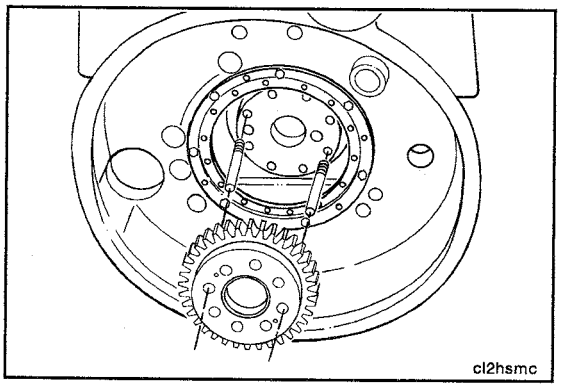
Remove capscrews (1 and 2) and install two guide pins, Part No. 3824929.



To gain access to the housing capscrews, use a cup plug driver, Part No. 3824927, to drive the cup plugs straight through into the housing.

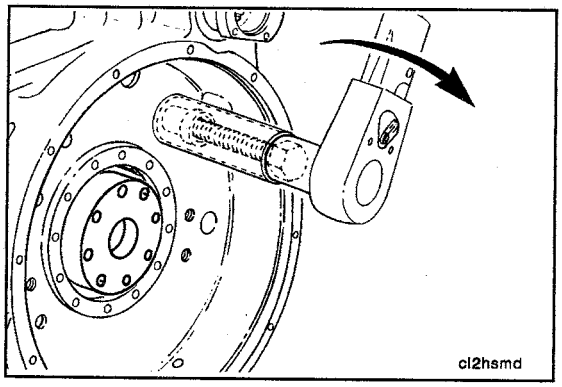
Retrieve the plugs from inside the housing.

NOTE: Do **not** attempt to back out or rotate the plugs from the housing. The cup plug bore will be damaged and oil leakage will occur.



Remove the crankshaft drive gear.

Remove the two guide pins from the crankshaft.



Remove the idler shaft retaining capscrew.

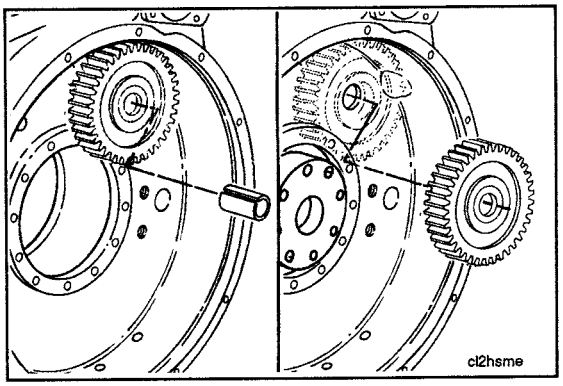
△ CAUTION △

When the idler shaft is removed, the idler gear can fall and become damaged. Hold the idler gear before pulling the idler shaft out.

Use idler shaft puller, Part No. 3823709, to remove the idler shaft.

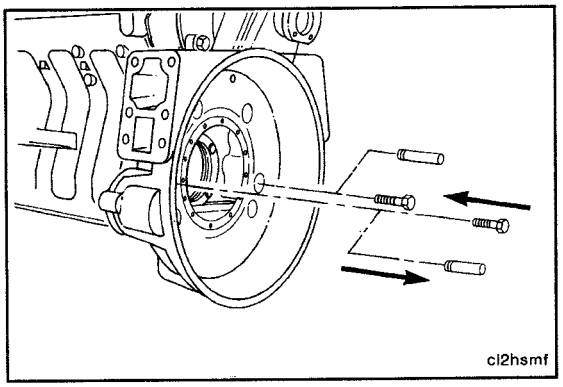
Remove the idler gear to gain access to the rest of the housing capscrews.

NOTE: Do **not** drop the idler gear bearings as the idler gear is removed. Damage to the bearings can result.



Remove two of the mounting capscrews, and install two guide pins, Part No. 3824930, to support the housing during removal.

Use offset wrench, Part No. 3824928, to remove the capscrews that are **not** in view. These capscrews are inside the housing.



⚠ WARNING ⚠

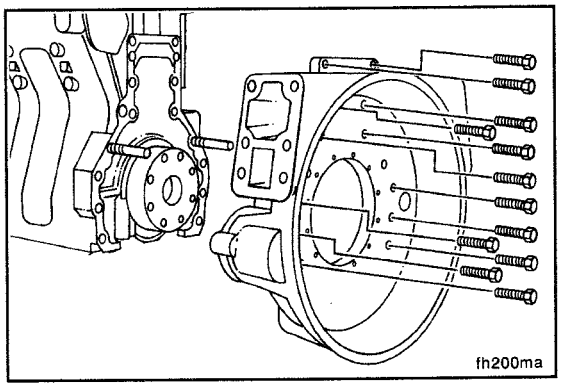
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

Remove the remaining capscrews.

Use a rubber hammer to loosen the flywheel housing.

NOTE: Do **not** damage the rear of the oil pan gasket when removing the flywheel housing.

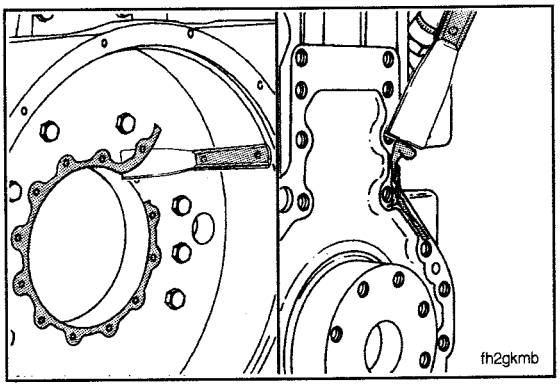
Remove the flywheel housing.

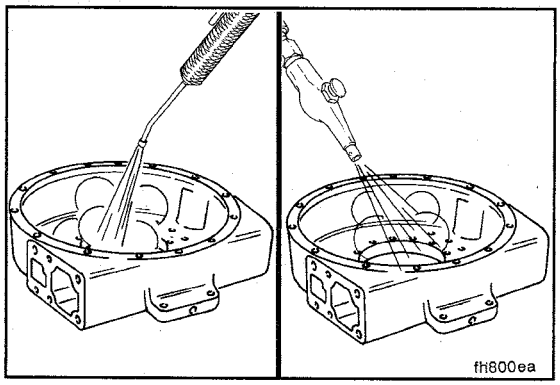


Clean (016-007-006)

Remove the gasket material from the flywheel housing oil seal gasket surface.

Clean the sealant from the cylinder block surface.

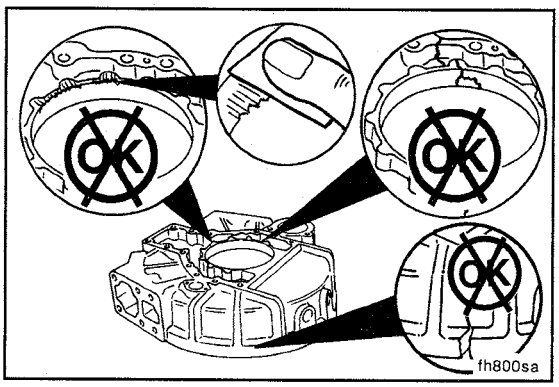




⚠ WARNING ⚠

When using a steam cleaner, wear protective clothing, as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

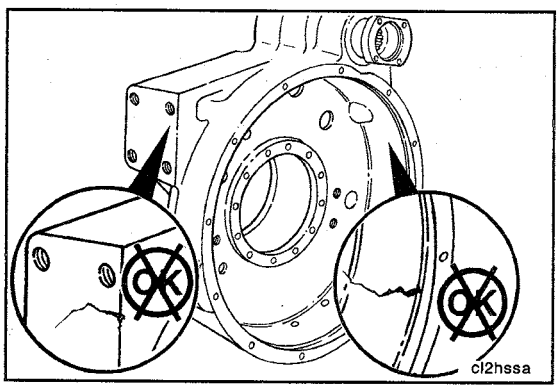
Use steam or solvent to clean the flywheel housing. Dry with compressed air.



Inspect for Reuse (016-007-007)

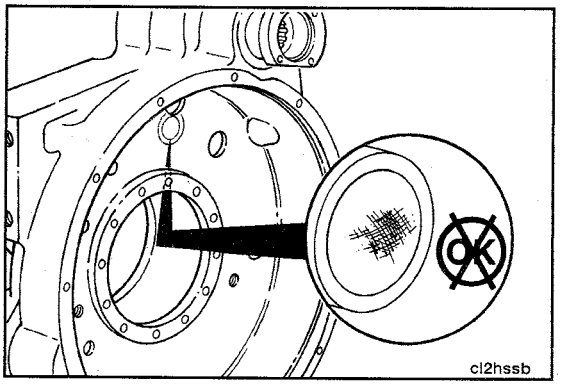
Inspect all surfaces for nicks, burrs, or cracks.

Use fine crocus cloth to remove small nicks and burrs.



Inspect the rear engine power take off housing for cracks at the rear engine mounting surfaces and the flywheel bore.

Replace the housing if it is cracked.

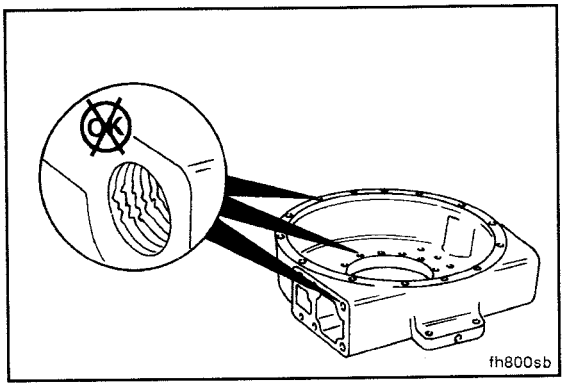


Inspect the idler shaft bushing for wear.

Replace the bushing if it is worn.

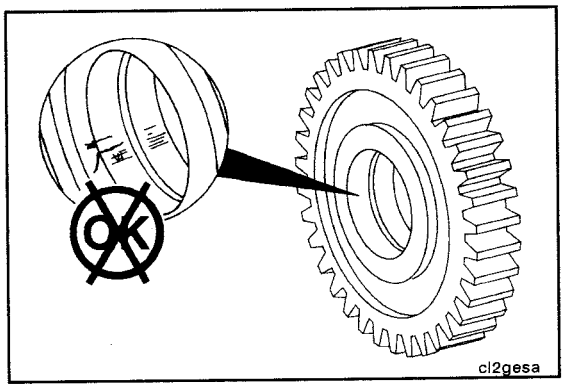
Inspect all threaded capscrew holes for damage.

Repair or replace the housing if the capscrew holes are damaged.



Closely inspect the bore, side faces, and teeth of the rear engine power take off idler gear.

Replace the gear if there are cracks, discoloration from excessive heat, or other damage.

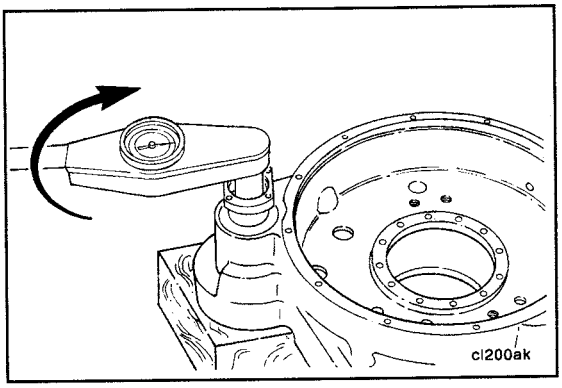


Check the output shaft rolling resistance with a torque wrench.

The rolling resistance **must** be between 0.6 to 1.1 N•m [5 to 10 in-lb].

If the resistance does **not** meet these specifications, refer to the L10, Engine Shop Manual, Bulletin No. 3810476, to add or subtract shims to obtain the correct rolling resistance.

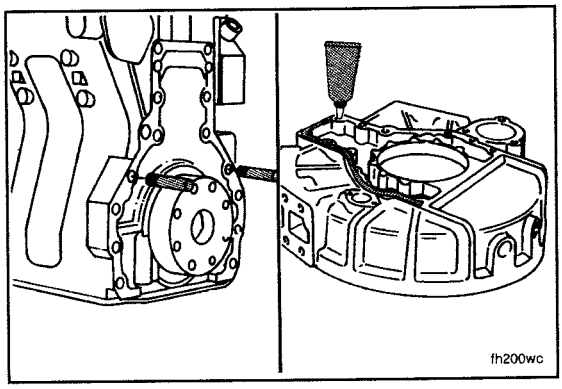
NOTE: Adding shims will increase resistance; removing shims will decrease resistance. Any combination of shims can be used.

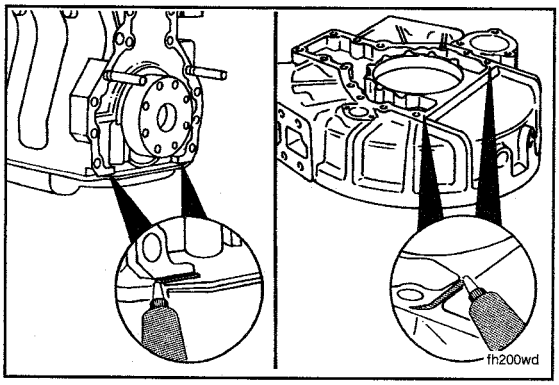


Install (016-007-026)

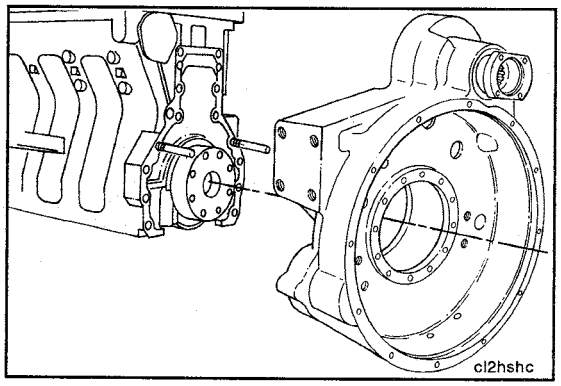
Install two guide pins, Part No. 3376697, in the cylinder block to help support and align the housing during installation.

Apply a 2 mm [1/16 in] bead of silicone sealant, Part No. 3823494, on the mounting surface of the housing and around each capscrew hole.





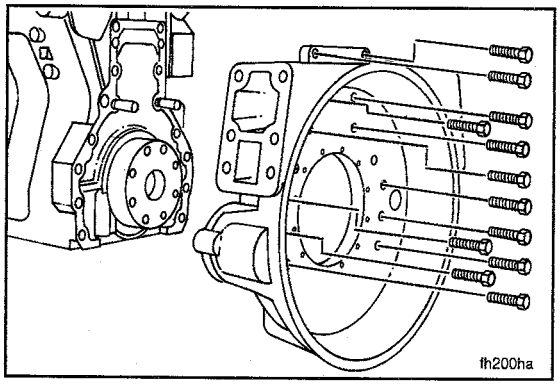
Apply silicone sealant to each rear corner of the oil pan gasket and flywheel housing mating surface.



⚠ WARNING ⚠

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

Use a hoist when installing the rear engine power take off flywheel housing over the guide pins.



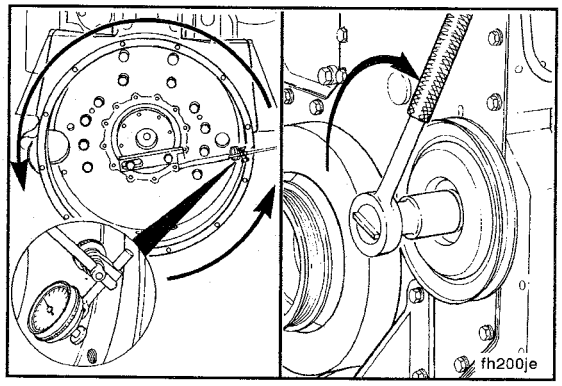
Install the flywheel housing over the guide pins.

NOTE: Do **not** damage the oil pan gasket when installing the flywheel housing.

The flywheel housing bore **must** be aligned with the crankshaft. Do **not** tighten the capscrews to the final torque value until the flywheel housing is aligned.

Install the capscrews. Remove the guide pins, and install the remaining two capscrews.

Torque Value: 7 N•m [60 in-lb]



Measure (016-007-010)

Bore Alignment

Use dial indicator gauge, Part No. 3376050, and dial gauge attachment, Part No. ST-1325, to measure the bore alignment.

Adjust the dial indicator gauge to zero "0."

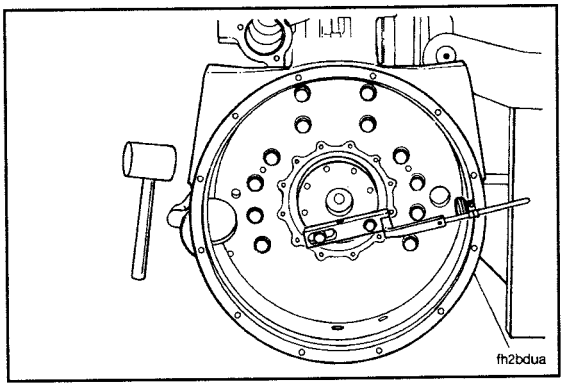
Use the accessory driveshaft to rotate the crankshaft one complete revolution (360 degrees).

Flywheel Housing Bore Alignment Maximum Total Indicator Reading

mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008

If the maximum bore alignment does **not** meet the specifications, use a rubber hammer to move the housing in the necessary direction, and repeat the measurement procedure.

If the bore alignment will **not** meet the specifications or the bore is **not** round, the housing **must** be replaced.



Face Alignment

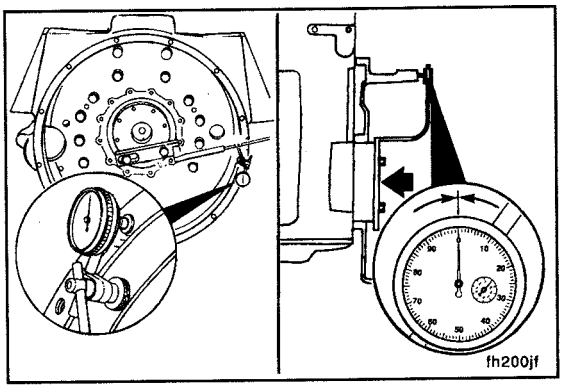
⚠ CAUTION ⚠

The tip of the gauge must not enter the capscrew holes or the gauge will be damaged.

Install the contact tip of the dial indicator gauge against the flywheel housing face.

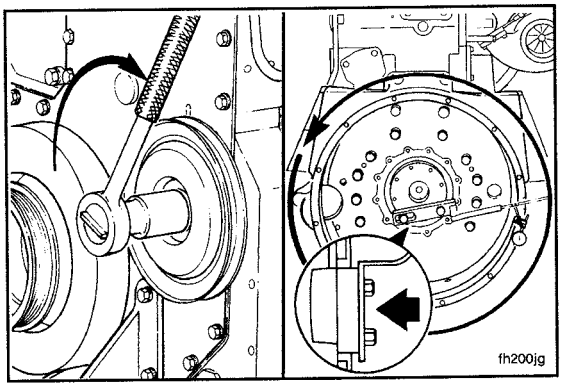
Push the crankshaft toward the front of the engine.

Adjust the dial indicator gauge to zero "0."



Monitor the dial indicator gauge while turning the crankshaft.

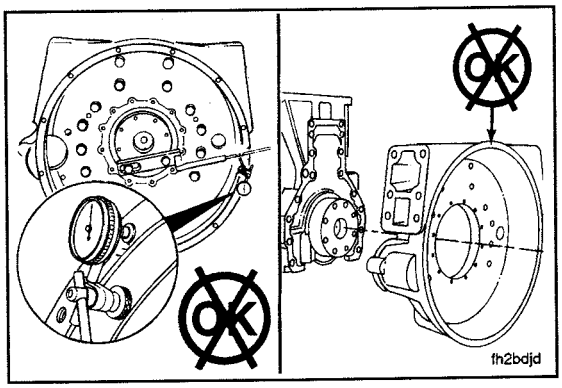
Use the accessory driveshaft to rotate the crankshaft one complete revolution (360 degrees) while keeping the crankshaft end thrust pushed forward.

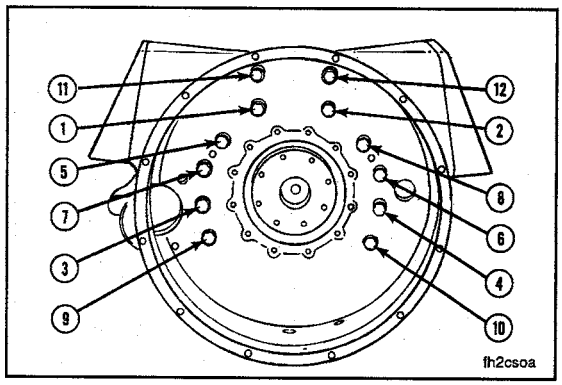


Flywheel Housing Face Alignment Maximum Total Indicator Reading

mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008

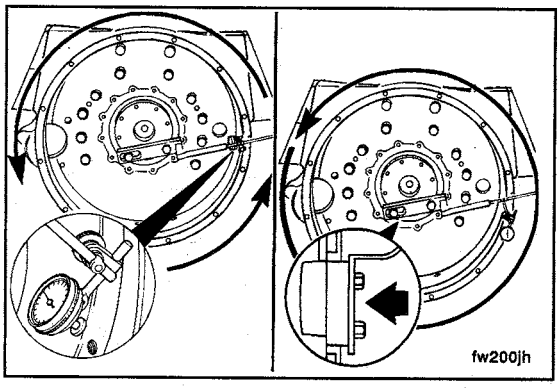
If the maximum face alignment does **not** meet the specifications, the flywheel housing **must** be replaced.





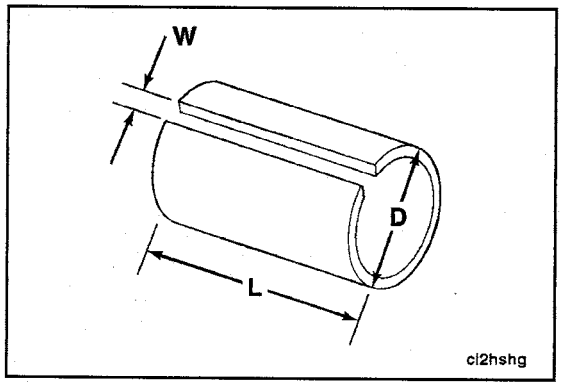
Tighten all capscrews in the sequence shown.

Torque Value: Step 1 68 N•m [50 ft-lb]
2 129 N•m [95 ft-lb]
3 197 N•m [145 ft-lb]



Measure the bore and face alignment again.

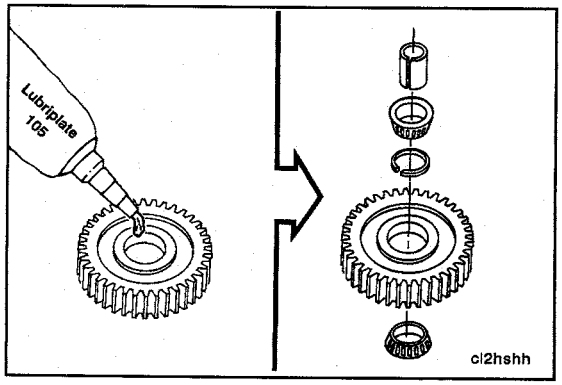
If bore and face alignment do **not** meet the specifications, loosen the housing capscrews. Tighten the capscrews, and measure the bore and face alignment again.



Manufacture a sleeve from 38.1-mm Outside Diameter [1.50-in] Outside Diameter **(D)** PVC, aluminum, thin wall hose, or equivalent, to the following dimensions:

Length (L): 25.4 mm [1.00 in]

Slot (W) 6.3 mm [0.25 in]



Apply Lubriplate™ 105, or equivalent, on the outer races and the bearings.

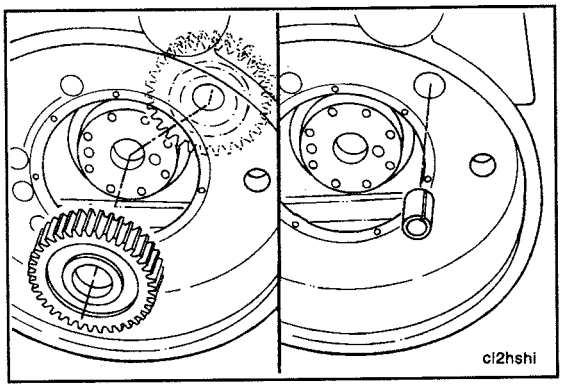
NOTE: The outer bearing races of new replacement gears are already pressed into the gear.

Install the bearing and spacer into the idler gear. Use the manufactured sleeve to hold the bearing assembly together when installing the idler gear assembly.

Apply a thin film of Lubriplate™ 105, or equivalent, into the idler shaft bore of the housing and on the idler shaft.

Install the idler gear assembly into the flywheel housing.

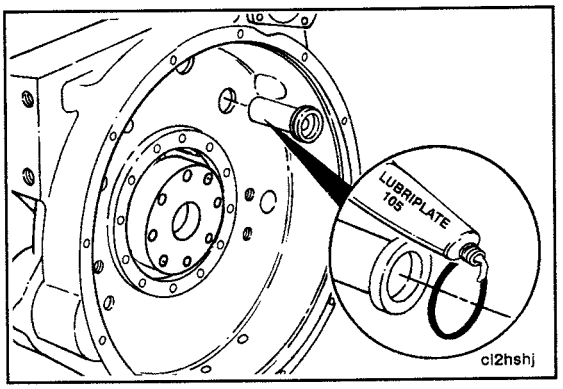
Hold the idler gear and bearings in place, and remove the plastic sleeve.



Use clean Lubriplate™ to lubricate the idler shaft o-ring, and install the o-ring onto the shaft.

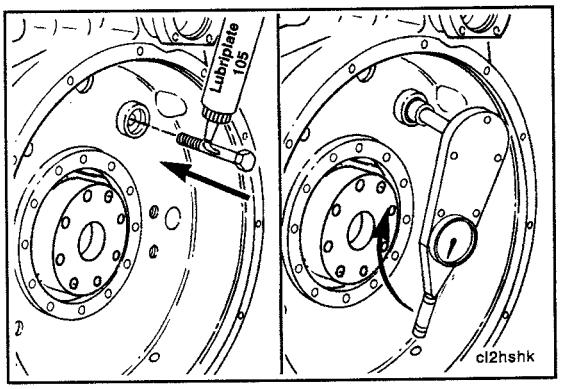
Hold the gear assembly in place and insert the idler shaft through the housing and idler gear bearings.

NOTE: Do **not** use a hammer when installing the idler shaft and capscrew, or the part can be damaged.



Apply Lubriplate™ 105 under the head of the idler shaft capscrew. Insert the capscrew through the idler shaft. Tighten the installation capscrew with a torque wrench.

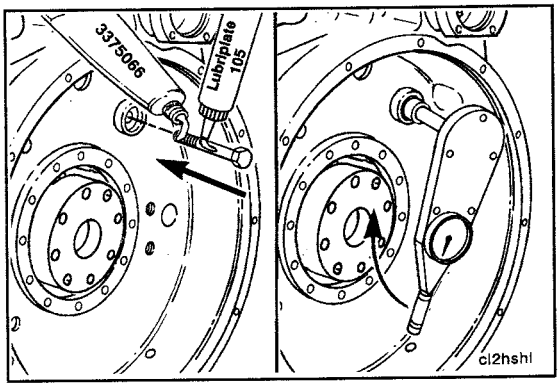
NOTE: The torque needed to draw the idler shaft in place **must not** exceed 88 N•m [65 ft-lb]. If installation torque exceeds this amount, it indicates misalignment between the bore and the shaft. Remove the idler shaft and install it again.

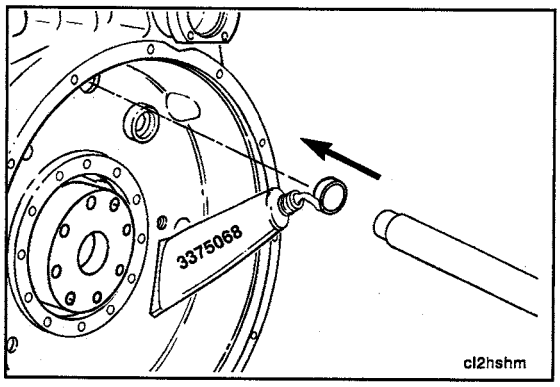


After the idler shaft has been seated, remove the capscrew.

Apply pipe sealant, Part No. 3375066, to the threads of the idler shaft capscrew. Apply Lubriplate™ 105 under the head of the capscrew. Install the capscrew and tighten to its final torque value.

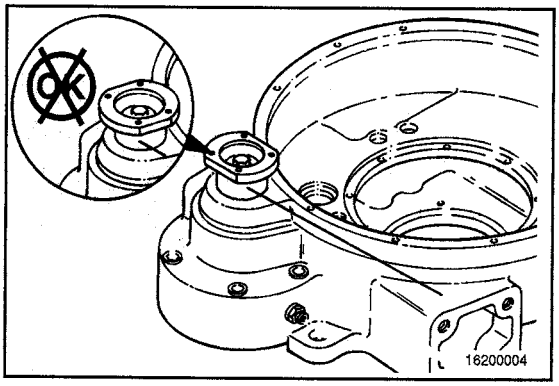
Torque Value: 102 N•m [75 ft-lb]



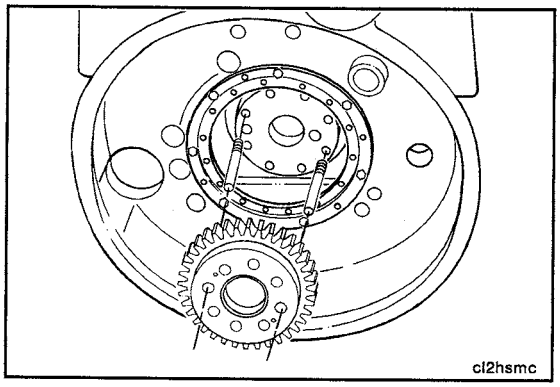


Apply a film of cup plug sealant, Part No. 3375068, to the outside diameter of the cup plug.

Use driver, Part No. 3823710, to install the cup plug into the housing as shown.



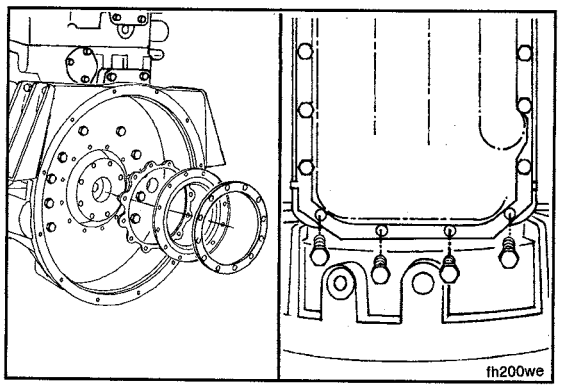
Turn the output flange so that the flat sides are on the top and bottom. This prevents any interference when the transmission is installed onto the housing.



Install two guide pins, Part No. 3824929, into the crankshaft flywheel mounting flange 180-degrees apart.

Make sure the crankshaft and crankshaft gear are clean.

Install the crankshaft gear on the guide pins.



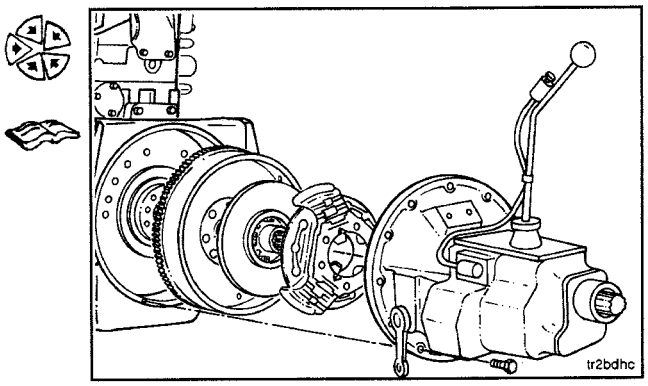
Install the rear crankshaft oil seal. Refer to Procedure 001-024.

Install the four oil pan rear mounting capscrews.

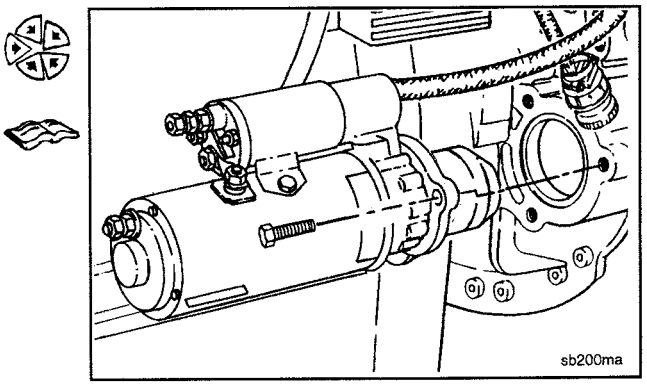
Torque Value: 47 N•m [35 ft-lb]

Install the flywheel and clutch, if equipped. Refer to Procedure 016-005.

Install the transmission and related components. Refer to the manufacturer's instructions.



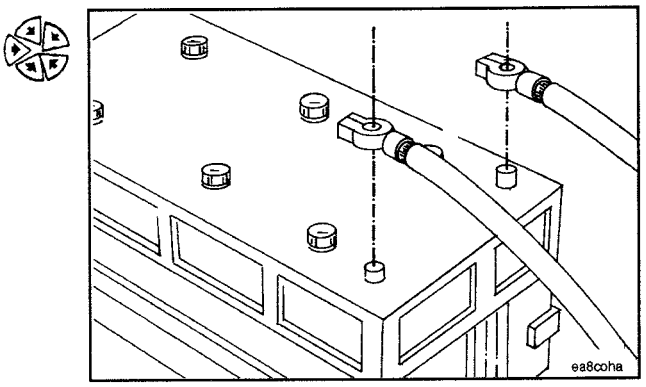
Install the starting motor. Refer to Procedure 013-020.



⚠ WARNING ⚠

Batteries can emit explosive gases. To avoid personal injury, always ventilate the compartment before servicing the batteries. To avoid acrcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Connect the battery cables.



Flywheel Ring Gear (016-008)

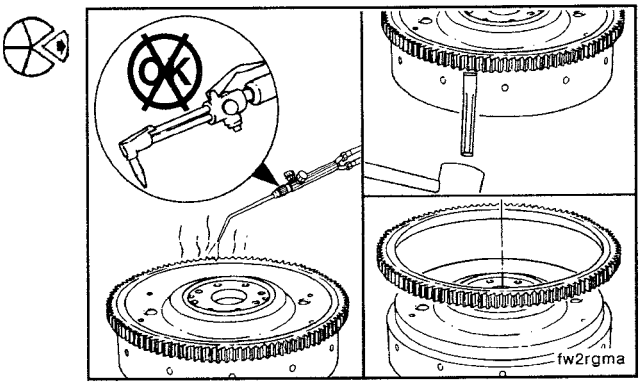
Remove (016-008-002)

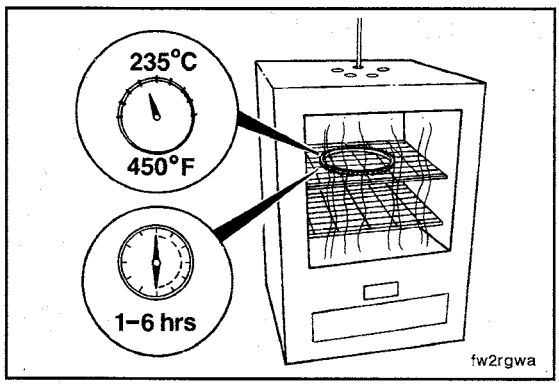
△ CAUTION △

Do not use a cutting torch to heat the ring gear. The flywheel can be damaged.

Heat the outside surface of the ring gear with a heating torch.

Use a hammer and blunt chisel to remove the gear from the flywheel.





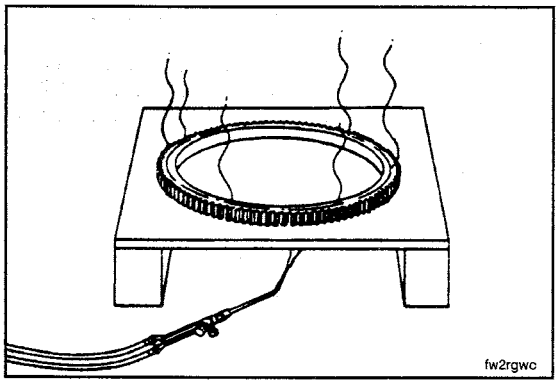
Install (016-008-026)

Do **not** attempt to install the ring gear without using heat.

Use an oven to heat the new ring gear for a minimum of one hour. Do **not** heat the ring gear for more than 6 hours.

Temperature: 235 °C [450 °F]

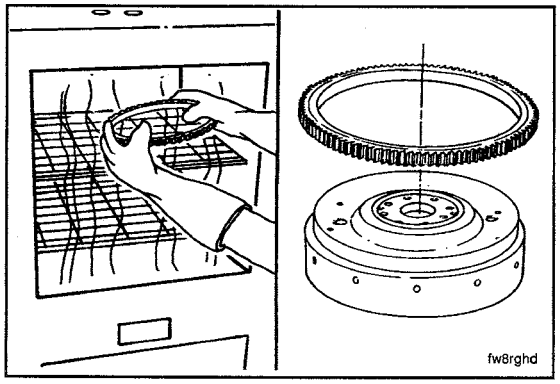
NOTE: Do **not** exceed the specified time or temperature.



If an oven is **not** available, use a heating torch to heat the gear. Use a Tempilstik crayon, or equivalent, to check the temperature of the gear.

A more even temperature is obtained by placing the ring gear on a metal plate and then heating the bottom side of the plate with the torch. Do **not** exceed the specified temperature.

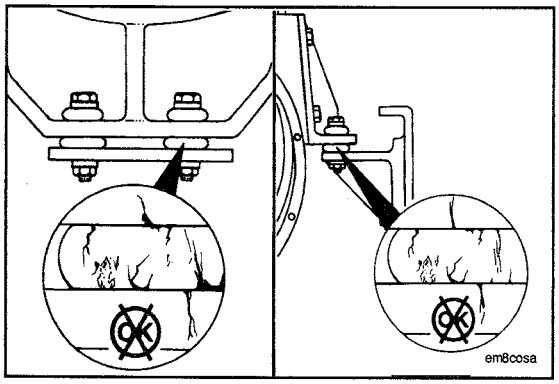
Temperature: 235 °C [450 °F]



⚠ WARNING ⚠

Use insulated gloves when handling heated parts. Hot parts can cause serious personal injury.

Install the ring gear on the flywheel before it cools. Allow the air to cool the gear. Do **not** use water or oil to reduce the cooling time.



Engine Mounts (016-010)

Install (016-010-026)

Inspect all rubber-cushioned mounts for cracks or damage.

Inspect all mounting brackets for cracks or damaged bolt holes.

NOTE: Damaged engine mounts and brackets can cause the engine to move out-of-alignment, can damage the driveline components in the equipment, and can result in vibration complaints.

Section 17 - Miscellaneous - Group 17

Section Contents

Page

Cup Plug 17-1
Clean 17-1
Inspect for Reuse 17-2
Install 17-2
Remove 17-1

Pipe Plug 17-3
Clean 17-3
Inspect for Reuse 17-3
Install 17-3
Remove 17-3

Straight Thread Plug 17-4
Clean 17-4
Inspect for Reuse 17-4
Install 17-5
Remove 17-4

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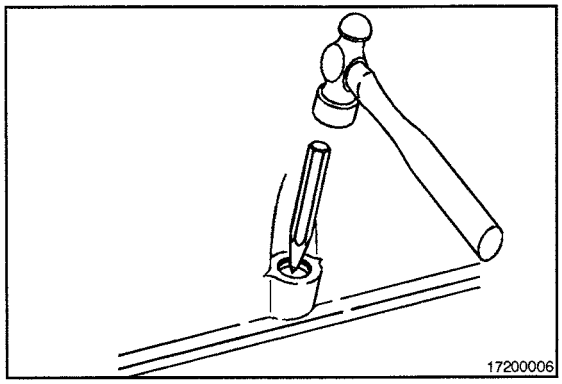
Cup Plug (017-002)

Remove (017-002-002)

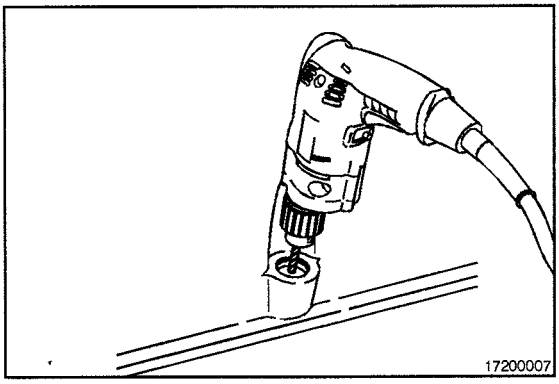
Use a center punch to mark the cup plugs for drilling.



⚠ CAUTION ⚠

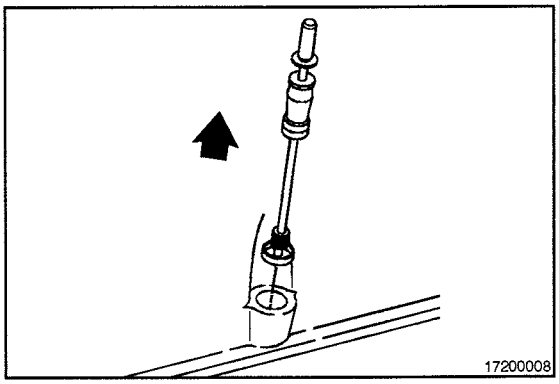
Do not allow metal shavings to fall inside the engine when drilling a hole in the cup plug. Damage to engine components can occur.

Drill a 1/8-inch hole in the cup plug.



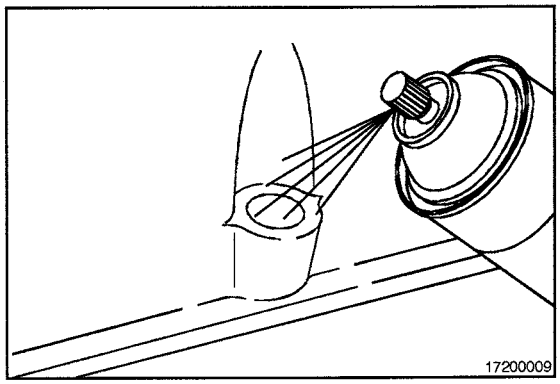
Use a dent puller to remove the plug.

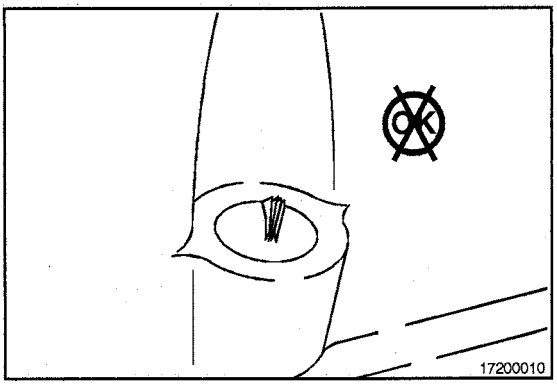
Discard all used cup plugs. Do **not** use them again.



Clean (017-002-006)

Use spray cleaner, Part No. 3823717 or equivalent, to clean the cup plug bores.



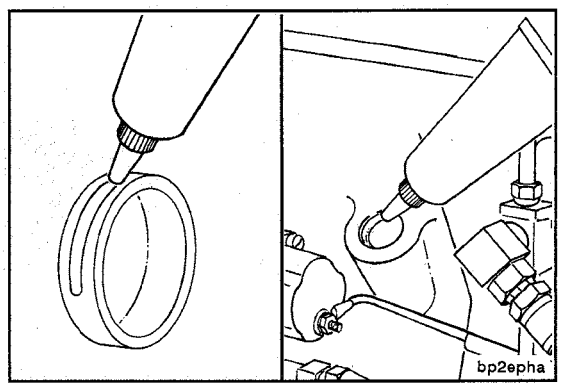


Inspect for Reuse (017-002-007)

Inspect the cup plug bores for damage.

Repair the cup plug bores, if necessary.

Refer to the L10 Alternative Repair Manual, Bulletin No. 3810310, for repair procedures and cup plug bore dimensions.

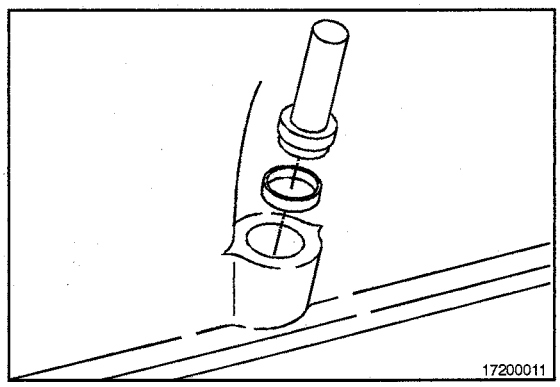


Install (017-002-026)

⚠ CAUTION ⚠

Excessive sealant can run back into the engine and cause damage to other components. Allow the sealant to dry for a minimum of two hours before operating the engine.

Apply a 2 mm [1/16 in] bead of cup plug lock 'n seal, Part No. 3375068 or equivalent, to the outside diameter of the cup plug and the inside diameter of the cup plug installation bore.

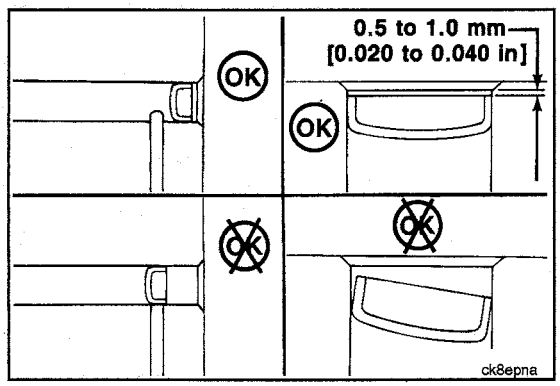


A cup plug driver **must** be used to install the cup plug to the correct depth in the cup plug bore.

Use the following cup plug drivers:

- Part No. 3822372 - 9.7 mm [0.38 in] cup plug.
- Part No. 3376816 - 25.4 mm [1.00 in] cup plug.
- Part No. 3376058 - 60.5 mm [2.38 in] cup plug.

Use cup plug driver handle, Part No. 3376795, with cup plug driver, Part No. 3376816.



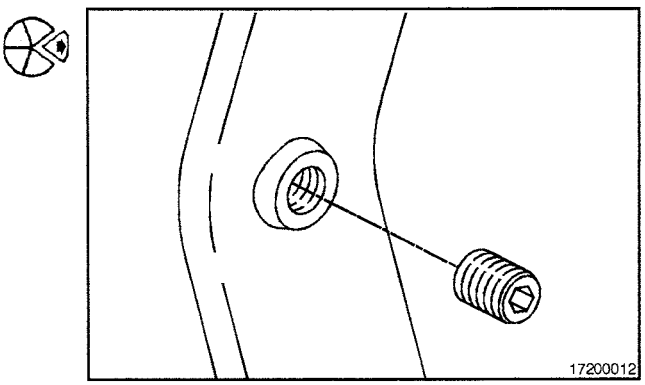
The cup plug **must** be installed with the edge of the plug 0.5 to 1.0 mm [0.020 to 0.040 in] deeper than the entrance chamber of the bore.

Do **not** install the plug too deep. The cross drillings in the cylinder block can be blocked shut. If the plug is **not** installed straight and flat, it **must** be replaced with a new cup plug.

Pipe Plug (017-007)

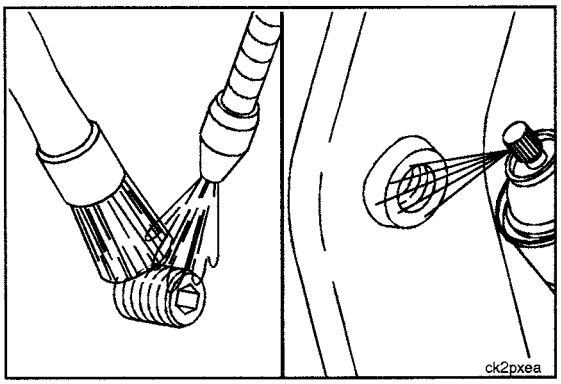
Remove (017-007-002)

Select the appropriate size Allen wrench and remove the pipe plug.



Clean (017-007-006)

Use spray cleaner, Part No. 3823717 or equivalent, to clean the threads of the pipe plugs and threaded bores.

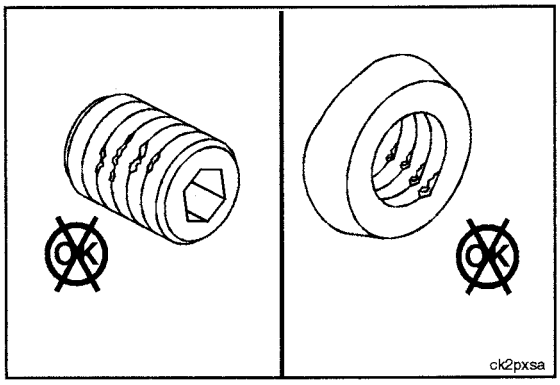


Inspect for Reuse (017-007-007)

Inspect the threads of the pipe plugs for mutilation or damage.

Inspect the threaded bores for damage.

Repair the bores, if necessary. Refer to the L10 Alternative Repair Manual, Bulletin No. 3810310.

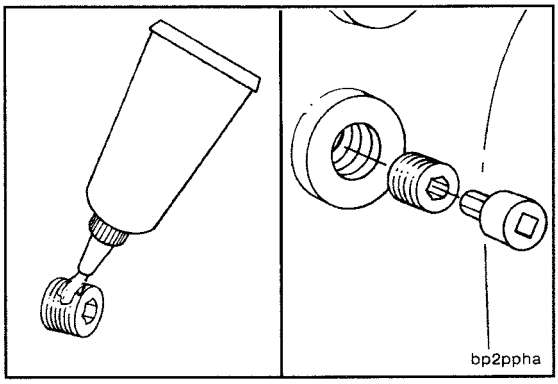


Install (017-007-026)

Apply a film of pipe plug sealant, Part No. 3375066 or equivalent, to the threads.

Install and tighten the pipe plugs.

Refer to the following chart for torque values:



Pipe Plug Torque Values

Size			Torque		Torque	
Thread	Actual Thread O.D.		In Aluminum Components		In Cast Iron or Steel Components	
in.	mm	[in]	N•m	[ft-lbs]	N•m	[ft-lbs]
1/16	8.1	[0.32]	5	[45 in-lb]	15	[10]
1/8	10.4	[0.41]	15	[10]	20	[15]
1/4	13.7	[0.54]	20	[15]	25	[20]
3/8	17.3	[0.68]	25	[20]	35	[25]
1/2	21.6	[0.85]	35	[25]	55	[40]
3/4	26.7	[1.05]	45	[35]	75	[55]
1	33.5	[1.32]	60	[45]	95	[70]
1¼	42.2	[1.66]	75	[55]	115	[85]
1½	48.3	[1.90]	85	[65]	135	[100]

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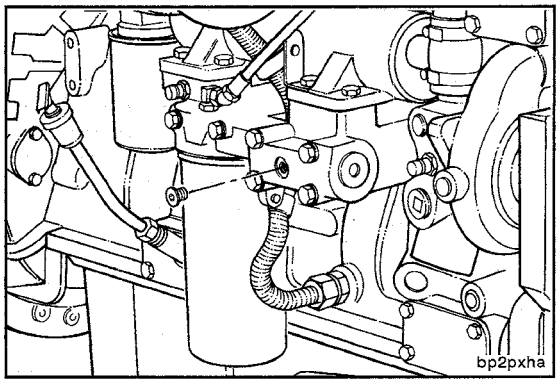
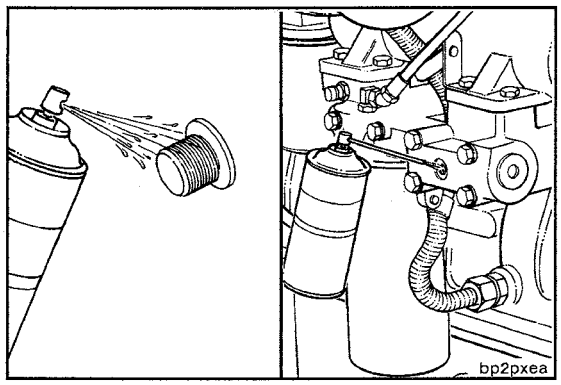
Tighten pipe plugs to the appropriate torque values.



Straight Thread Plug (017-011)

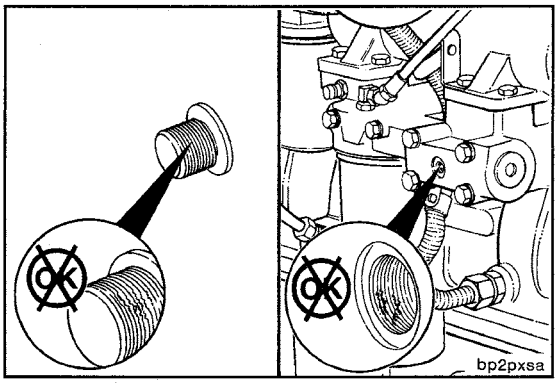
Remove (017-011-002)

Select the appropriate size Allen wrench or socket, and remove the plug.



Clean (017-011-006)

Use spray cleaner, Part No. 3823717 or equivalent, to clean the threads of the straight thread plugs and threaded bores.



Inspect for Reuse (017-011-007)

Inspect the threads of the pipe plugs for mutilation or damage.

Inspect the threaded bores for damage.

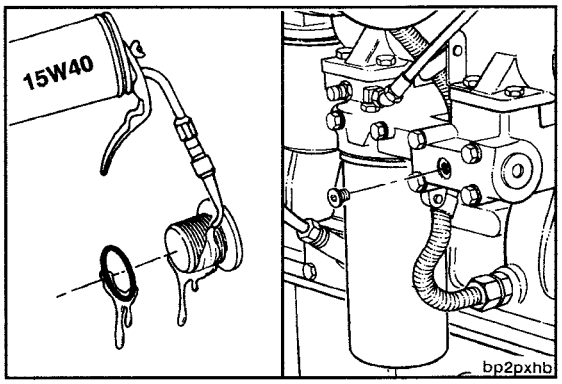
Repair the bores, if necessary. Refer to the L10 Alternative Repair Manual, Bulletin No. 3810310.

Install (017-011-026)

Install a new o-ring on the plug. Lubricate with clean 15W-40 oil.

Install and tighten the plugs.

Refer to the following chart for torque values:



Tighten straight thread plugs to the appropriate torque value.

Straight Thread O-Ring Plugs

Thread Size Inches	Torque - lbf			
	N•m	In-lb	N•m	ft-lb
1/4	4	35		
3/8	6	50		
1/2	8	70		
9/16	12	105		
5/8	16	145		
3/4			20	15
7/8			35	20
1			40	30
1-1/16			45	35
1-3/16			55	40

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NOTES

Section 20 - Vehicle Braking - Group 20

Section Contents

Page

Clutch Switch 20-1
Adjust 20-8
Clean 20-5
Initial Check 20-1
Inspect for Reuse 20-5
Install 20-6
Remove 20-4

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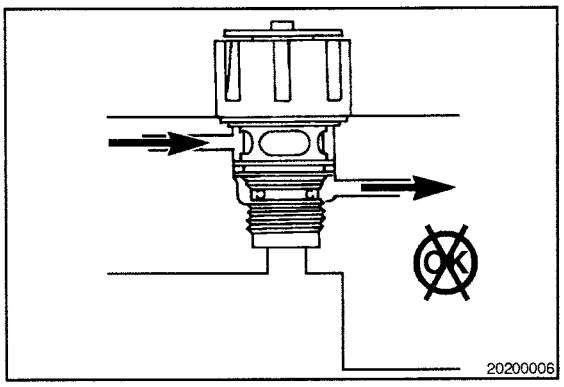
Clutch Switch (020-001)

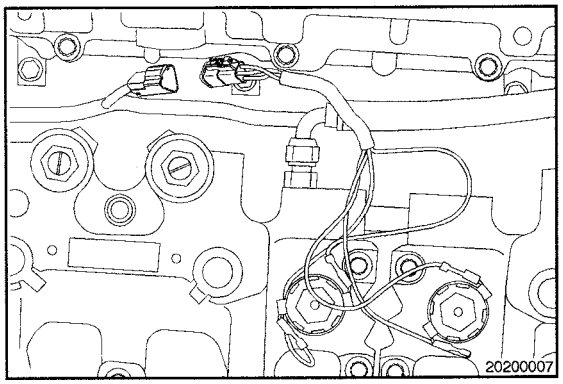
Initial Check (020-001-001)

An engine equipped with an engine brake can fail to start or perform properly due to one or more of the following:

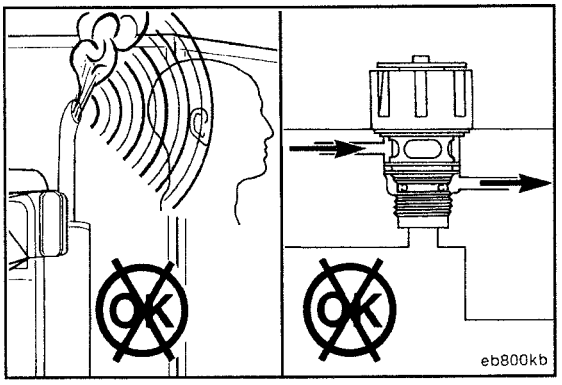
- Engine will **not** start due to a stuck oil flow solenoid valve.



NOTE: To check for a stuck solenoid valve, disconnect the electrical connection to the engine brakes, and operate the engine.

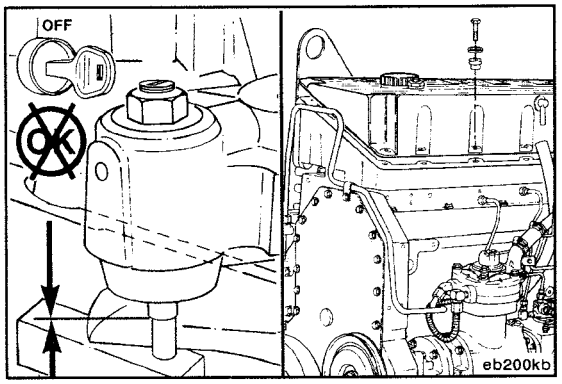


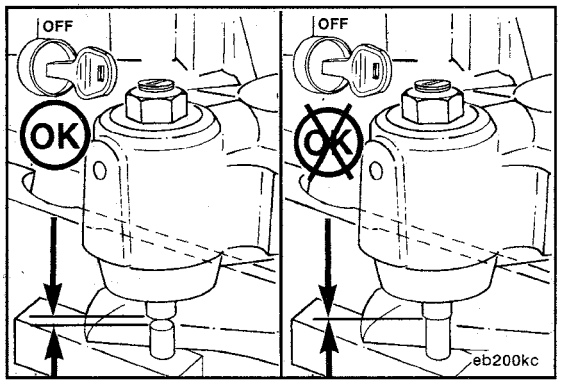
If exhaust gases can be heard escaping past the valves, the solenoid valve or valves **must** be replaced. Contact an authorized engine brake dealer.



- Engine will **not** start or runs rough because a slave piston was adjusted incorrectly or damaged

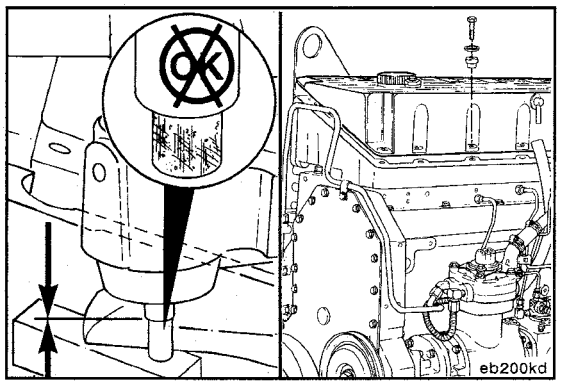
To check the slave piston, remove the rocker lever cover. Refer to Procedure 003-011.





Check the slave piston clearance. The clearance **must** be 0.38 mm [0.015 in].

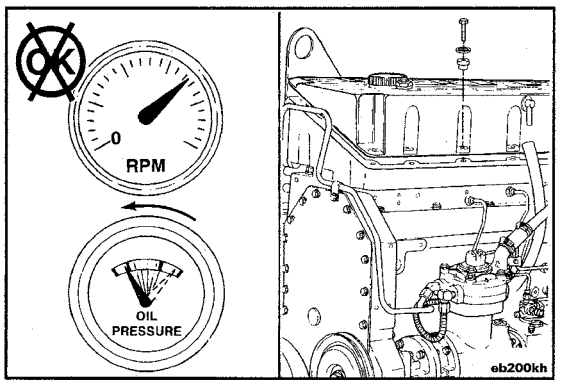
Refer to Engine Brake - Adjustment in Procedure 003-004 to adjust the clearance.



Inspect the slave piston for damage.

NOTE: If the slave piston is damaged, contact an authorized engine brake dealer for repair.

Install the rocker lever cover. Refer to Procedure 003-011.

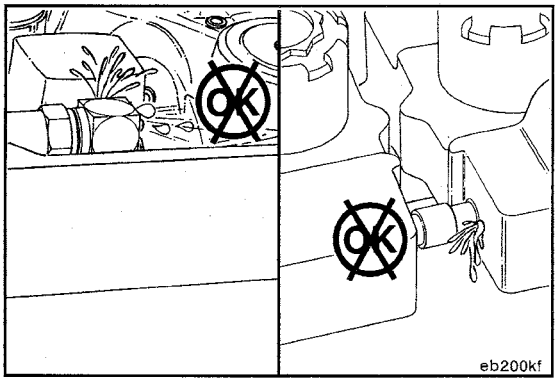


- Sudden drop in lubricating oil pressure.

Remove the rocker lever cover. Refer to Procedure 003-011.

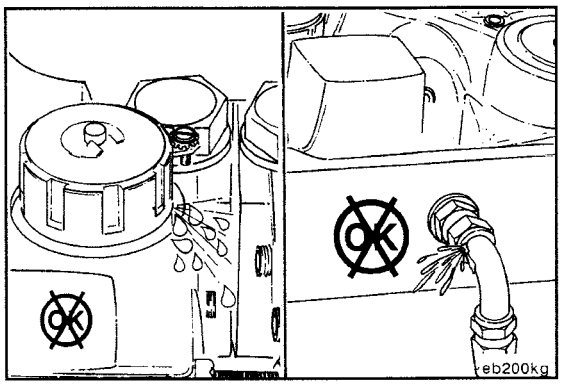
NOTE: If repairs are necessary, contact an authorized engine brake dealer.

Operate the engine and check for the following problems:

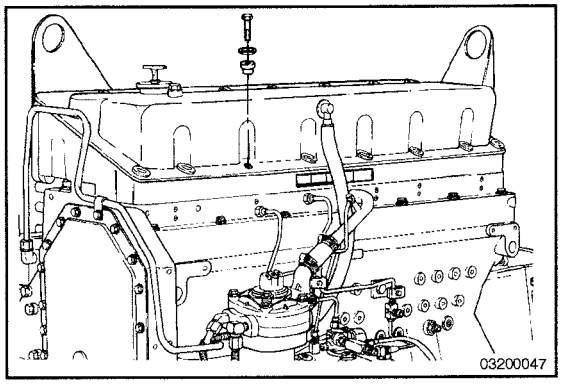


- Oil supply hose loose or missing
- Oil connector seal loose or missing

- Upper solenoid valve seal ring missing or damaged
- External oil supply hose or fitting cracked or leaking.



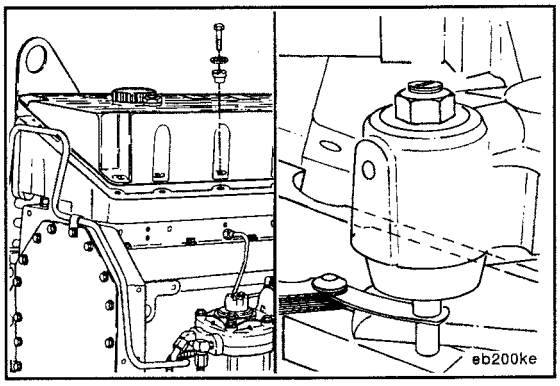
Install the rocker lever cover. Refer to Procedure 003-011.



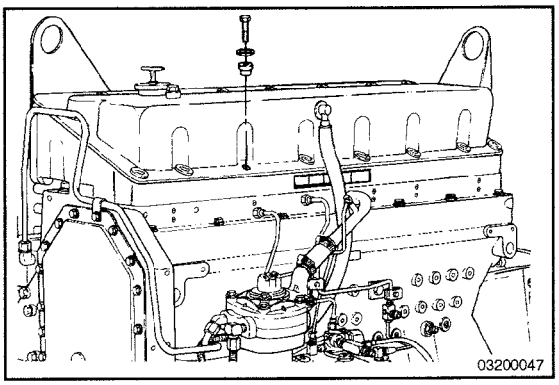
- Engine misfiring or loss of power.

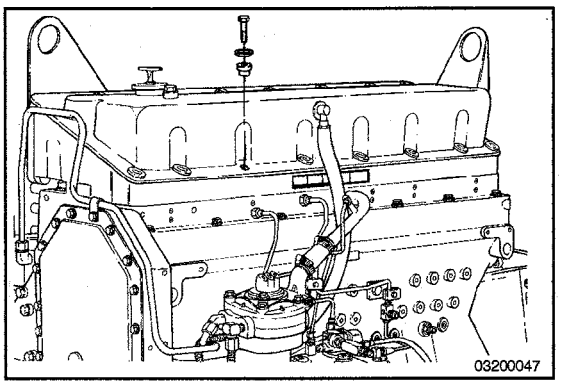
Remove the rocker lever cover. Refer to Procedure 003-011.

Adjust the slave piston clearance. Refer to Engine Brake - Adjustment in Procedure 003-004.



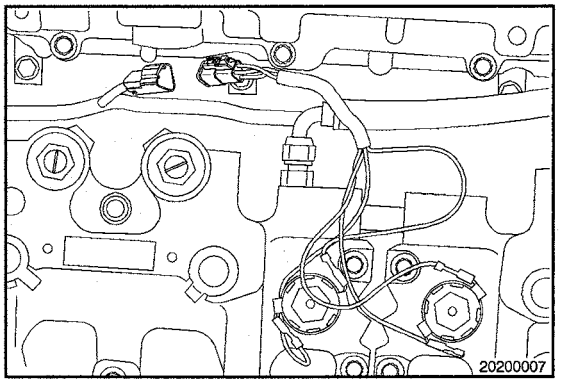
Install the rocker lever cover. Refer to Procedure 003-011.



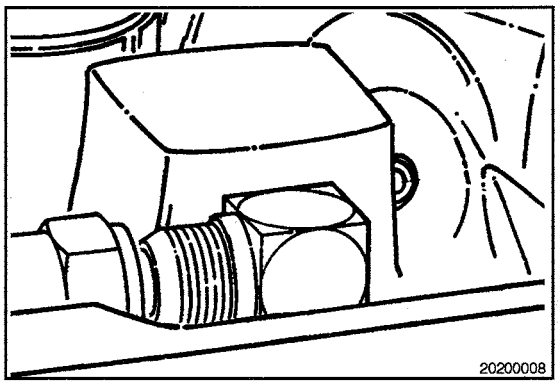


Remove (020-001-002)

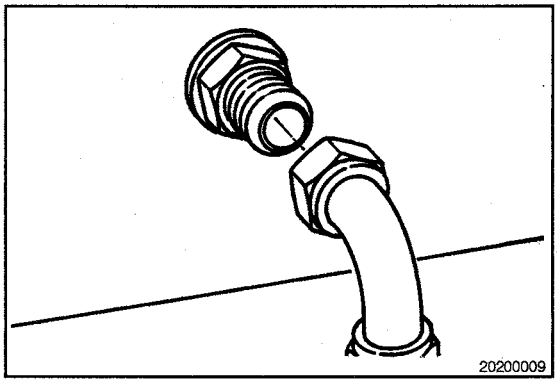
Remove the rocker lever cover. Refer to Procedure 003-011.



Disconnect the solenoid power and ground wires from the terminals on the inside of the rocker lever housing spacer.

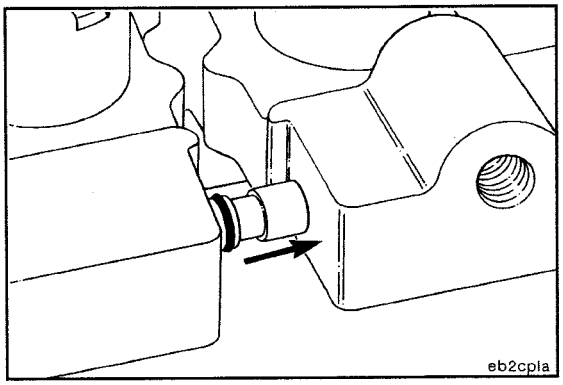


Disconnect the internal oil supply hose connection.

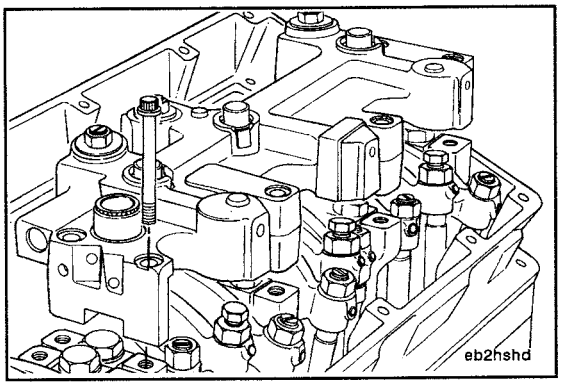


Disconnect the external oil supply hose connection.

Press the connector into the front housing to allow clearance for housing removal.

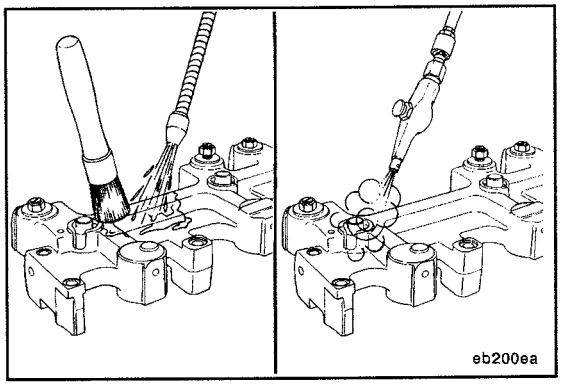


Remove the capscrews and both engine brake housings.



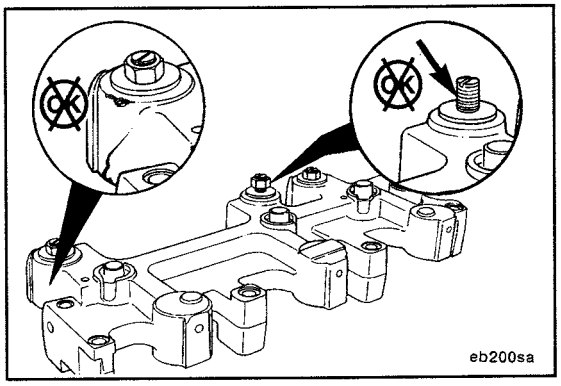
Clean (020-001-006)

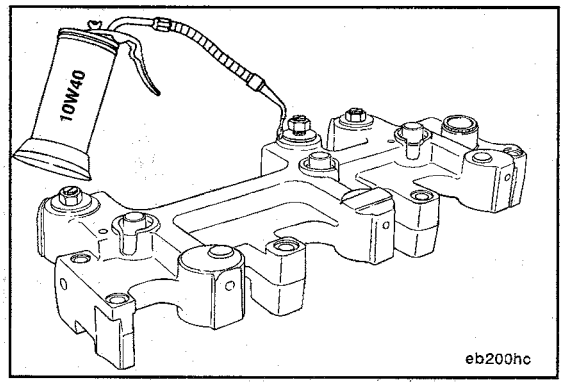
Use an approved solvent to clean the brake housings. Dry with compressed air.



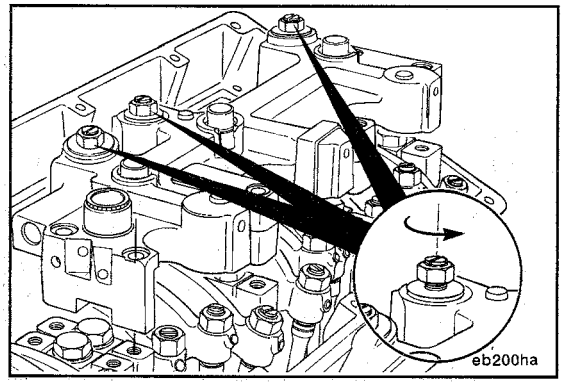
Inspect for Reuse (020-001-007)

Inspect the housings for any missing or damaged parts.





Apply a thin film of clean 15W-40 oil to the machined surfaces.

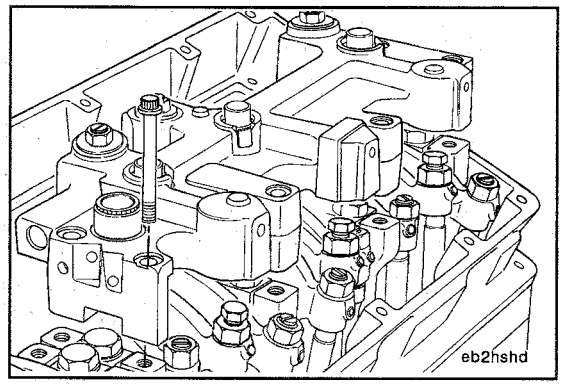


Install (020-001-026)

Loosen the locknuts on the slave pistons.

Make sure the slave pistons are fully retracted.

Install the rear engine brake housing on the rear rocker lever supports.

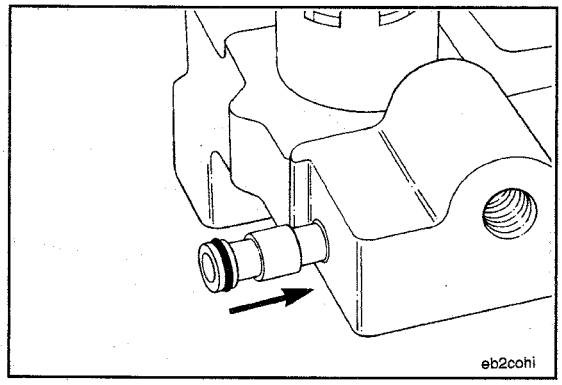


Use clean 15W-40 oil to coat the bottom side of the capscrew heads and threads.

NOTE: Washers are **not** used with the capscrews.

Install the capscrews in the rocker lever supports.

Do **not** tighten the capscrews.



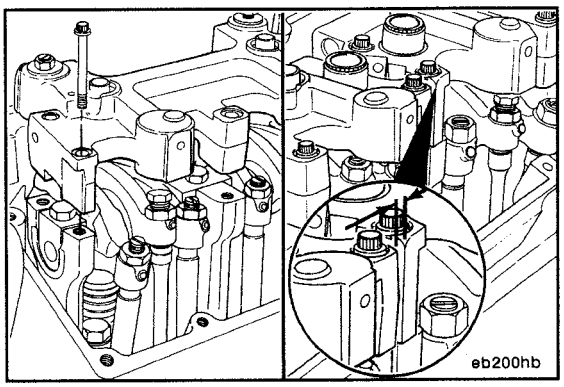
Use clean 15W-40 oil to lubricate the o-rings.

Press the connector all the way into the front housing by hand.

When installing the front housing, be sure the oil connector and o-ring are in a position to be pushed into the rear housing.

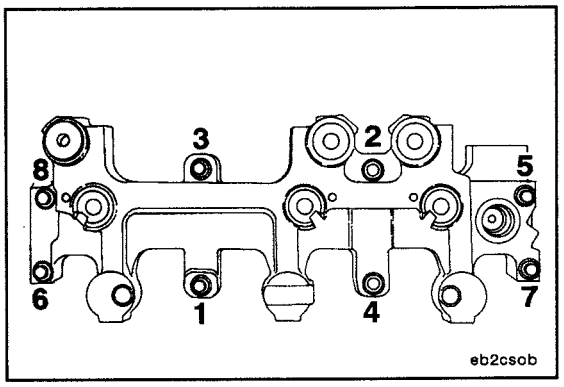
Install the front engine brake housing on the front rocker lever supports.

Center the oil connector between the front and rear housings before tightening the capscrews.



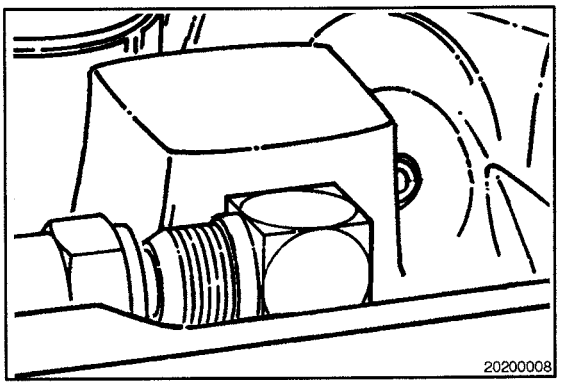
Tighten the capscrews in the sequence shown.

Torque Value: 81 N•m [60 ft-lb]



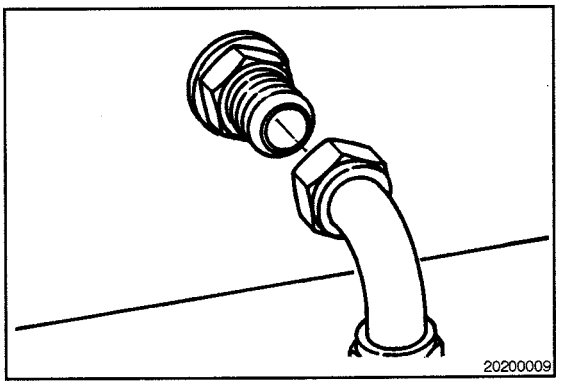
Install the internal oil connector supply hose, and tighten the capscrews.

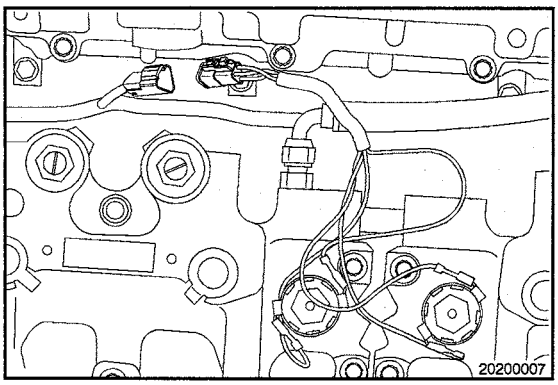
Torque Value: 19 N•m [14 ft-lb]



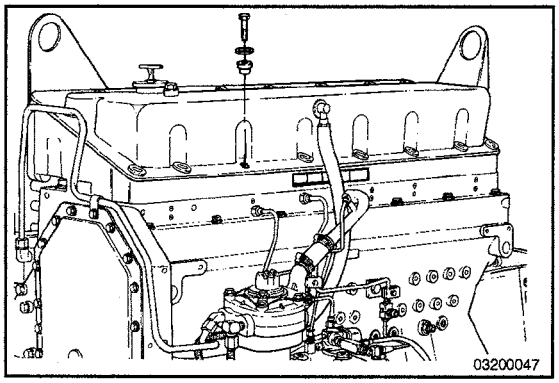
Install the external oil connector supply hose, and tighten the capscrews.

Torque Value: 19 N•m [14 ft-lb]

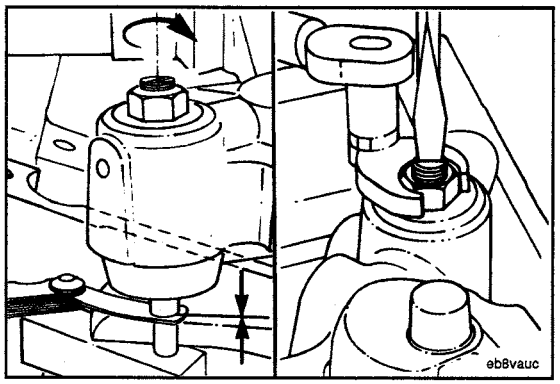




Connect the solenoid power and ground wires to the terminals on the inside of the rocker lever housing, red to the rear housing solenoid and white to the front housing solenoid.



Install the rocker lever cover. Refer to Procedure 003-011.



Adjust (020-001-029)

To obtain maximum brake operating efficiency, the engine brakes **must** be adjusted. Refer to Procedure 003-004 (Overhead Adjustment) for the correct engine brake adjusting procedure.

Section L - Service Literature

Section Contents

Page

Additional Service Literature L-1
Service Literature Ordering Location L-2

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Additional Service Literature

The following publications can be purchased by filling in and mailing the Literature Order Form:

Service Literature Ordering Location

Region	Ordering Location
United States and Canada	Cummins Distributors or Contact 1-800-DIESELS (1-800-343-7357)
U.K., Europe, Mid-East, Africa, and Eastern European Countries	Cummins Engine Co., Ltd. Royal Oak Way South Daventry Northants, NN11 5NU, England
South and Central America (excluding Brazil and Mexico)	Cummins Americas, Inc. 16085 N.W. 52nd Avenue Hialeah, FL 33104
Brazil and Mexico	Cummins Engine Co., Inc. International Parts Order Dept., MC 40931 Box 3005 Columbus, IN 47202-3005
Far East (excluding Australia and New Zealand)	Cummins Diesel Sales Corp. Literature Center 8 Tanjong Penjuru Jurong Industrial Estate Singapore
Australia and New Zealand	Cummins Diesel Australia Maroondah Highway, P.O.B. 139 Ringwood 3134 Victoria, Australia

Obtain current price information from your local Cummins Distributor.

Section M - Component Manufacturers

Section Contents

Page

Component Manufacturers' Addresses M-1
Air Compressors M-1
Air Cylinders M-1
Air Heaters M-1
Air Starting Motors M-1
Alternators M-1
Auxiliary Brakes M-1
Belts M-1
Catalytic Convertors M-1
Clutches M-1
Coolant Heaters M-2
Coolant Level Switches M-1
Drive Plates M-2
Electric Starting Motors M-2
Electronic Switches M-2
Engine Protection Controls M-2
Fan Clutches M-2
Fans M-2
Fault Lamps M-2
Filters M-2
Flexplates M-2
Fuel Coolers M-2
Fuel Pumps M-2
Fuel Warmers M-2
Gauges M-3
Governors M-3
Heat Sleeves M-3
Hydraulic and Power Steering Pumps M-3
In-Line Connectors M-3
Oil Heaters M-3
Prelubrication Systems M-3
Radiators M-3
Throttle Assemblies M-3
Torque Converters M-3

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Component Manufacturers' Addresses

NOTE: The following list contains addresses and telephone numbers of suppliers of accessories used on Cummins engines. Suppliers can be contacted directly for any specifications **not** covered in this manual.

Air Compressors

Bendix Heavy Vehicles Systems
Div. of Allied Automotive
901 Cleveland Street
Elyria, OH 44036
Telephone: (216) 329-9000

Holset Engineering Co., Inc.
1320 Kemper Meadow Drive
Suite 500
Cincinnati, OH 45240
Telephone: (513) 825-9600

Midland-Grau
Heavy Duty Systems
Heavy Duty Group Headquarters
10930 N. Pamona Avenue
Kansas City, MO 64153
Telephone: (816) 891-2470

Air Cylinders

Bendix Ltd.
Douglas Road
Kingswood
Bristol
England
Telephone: 0117-671881

Catching Engineering
1733 North 25th Avenue
Melrose Park, IL 60160
Telephone: (708) 344-2334

TEC - Hackett Inc.
8909 Rawles Avenue
Indianapolis, IN 46219
Telephone: (317) 895-3670

Air Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Kim Hotstart Co.
P.O. Box 11245
Spokane, WA 99211-0245
Telephone: (509) 534-6171

Air Starting Motors

Ingersoll Rand
Chorley New Road
Horwich
Bolton
Lancashire
England
BL6 6JN
Telephone: 01204-65544

Ingersoll-Rand Engine
Starting Systems
888 Industrial Drive
Elmhurst, IL 60126
Telephone: (708) 530-3875

StartMaster
Air Starting Systems
A Division of Sycon Corporation
9595 Cheney Avenue
P. O. Box 491
Marion, OH 43302
Telephone: (614) 382-5771

Alternators

Robert Bosch Ltd.
P.O. Box 98
Broadwater Park
North Orbital Road
Denham
Uxbridge
Middlesex UD9 5HG
England
Telephone: 01895-833633

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 01744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.C. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 01908-66001

C. E. Niehoff & Co.
2021 Lee Street
Evanston, IL 60202
Telephone: (708) 866-6030

Delco-Remy America
2401 Columbus Avenue
P.O. Box 2439
Anderson, IN 46018
Telephone: (317) 646-3528

Leece-Neville Corp.
400 Main Street
Arcade, NY 14009
Telephone: (716) 492-1700

Auxiliary Brakes

The Jacobs Manufacturing Company
Vehicle Equipment Division
22 East Dudley Town Road
Bloomfield, CT 06002
Telephone: (203) 243-1441

Belts

Dayco Rubber U.K.
Sheffield Street
Stockport
Cheshire
SK4 1RV
England
Telephone: 061-432-5163

T.B.A. Belting Ltd.
P.O. Box 77
Wigan
Lancashire
WN2 4XQ
England
Telephone: 01942-59221

Dayco Mfg.
Belt Technical Center
1955 Enterprize
Rochester Hills, MI 48309
Telephone: (810) 853-8300

Gates Rubber Company
900 S. Broadway
Denver, CO 80217

Goodyear Tire and
Rubber Company
Industrial Products Div.
2601 Fortune Circle East
Indianapolis, IN 46241
Telephone: (317) 898-4170

Catalytic Convertors

Donaldson Company, Inc.
1400 West 94th Street
P.O. Box 1299
Minneapolis, MN 55440
Telephone: (612) 887-3835

Nelson Division
Exhaust and Filtration Systems
1801 U.S. Highway 51 P.O. Box 428
Stoughton, WI 53589
Telephone: (608) 873-4200

Walker Manufacturing
3901 Willis Road
P.O. Box 157
Grass Lake, MI 49240
Telephone: (517) 522-5500

Coolant Level Switches

Robertshaw Controls Company
P.O. Box 400
Knoxville, TN 37901
Telephone: (216) 885–1773

Clutches

Twin Disc International S.A.
Chaussee de Namur
Nivelles
Belguim
Telephone: 067-224941

Twin Disc Incorporated
1328 Racine Street
Racine, WI 53403
Telephone: (414) 634-1981

Coolant Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Drive Plates

Detroit Diesel Allison
Division of General Motors
Corporation
P.O. Box 894
Indianapolis, IN 46206-0894
Telephone: (317) 242-5000

Electric Starting Motors

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 01744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.C. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 0908-66001

Delco-Remy America
2401 Columbus Avenue
P.O. Box 2439
Anderson, IN 46018
Telephone: (317) 646-3528

Leece-Neville Corp.
400 Main Street
Arcade, NY 14009
Telephone: (716) 492-1700

Nippondenso Inc.
2477 Denso Drive
P.O. Box 5133
Southfield, MI 48086
Telephone: (313) 350-7500

Electronic Switches

Cutler-Hammer Products
Eaton Corporation
4201 N. 27th Street
Milwaukee, WI 53216
Telephone: (414) 449–6600

Engine Protection Controls

Flight Systems Headquarters
Hempt Road
P.O. Box 25
Mechanicsburg, PA 17055
Telephone: (717) 697–0333

The Nason Company
2810 Blue Ridge Blvd.
West Union, SC 29696
Telephone: (803) 638-9521

Teddington Industrial
Equipment
Windmill Road
Sunburn on Thames
Middlesex
TW16 7HF
England
Telephone: 09327-85500

Fan Clutches

Kysor Cooling Systems N.A.
6040 West 62nd Street
Indianapolis, IN 46278
Telephone: (317) 328–3330

Holset Engineering Co. Ltd.
P.O. Box A9
Turnbridge
Huddersfield, West Yorkshire
England HD6 7RD
Telephone: 01484-22244

Horton Industries, Inc.
P.O. Box 9455
Minneapolis, MN 55440
Telephone: (612) 378-6410

Rockford Clutch Company
1200 Windsor Road
P.O. Box 2908
Rockford, IL 61132-2908
Telephone: (815) 633-7460

Fans

Truflo Ltd.
Westwood Road
Birmingham
B6 7JF
England
Telephone: 021-557-4101

Hayes-Albion Corporation
Jackson Manufacturing Plant
1999 Wildwood Avenue
Jackson, MI 49202
Telephone: (517) 782-9421

Engineered Cooling Systems, Inc.
201 W. Carmel Drive
Carmel, IN 46032
Telephone: (317) 846-3438

Brookside Corporation
P.O. Box 30
McCordsville, IN 46055
Telephone: (317) 335-2014

TCF Aerovent Company
9100 Purdue Rd., Suite 101
Indianapolis, IN 46268-1190
Telephone: (317) 872-0030

Kysor-Cadillac
1100 Wright Street
Cadillac, MI 49601
Telephone: (616) 775-4681

Schwitzer
6040 West 62nd Street
P.O. Box 80-B
Indianapolis, IN 46206
Telephone: (317) 328-3010

Fault Lamps

Cutler-Hammer Products
Eaton Corporation
4201 N. 27th Street
Milwaukee, WI 53216
Telephone: (414) 449–6600

Filters

Fleetguard International Corp.
Cavalry Hill Industrial Park
Weedon
Northampton NN7 4TD
England
Telephone: 01327-41313

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: 1–800–22–Filters
(1–800–223–4583)

Flexplates

Corrugated Packing and
Sheet Metal
Hamsterley
Newcastle Upon Tyne
England
Telephone: 01207-560-505

Allison Transmission
Division of General Motors
Corporation
P.O. Box 894
Indianapolis, IN 46206-0894
Telephone: (317) 242-5000

Midwest Mfg. Co.
29500 Southfield Road, Suite 122
Southfield, MI 48076
Telephone: (313) 642-5355

Wohlert Corporation
708 East Grand River Avenue
P.O. Box 20217
Lansing, MI 48901
Telephone: (517) 485-3750

Fuel Coolers

Hayden, Inc.
1531 Pomona Road
P.O. Box 848
Corona, CA 91718–0848
Telephone: (909) 736–2665

Fuel Pumps

Robert Bosch Corp.
Automotive Group
2800 South 25th Ave.
Broadview, IL 60153

Fuel Warmers

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Gauges

A.I.S.
Dyffon Industrial Estate
Ystrad Mynach
Hengoed
Mid Glamorgan
CF8 7XD
England
Telephone: 01443-812791

Grasslin U.K. Ltd.
Vale Rise
Tonbridge
Kent
TN9 1TB
England
Telephone: 01732-359888

Icknield Instruments Ltd.
Jubilee Road
Letchworth
Herts
England
Telephone: 04626-5551

Superb Tool and Gauge Co.
21 Princip Street
Birmingham
B4 61E
England
Telephone: 021-359-4876

Kabi Electrical and Plastics
Cranborne Road
Potters Bar
Herts
EN6 3JP
England
Telephone: 01707-53444

Datcon Instruments
P.O. Box 128
East Petersburg, PA 17520
Telephone: (717) 569-5713

Rochester Gauges, Inc.
11616 Harry Hines Blvd.
P.O. Box 29242
Dallas, TX 75229
Telephone: (214) 241-2161

Governors

Woodward Governors Ltd.
P.O. Box 15
663/664 Ajax Avenue
Slough
Bucks
SL1 4DD
England
Telephone: 01753-26835

Woodward Governor Co.
P.O. Box 1519
Fort Collins, CO 80522
Telephone: (303) 482-5811
(800) 523-2831

Barber Colman Co.
1354 Clifford Avenue
Loves Park, IL 61132
Telephone: (815) 637-3000

United Technologies
Diesel Systems
1000 Jorie Blvd.
Suite 111
Oak Brook, IL 69521
Telephone: (312) 325-2020

Heat Sleeves

Bentley Harris Manufacturing Co.
100 Bentley Harris Way
Gordonville, TN 38563
Telephone: (313) 348-5779

Hydraulic and Power Steering Pumps

Hobourn Automotive
Temple Farm Works
Priory Road
Strood
Rochester
Kent, England
ME2 2BD
Telephone: 01634-71773

Honeywell Control Systems Ltd.
Honeywell House
Charles Square
Bracknell
Berks RG12 1EB
Telephone: 01344-4245

Sundstrand Hydratec Ltd.
Cheney Manor Trading Estate
Swindon
Wiltshire
SN2 2PZ
England
Telephone: 01793-30101

Sperry Vickers
P.O. Box 302
Troy, MI 48084
Telephone: (313) 280-3000

Z.F.
P.O. Box 1340
Grafvonsoden Strasse
5-9 D7070
Schwaebisch Gmuend
Germany
Telephone: 7070-7171-31510

In-Line Connectors

Pioneer-Standard Electronics, Inc.
5440 Neiman Parkway
Solon, OH 44139
Telephone: (216) 349-1300

Deutsch
Industrial Products Division
37140 Industrial Avenue
Hemet, CA 92343
Telephone: (714) 929-1200

Oil Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Kim Hotstart Co.
P.O. Box 11245
Spokane, WA 99211-0245
Telephone: (509) 534-6171

Prelubrication Systems

RPM Industries, Inc.
Suite 109
55 Hickory Street
Washington, PA 15301
Telephone: (412) 228-5130

Radiators

JB Radiator Specialties, Inc.
P.O. Box 292087
Sacramento, CA 95829-2087
Telephone: (916) 381-4791

The G&O Manufacturing Company
100 Gando Drive
P.O. Box 1204
New Haven, CT 06505-1204
Telephone: (203) 562-5121

Young Radiator Company
2825 Four Mile Road
Racine, WI 53404
Telephone: (910) 271-2397

L and M Radiator, Inc.
1414 East 37th Street
Hibbing, MN 55746
Telephone: (218) 263-8993

Throttle Assemblies

Williams Controls, Inc.
14100 SW 72nd Avenue
Portland, OR 97224
Telephone: (503) 684-8600

Torque Converters

Twin Disc International S.A.
Chaussee de Namur
Nivelles
Belgium
Telephone: 067-224941

Twin Disc Incorporated
1328 Racine Street
Racine, WI 53403-1758
Telephone: (414) 634-1981

Rockford Powertrain, Inc.
Off-Highway Systems
1200 Windsor Road
P.O. Box 2908
Rockford, IL 61132-2908
Telephone: (815) 633-7460

Modine Mfg. Co.
1500 DeKoven Avenue
Racine, WI 53401
Telephone: (414) 636-1640

NOTES

Section V - Specifications

Section Contents

Page

Air Intake System - Specifications V-39
Air Intake Restriction V-39
Charge-Air Cooler (CAC) V-39
Turbocharger Axial Clearance V-39
Turbocharger Radial Bearing Clearance V-39
Turbocharger Wastegate Actuator V-40
Turbocharger Wastegate Controller V-40
Turbocharger Wastegate Valve Body V-40

Air Intake System - Torque Values V-41
Air Intake Manifold V-41
Air Leaks, Air Intake and Exhaust Systems V-41
Turbocharger V-41
Turbocharger Wastegate Actuator V-42
Turbocharger Wastegate Controller V-42

Cam Followers/Tappets - Specifications V-20
Cam Follower Assembly V-20

Cam Followers/Tappets - Torque Values V-21
Cam Follower Assembly V-21

Capscrew Markings and Torque Values V-58
Capscrew Markings and Torque Values - Metric V-59
Capscrew Markings and Torque Values - U.S. Customary V-60

Compressed Air System - Specifications V-46
Air Compressor Carbon Buildup V-46
Air Governor (Air Compressor Pumps Continuously) V-46

Compressed Air System - Torque Values V-47
Air Compressor V-47
Air Compressor Carbon Buildup V-47
Air Compressor Unloader and Valve Assembly V-47

Cooling System - Specifications V-31
Coolant Thermostat V-31
Cooling System V-31
Fan Clutch, Air-Disengaged V-31
Fan Clutch, Air-Engaged V-31
Fan Clutch, Electric V-31
Fan Drive Idler Pulley Assembly V-32
Fan Hub, Belt Driven V-32
Radiator V-32
Radiator Pressure Cap V-32
Water Pump V-32

Cooling System - Torque Values V-33
Coolant Filter Head V-33
Coolant Heater Housing V-33
Coolant Thermostat V-33
Coolant Thermostat Housing Support V-33
Coolant Thermostat Seal V-34
Cooling Fan Drive Belt V-33
Cooling Systeml V-34
Fan Clutch, Electric V-34
Fan Clutch, Viscous V-34
Fan, Cooling V-35
Fan Drive Idler Pulley Assembly V-35
Fan Hub, Belt Driven V-35
Fan Spacer and Pulley V-35
Water Pump V-35

Cylinder Block - Specifications V-1
Bearings, Connecting Rod V-1
Bearings, Main V-1
Bearings, Thrust V-1

Page

Camshaft V-1
Camshaft Bushings V-1
Camshaft End Clearance V-9
Camshaft Gear (Camshaft Installed) V-2
Connecting Rod V-2
Crankshaft Gear, Front (Crankshaft Installed) V-3
Cylinder Block and Liner Seats V-3
Cylinder Liner V-3
Cylinder Liner Protrusion V-8
Gear Housing, Front V-4
Idler Gear, Camshaft V-4
Idler Gear, Hydraulic Pump V-5
Idler Gear, Water Pump V-6
Piston V-7
Piston and Connecting Rod Assembly V-8
Piston Cooling Nozzle V-7
Piston Rings V-7
Vibration Damper V-7

Cylinder Block - Torque Values V-10
Accessory Drive Seal V-10
Alternator Drive Seal V-10
Bearings, Connecting Rod V-10
Bearings, Main V-10
Camshaft V-10
Crankshaft Pulley V-10
Crankshaft Seal, Front V-11
Crankshaft Seal, Rear V-11
Cylinder Liner Protrusion V-13
Gear Cover, Front V-11
Gear Housing, Front V-12
Idler Gear, Camshaft V-12
Idler Gear, Hydraulic Pump V-12
Idler Gear, Water Pump V-12
Piston and Connecting Rod Assembly V-13
Piston Cooling Nozzle V-13
Water Header Plate, Cylinder Block V-13

Cylinder Head - Specifications V-14
Cylinder Head V-14

Cylinder Head - Torque Values V-15
Cylinder Head V-15

Drive Belt Tension V-64

Drive Units - Specifications V-37
Hydraulic Pump Drive V-37

Drive Units - Torque Values V-38
Accessory Drive V-38
Accessory Drive Pulley V-38
Alternator Drive Pulley V-38
Hydraulic Pump Drive V-38

Electrical Equipment - Torque Values V-48
Alternator V-48
Drive Belt, Alternator V-48
Starting Motor V-48

Engine Testing - Specifications V-49
Engine Testing (Chassis Dynamometer) V-49

Exhaust System - Specifications V-44
Exhaust Manifold, Dry V-44
Exhaust Restriction V-44

Exhaust System - Torque Values V-45
Exhaust Manifold, Dry V-45

Fraction, Decimal, Millimeter Conversions V-63

Fuel System - Specifications V-22

Page

Fuel Flow V-22
Fuel Shutoff Valve (FSOV) V-22

Fuel System - Torque Values V-23
Fuel Pump V-23
Fuel Pump Gear Pump Check Valve V-23
Fuel Pump Pulsation Damper V-23
Fuel Shutoff Valve V-23

Injectors and Fuel Lines - Specifications V-24
Cylinder Misfires or Smokes V-24
Fuel Drain Line Restriction V-24
Fuel Inlet Restriction V-24

Injectors and Fuel Lines - Torque Values V-25
ECM Cooling Plate, Fuel Cooled V-25
Injector V-25

Lubricating Oil System - Specifications V-26
Lubricating Oil Contamination V-28
Lubricating Oil Cooler V-26
Lubricating Oil High Pressure Relief Valve V-26
Lubricating Oil Pressure Regulator (Main Rifle) V-27
Lubricating Oil Pump V-27
Lubricating Oil System V-27
Lubricating Oil Thermostat V-28

Lubricating Oil System - Torque Values V-29
Centinel™ System (ISM Engines) V-30
Lubricating Oil Cooler V-29
Lubricating Oil Dipstick Housing V-29
Lubricating Oil Filter Head V-29
Lubricating Oil Pan V-29
Lubricating Oil Pressure Regulator (Main Rifle) V-30
Lubricating Oil Pump V-30
Lubricating Oil Transfer Tube V-30
Lubricating Oil Viscosity Sensor V-30

Miscellaneous - Specifications V-54
Cup Plug V-54

Mounting Adaptations - Specifications V-51
Flywheel V-51
Flywheel Housing, REPTO V-51
Flywheel Ring Gear V-52

Mounting Adaptations - Torque Values V-53
Engine Lifting Brackets V-53
Engine Support Bracket, Front V-53
Flywheel V-53
Flywheel Housing V-53
Flywheel Housing, REPTO V-53

Newton-Meter to Foot-Pound Conversion Chart V-61

Pipe Plug Torque Values V-57

Rocker Levers - Specifications V-16
Overhead Set V-16
Rocker Lever Assembly V-17

Rocker Levers - Torque Values V-19
Crankcase Breather (Internal) V-19
Overhead Set V-19
Rocker Lever Assembly V-19
Rocker Lever Housing V-19

Tap-Drill Chart - U.S. Customary and Metric V-56

Vehicle Braking - Torque Values V-55
Clutch Switch V-55

Weights and Measures - Conversion Factors V-62

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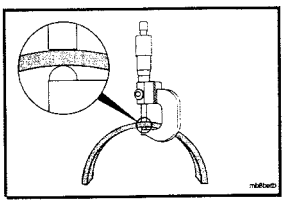
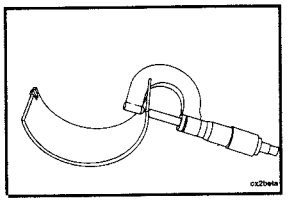
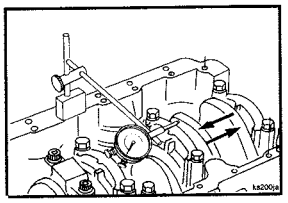
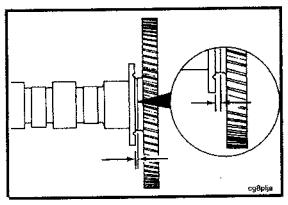
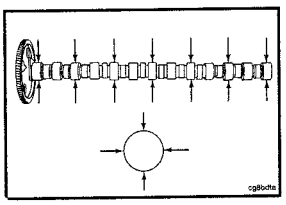
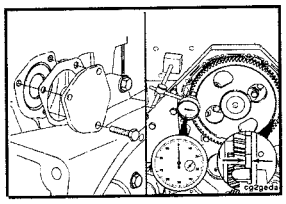
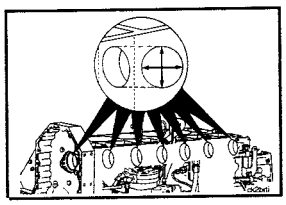
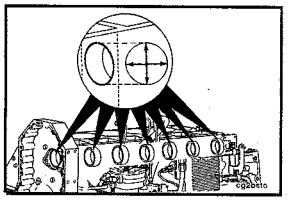
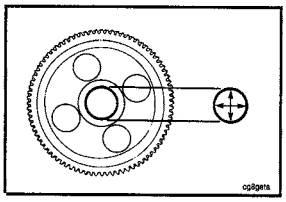
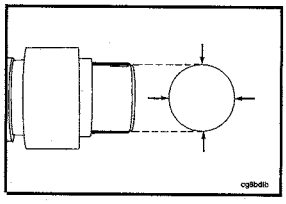
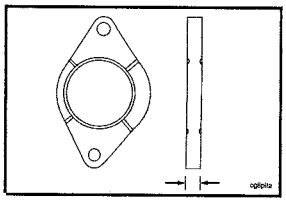
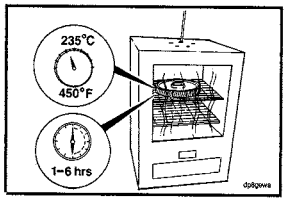
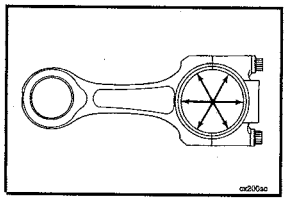
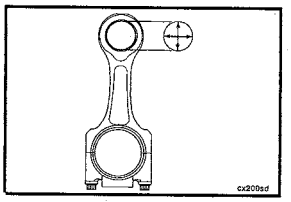
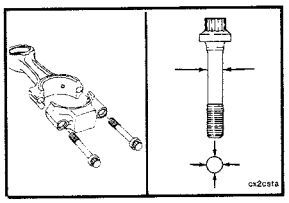
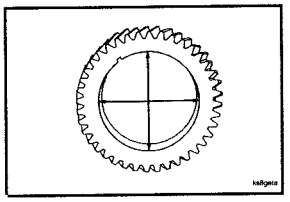
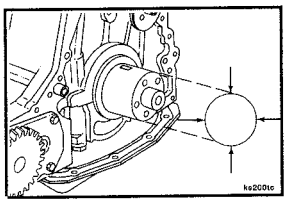
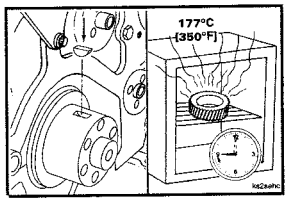
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Cylinder Block - Specifications					
Bearings, Connecting Rod (001-005)					
Standard Connecting Rod Bearing Thickness		2.430 mm 2.473 mm	MIN MAX	0.0957 in 0.0974 in	
Bearings, Main (001-006)					
Standard Main Bearing Shell Thickness		3.894 mm 3.945 mm	MIN MAX	0.1533 in 0.1553 in	
Bearings, Thrust (001-007)					
Crankshaft End Clearance		0.10 mm 0.56 mm	MIN MAX	0.004 in 0.022 in	
Camshaft (001-008)					
Camshaft Thrust Plate Clearance		0.13 mm 0.33 mm	MIN MAX	0.005 in 0.013 in	
Camshaft Bushing Journal Outside Diameter		71.960 mm 72.013 mm	MIN MAX	2.8331 in 2.8352 in	
Camshaft End Clearance		0.13 mm 0.33 mm	MIN MAX	0.005 in 0.013 in	
Camshaft Bushings (001-010)					
Cylinder Block Camshaft Bore I.D.		76.987 mm 77.040 mm	MIN MAX	3.0310 in 3.0331 in	

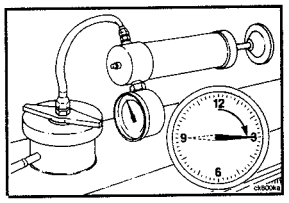
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
 **Camshaft Bushing I.D. Installed**		72.078 mm 72.142 mm	MIN MAX	2.8377 in 2.8402 in
 **Camshaft Gear (Camshaft Installed) (001-012)**				
Camshaft Gear Bore I.D.		46.912 mm 46.938 mm	MIN MAX	1.8469 in 1.8479 in
 **Camshaft Gear Journal O.D.**		46.987 mm 47.013 mm	MIN MAX	1.8499 in 1.8509 in
 **Camshaft Thrust Plate Thickness**		8.96 mm 9.04 mm	MIN MAX	0.353 in 0.356 in
 **Warning: To avoid severe burns, wear protective gloves when installing the camshaft gear.** **Camshaft Gear Installation Temperature** Heat the gear in an oven for a minimum of 1 hour, but **not** longer than 6 hours.				
Temperature:		235 °C		450 °F
 **Connecting Rod (001-014)**				
Connecting Rod Crankshaft Bore I.D.		83.975 mm 84.025 mm	MIN MAX	3.3061 in 3.3080 in
 **Piston Pin Bushing I.D.**		54.054 mm 54.099 mm	MIN MAX	2.1281 in 2.1299 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Connecting Rod Capscrew O.D.		12.60 mm 12.80 mm	MIN MAX	0.496 in 0.504 in	

Crankshaft Gear, Front (Crankshaft Installed) (001-018)

Crankshaft Gear Bore Inside Diameter		85.910 mm 85.935 mm	MIN MAX	3.3823 in 3.3833 in	
Crankshaft Gear Journal Outside Diameter		85.975 mm 86.000 mm	MIN MAX	3.3848 in 3.3858 in	
Crankshaft Gear Installation Temperature Temperature:		177 °C		350 °F	

Cylinder Block and Liner Seats (001-027)

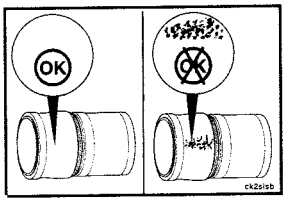
Cylinder Liner Seat Air Pressure:		138 kPa		20 psi	

Cylinder Liner (001-028)

Liner Pitting

Inspect the outside diameter for excessive corrosion or pitting. Liners with pitting generally can **not** be reused. However, if the pitting is light and can be removed with fine emery cloth, the liner can be reused.

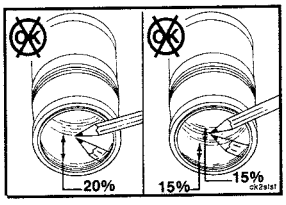
Pits **must not** be more than 1.60-mm [0.060-in] deep.

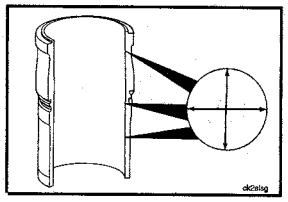
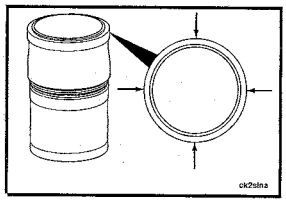
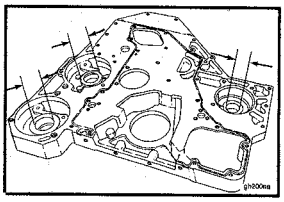
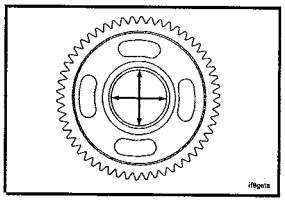
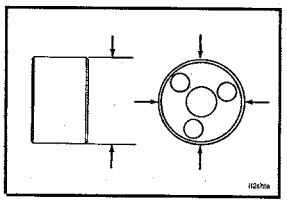
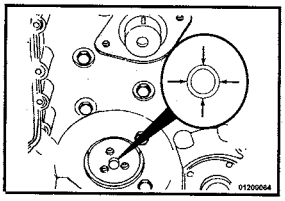
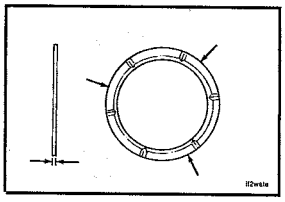


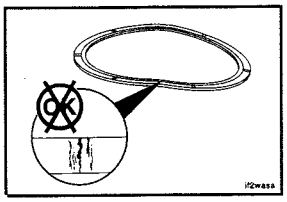
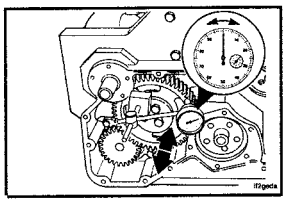
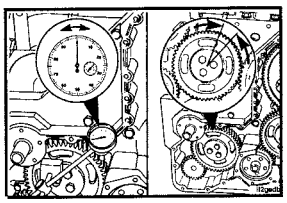
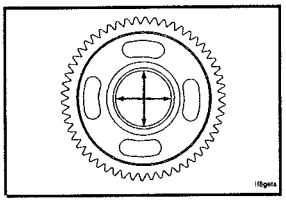
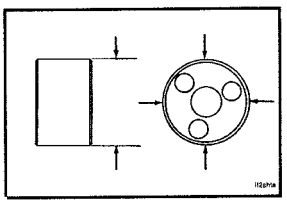
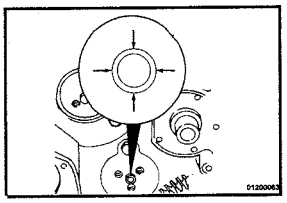
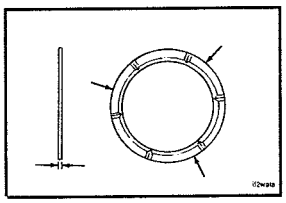
Liner Polish

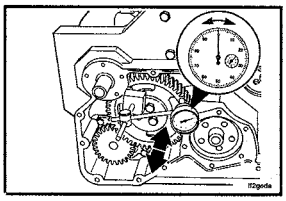
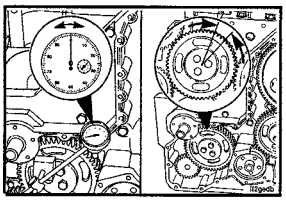
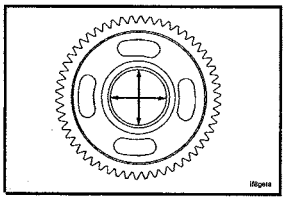
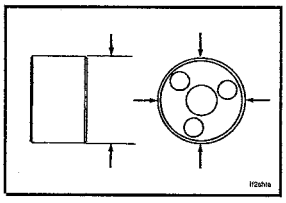
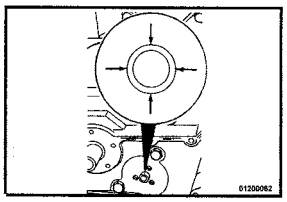
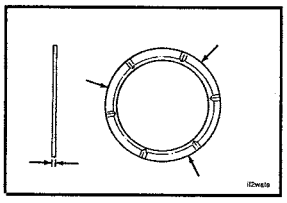
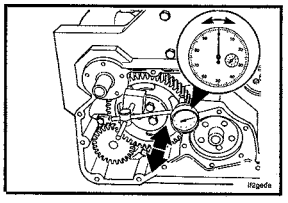
Replace the liner if:

- A heavy polish is present over 20 percent of the piston ring travel area.
- 30 percent of the piston ring travel area has both moderate and heavy polish and one-half (15 percent) is heavy polish.

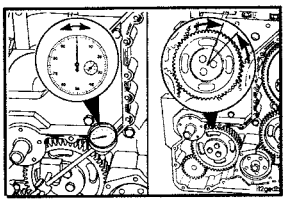


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
 **Cylinder Liner I.D.**		125.000 mm 125.095 mm	MIN MAX	4.9213 in 4.9250 in
 **Cylinder Liner Top Press Fit O.D.**		145.938 mm 145.976 mm	MIN MAX	5.7456 in 5.7471 in
 **Gear Housing, Front (001-033)**				
Gear Housing Bearing Bore I.D.				
Hydraulic Drive		41.967 mm 41.992 mm	MIN MAX	1.6522 in 1.6532 in
Water Pump		36.967 mm 36.992 mm	MIN MAX	1.4553 in 1.4564 in
Accessory Drive		45.100 mm 45.125 mm	MIN MAX	1.7756 in 1.7766 in
 **Idler Gear, Camshaft (001-036)**				
Camshaft Idler Gear Bushing Bore Inside Diameter		60.045 mm 60.100 mm	MIN MAX	2.3640 in 2.3661 in
 **Camshaft Idler Gear Shaft Outside Diameter**		59.975 mm 60.008 mm	MIN MAX	2.3612 in 2.3625 in
 **Camshaft Idler Ring Dowel Outside Diameter**		19.217 mm 19.243 mm	MIN MAX	0.7566 in 0.7576 in
 **Camshaft Idler Thrust Washer Thickness**		2.400 mm 2.470 mm	MIN MAX	0.0945 in 0.0972 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Thrust Washer Inspection Flex the thrust washers approximately 3 to 6 mm [1/8 to 1/4 in], and inspect the surfaces for cracks.					
Idler Gear End Clearance		0.30 mm 0.53 mm	MIN MAX	0.012 in 0.021 in	
Idler Gear Backlash		0.08 mm 0.38 mm	MIN MAX	0.003 in 0.015 in	
Idler Gear, Hydraulic Pump (001-039)					
SAE 'A' and 'B' Hydraulic Drive Idler Gear Bushing Bore Inside Diameter		60.045 mm 60.100 mm	MIN MAX	2.3640 in 2.3661 in	
SAE 'A' and 'B' Hydraulic Drive Idler Gear Shaft Outside Diameter		59.975 mm 60.008 mm	MIN MAX	2.3612 in 2.3625 in	
SAE 'B-B' Hydraulic Drive Idler Gear Shaft Outside Diameter		63.455 mm 63.486 mm	MIN MAX	2.4982 in 2.4994 in	
Hydraulic Drive Idler Ring Dowel Outside Diameter		19.217 mm 19.243 mm	MIN MAX	0.7566 in 0.7576 in	
Hydraulic Drive Idler Thrust Washer Thickness		2.400 mm 2.470 mm	MIN MAX	0.0945 in 0.0972 in	

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
 **Idler Gear End Clearance**		0.30 mm 0.53 mm	MIN MAX	0.012 in 0.021 in
 **Idler Gear Backlash**		0.08 mm 0.38 mm	MIN MAX	0.003 in 0.015 in
 **Idler Gear, Water Pump (001-040)** **Water Pump Idler Gear Bushing Bore Inside Diameter**		60.045 mm 60.100 mm	MIN MAX	2.3640 in 2.3661 in
 **Water Pump Idler Gear Shaft Outside Diameter**		59.975 mm 60.008 mm	MIN MAX	2.3612 in 2.3625 in
 **Water Pump Idler Ring Dowel Outside Diameter**		19.217 mm 19.243 mm	MIN MAX	0.7566 in 0.7576 in
 **Water Pump Idler Thrust Washer Thickness**		2.400 mm 2.470 mm	MIN MAX	0.0945 in 0.0972 in
 **Idler Gear End Clearance**		0.30 mm 0.53 mm	MIN MAX	0.012 in 0.021 in

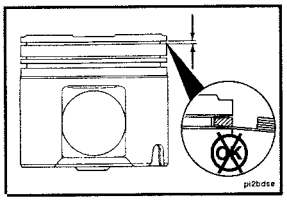
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Idler Gear Backlash		0.08 mm	MIN	0.003 in
		0.38 mm	MAX	0.015 in



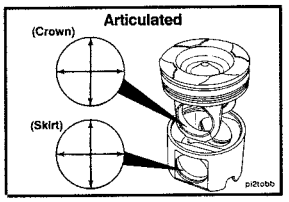
Piston (001-043)

Piston Ring Groove

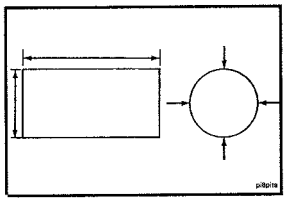
Hold a new ring in the groove even with the outside diameter of the piston. Install a 0.15-mm [0.006-in] feeler gauge. If the feeler gauge enters the groove without resistance, there is too much wear. Replace the piston.



Articulated Piston Pin Bore Inside Diameter (Crown)		54.040 mm	MIN	2.1276 in
		54.055 mm	MAX	2.1281 in
Articulated Piston Pin Bore Inside Diameter (Skirt)		54.007 mm	MIN	2.1263 in
		54.015 mm	MAX	2.1266 in

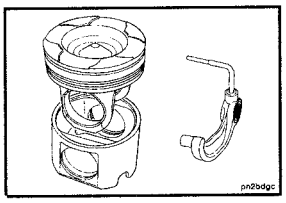


Piston Pin Outside Diameter		53.997 mm	MIN	2.1259 in
		54.003 mm	MAX	2.1261 in
Piston Pin Length		101.70 mm	MIN	4.0039 in
		102.00 mm	MAX	4.0157 in



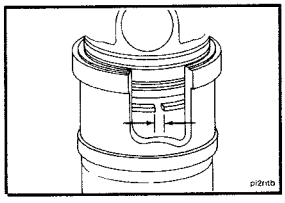
Piston Cooling Nozzle (001-046)

Piston Cooling Nozzle Length		44.5 mm	Nominal	1.752 in



Piston Rings (001-047)

Piston Ring Gap				
Top		0.46 mm	MIN	0.018 in
		0.71 mm	MAX	0.028 in
Intermediate		0.76 mm	MIN	0.030 in
		1.14 mm	MAX	0.045 in
Oil		0.25 mm	MIN	0.010 in
		0.64 mm	MAX	0.025 in



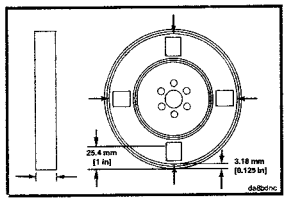
Vibration Damper (001-052)

Vibration Damper Thickness

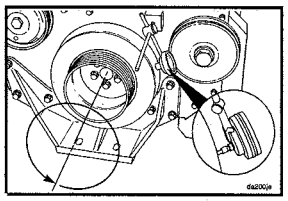
Measure and record the vibration damper thickness at two points at each of the four locations.

- Measure the thickness at 3.18 mm [0.125 in] from the outer lip.
- Measure the thickness at 25.4 mm [1.0 in] from the outer lip.

If the variations between any of the eight measurements exceed 0.25 mm [0.010 in], or if the thickness at any point exceeds 45 mm [1.772 in], replace the vibration damper.



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

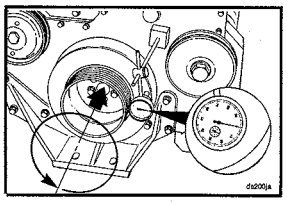


Vibration Damper Eccentricity

To measure damper eccentricity (out of round), install the dial indicator gauge, Part No. 3376050 and extension Part No. ST-537-4, on the gear cover as indicated.

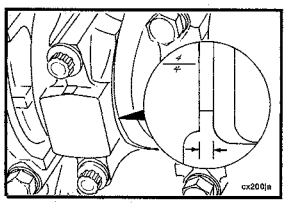
Rotate the crankshaft with the accessory driveshaft one complete revolution (360 degrees), and record the total indicator movement.

Replace the vibration damper if the eccentricity exceeds 0.28 mm [0.011 in].



Vibration Damper Face Alignment

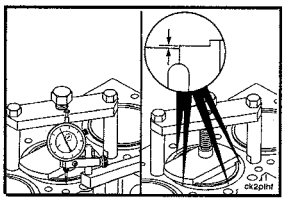
Replace the damper if wobble exceeds 0.28 mm [0.011 in].



Piston and Connecting Rod Assembly (001-054)

Connecting Rod Side Clearance

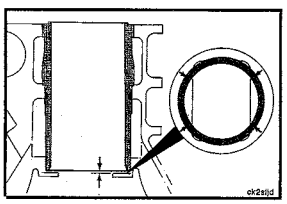
0.10 mm	MIN	0.004 in
0.30 mm	MAX	0.012 in



Cylinder Liner Protrusion (001-064)

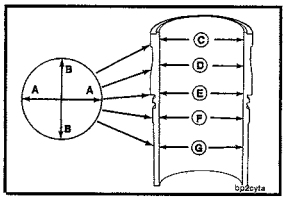
Cylinder Liner Protrusion

0.00 mm	MIN	0.000 in
0.13 mm	MAX	0.005 in



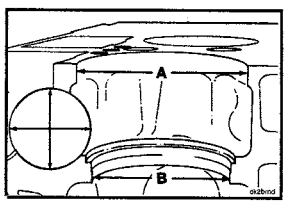
Cylinder Liner-to-Block Clearance

0.25 mm	MIN	0.010 in



Cylinder Liner Bore

Measure the liner bore for out of roundness at points "C," "D," "E," "F," and "G." Measure each point in the direction "AA" and "BB". The bore **must not** be more than 0.10 mm [0.004 in] out-of-round.



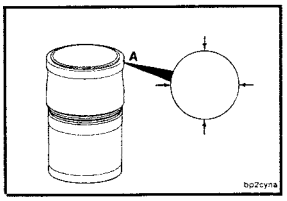
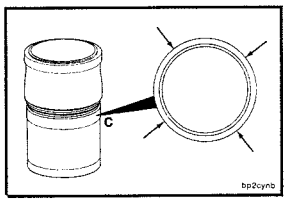
Cylinder Block Upper Liner Bore Inside Diameter (A)

145.900 mm	MIN	5.7441 in
146.027 mm	MAX	5.7491 in

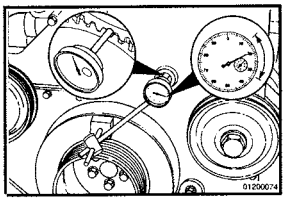
Measure the cylinder block liner seal seat bore (B) 8.0 to 13.5 mm [0.32 to 0.53 in] below the counterbore.

Cylinder Block Liner Seal Seat Bore Inside Diameter (B)

138.063 mm	MIN	5.4355 in
138.113 mm	MAX	5.4375 in

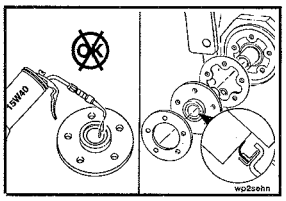
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Cylinder Liner Top Press Fit Outside Diameter (A)		145.938 mm 145.976 mm	MIN MAX	5.7456 in 5.7471 in	
Cylinder Liner Seal Seat Outside Diameter (C)		137.937 mm 138.013 mm	MIN MAX	5.4306 in 5.4336 in	

Camshaft End Clearance (001-065)

Camshaft End Clearance		0.13 mm 0.33 mm	MIN MAX	0.005 in 0.013 in	

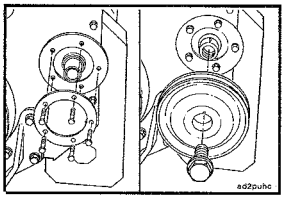
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

Cylinder Block - Torque Values



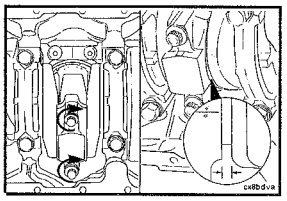
Alternator Drive Seal (001-001)

Alternator Drive Seal Mounting Capscrews	1	7 N•m	60 in-lb
	2	20 N•m	175 in-lb



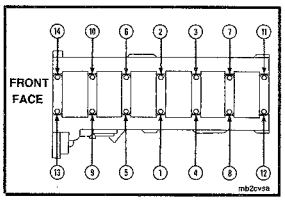
Accessory Drive Seal (001-003)

Accessory Drive Seal Mounting Capscrews	1	7 N•m	60 in-lb
	2	20 N•m	175 in-lb



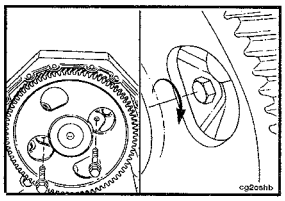
Bearings, Connecting Rod (001-005)

Connecting Rod Capscrews	1	68 N•m	50 ft-lb
	2	142 N•m	105 ft-lb
	3	210 N•m	155 ft-lb
	4	Loosen completely	
	5	Repeat steps 1 through 3	



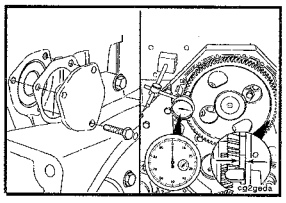
Bearings, Main (001-006)

Main Bearing Cap Mounting Capscrews	1	68 N•m	50 ft-lb
	2	142 N•m	105 ft-lb
	3	210 N•m	155 ft-lb
	4	Loosen completely	
	5	Repeat steps 1 through 3	

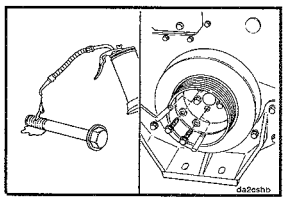


Camshaft (001-008)

Camshaft Thrust Plate Mounting Capscrews	47 N•m	35 ft-lb

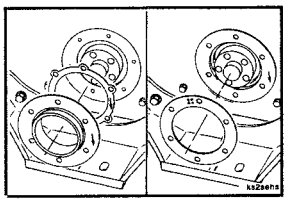
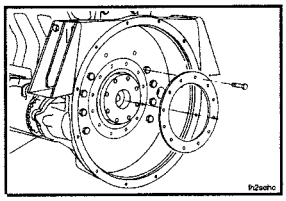
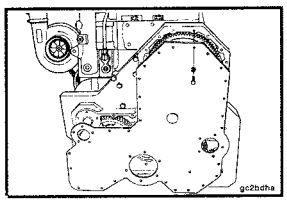
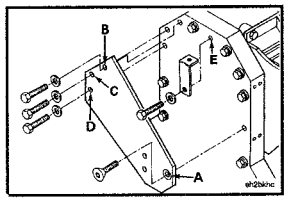
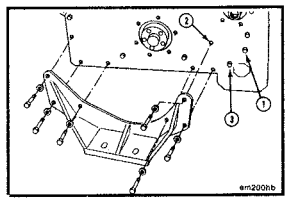
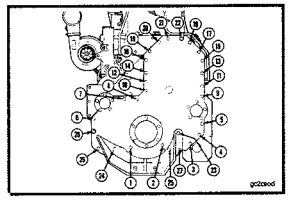
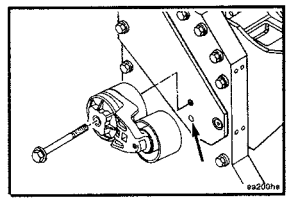


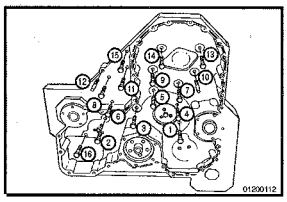
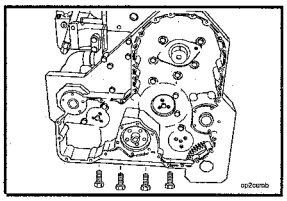
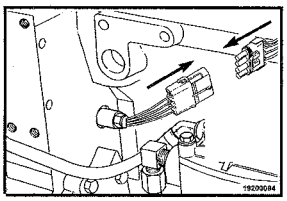
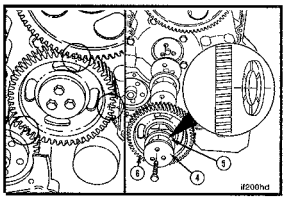
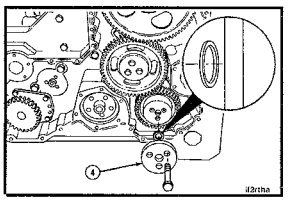
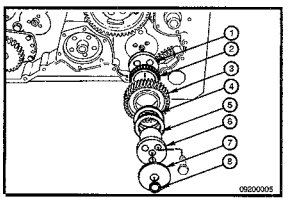
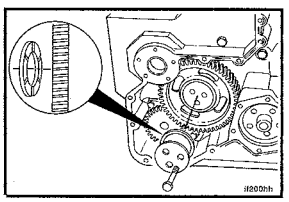
Camshaft Rear Cover Plate Mounting Capscrews	47 N•m	35 ft-lb



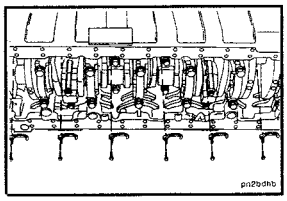
Crankshaft Pulley (001-022)

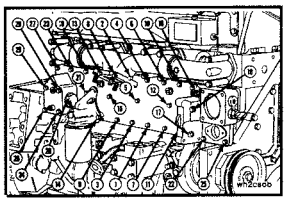
Crankshaft Pulley Mounting Capscrews	203 N•m	150 ft-lb

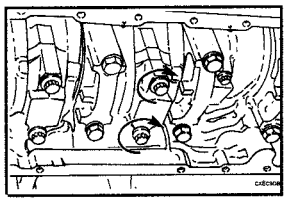
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Crankshaft Seal, Front (001-023)				
Front Crankshaft Seal Mounting Capscrews	1	7 N•m	60 in-lb	
	2	20 N•m	180 in-lb	
Crankshaft Seal, Rear (001-024)				
Rear Crankshaft Seal Mounting Capscrews	1	7 N•m	60 in-lb	
	2	20 N•m	180 in-lb	
Gear Cover, Front (001-031)				
Gear Cover Mounting Capscrews		6 N•m	55 in-lb	
Belt Tensioner Bracket Capscrews		6 N•m	55 in-lb	
Front Engine Support Mounting Capscrews		6 N•m	55 in-lb	
Gear Cover Mounting Capscrews				
Capscrews 1 through 22:		20 N•m	15 ft-lb	
Capscrews 23 through 28:		68 N•m	50 ft-lb	
Automatic Belt Tensioner Capscrew		43 N•m	32 ft-lb	

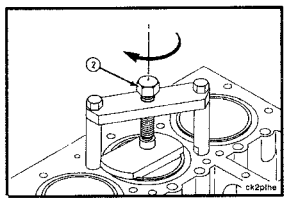
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	**Gear Housing, Front (001-033)**		
Gear Housing Mounting Capscrews	1 2	20 N•m 68 N•m	15 ft-lb 50 ft-lb
	**Oil Pan to Gear Housing Mounting Capscrews**	47 N•m	35 ft-lb
	**Engine Position Sensor**	34 N•m	25 ft-lb
	**Idler Gear, Camshaft (001-036)**		
Camshaft Idler Gear Mounting Capscrews	1 2	61 N•m Rotate 60 degrees	45 ft-lb
	**Idler Gear, Hydraulic Pump (001-039)**		
SAE 'A' and SAE 'B' Gear Retainer	1 2	61 N•m Rotate 60 degrees	45 ft-lb
	**SAE 'B-B' Hydraulic Drive Idler Gear Assembly**		
	1 2	61 N•m Rotate 60 degrees	45 ft-lb
	**Idler Gear, Water Pump (001-040)**		
Front Thrust Bearing	1 2	61 N•m Rotate 60 degrees	45 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Piston Cooling Nozzle (001-046)			
Piston Cooling Nozzle Mounting Capscrew		28 N•m	21 ft-lb
Water Header Plate, Cylinder Block (001-053)			
Water Header Plate		54 N•m	40 ft-lb
Piston and Connecting Rod Assembly (001-054)			
Connecting Rod Mounting Capscrews	1	68 N•m	50 ft-lb
	2	142 N•m	105 ft-lb
	3	210 N•m	155 ft-lb
	4	Loosen completely	
	5	Repeat steps 1 through 3	
Cylinder Liner Protrusion (001-064)			
Cylinder Liner Clamping Plate		136 N•m	100 ft-lb





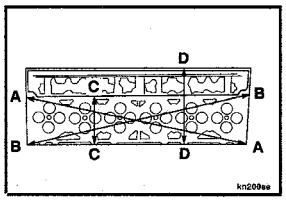




Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

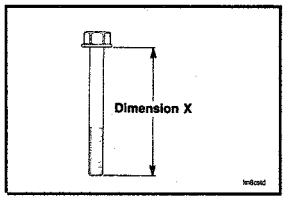
Cylinder Head - Specifications

Cylinder Head (002-004)



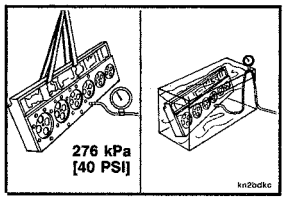
Cylinder Head Flatness

AA and BB	0.200 mm	MAX	0.008 in
CC	0.076 mm	MAX	0.003 in
DD	0.127 mm	MAX	0.005 in



Cylinder Head Capscrew Free Length

3045849	74.5 mm	MAX	2.933 in
3045850	139.5 mm	MAX	5.492 in

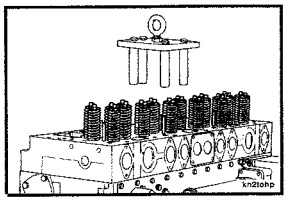
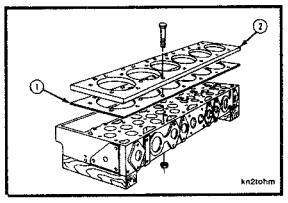
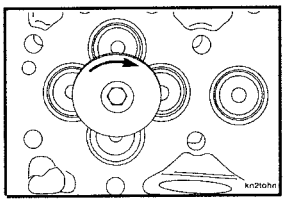
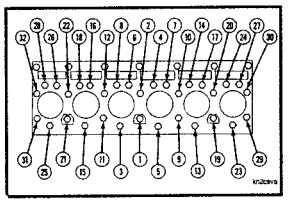
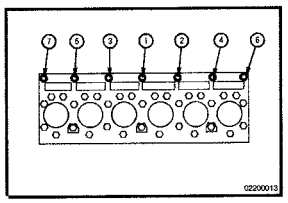
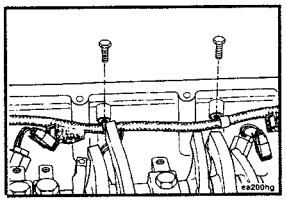


Air Pressure for Pressure Test

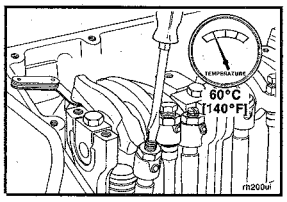
Air Pressure	276 kPa	40 psi

Water Temperature for Pressure Test

Water Temperature:	60 °C	140 °F

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Cylinder Head - Torque Values				
Cylinder Head (002-004)				
Cylinder Head Lifting Bracket		47 N•m	35 ft-lb	
Water Test Fixture Mounting Capscrews		47 N•m	35 ft-lb	
Injector Sleeve Holding Tool Capscrews		75 N•m	55 ft-lb	
Cylinder Head Mounting Capscrews	1 2 3	136 N•m 217 N•m Rotate 90 Degrees	100 ft-lb 160 ft-lb	
Note: Rotate at least one flat, but **not** more than two.				
Cylinder Head Mounting Capscrews		68 N•m	50 ft-lb	
Internal Engine Harness Holding Clamp Capscrews		20 N•m	15 in-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.



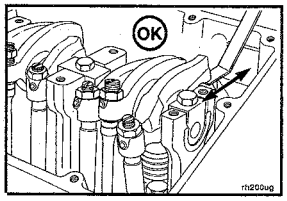
Rocker Levers - Specifications

Overhead Set (003-004)

Overhead Lash Measurements

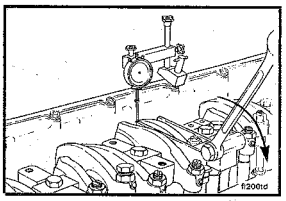
All overhead lash measurements **must** be made when the engine is cold. Stabilized coolant temperature **must** be at 60°C [140°F] or below.

Injector and Valve Measurement Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder	
		Injector	Valve
Start	A	1	1
Advance to	B	5	5
Advance to	C	3	3
Advance to	A	6	6
Advance to	B	2	2
Advance to	C	4	4
Firing Order: 1-5-3-6-2-4			



M Series Valve Lash Recheck Limits

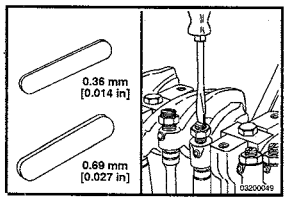
Intake	0.10 mm	MIN	0.004 in
	0.41 mm	MAX	0.016 in
Exhaust	0.46 mm	MIN	0.018 in
	0.76 mm	MAX	0.030 in



M Series Injector Lash Recheck Limits

0.51 mm	MIN	0.020 in
2.04 mm	MAX	0.080 in

Valve, Injector, and Engine Brake Adjustment Specifications		
	mm	in
Intake Valve	0.36	0.014
Exhaust Valve	0.69	0.027
Engine Brake	0.38	0.015



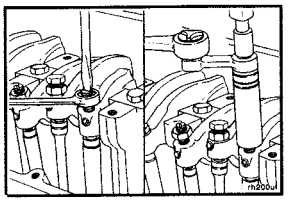
Valve Lash Specification		
	mm	in
Intake	0.36	0.014
Exhaust	0.69	0.027

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

Touch Method

Torque Value:

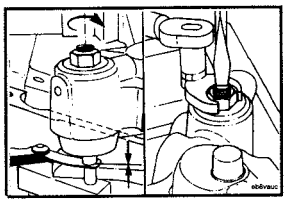
- **Without** torque wrench adapter:
  61 N•m [45 ft-lb]
- **With** torque wrench adapter, Part No. 3163196:
  47 N•m [35 ft-lb]



Engine Brake Adjust

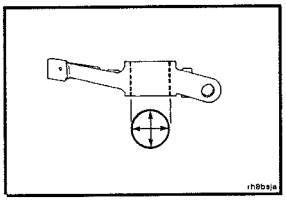
Torque Value:

- **Without** torque wrench adapter:
  34 N•m [25 ft-lb]
- **With** torque wrench adapter, Part No. 3163196:
  30 N•m [22 ft-lb]

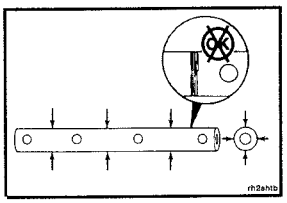


Rocker Lever Assembly (003-009)

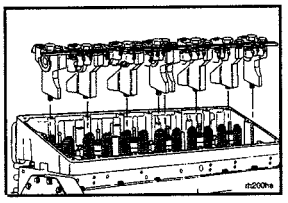
Rocker Lever Bushing Inside Diameter (Installed)	34.887 mm	MIN	1.3735 in	
	34.990 mm	MAX	1.3776 in	



Rocker Lever Shaft Outside Diameter	34.837 mm	MIN	1.3715 in
	34.864 mm	MAX	1.3726 in

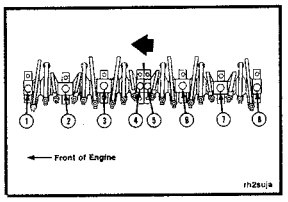


Rocker Lever Installation Side Clearance	0.50 mm	Nominal	0.020 in



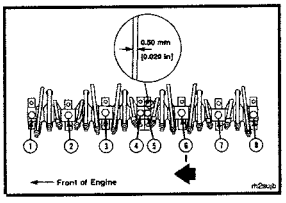
Initial Torque Rocker Lever Assemblies

Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.

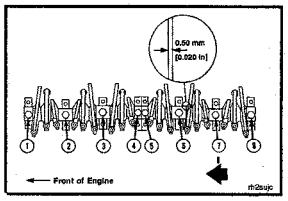


Initial Torque Rocker Lever Assemblies

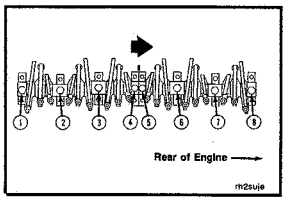
Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.



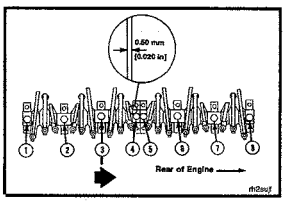
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.



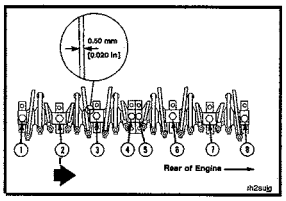
Initial Torque Rocker Lever Assemblies
Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.



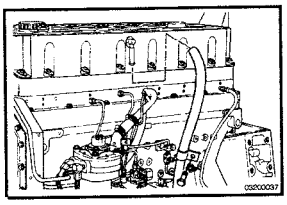
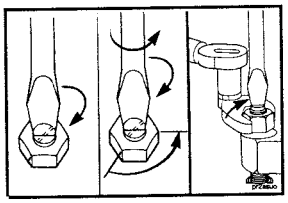
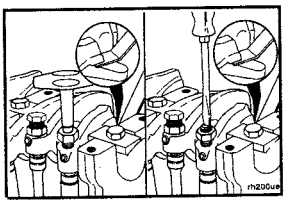
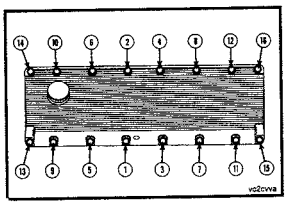
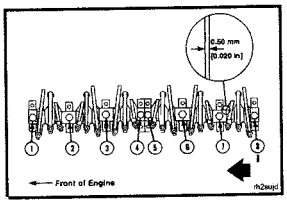
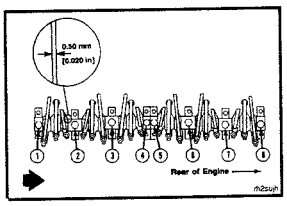
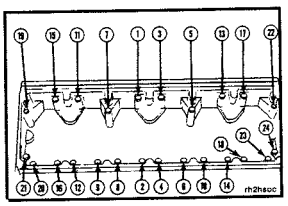
Initial Torque Rocker Lever Assemblies
Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.



Initial Torque Rocker Lever Assemblies
Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.



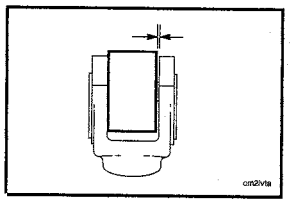
Initial Torque Rocker Lever Assemblies
Tighten the mounting capscrews to 5 N•m [45 in-lb] at this time.

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Rocker Levers - Torque Values				
Crankcase Breather (Internal) (003-002)				
Breather Tube Bracket		27 N•m	20 ft-lb	
Overhead Set (003-004)				
CELECT™ Injector Adjustment				
Turn the adjusting screw in until you can feel it lightly bottom the plunger.				
Back out the adjusting screw two flats, 120 degrees. Hold the adjusting screw, and tighten the locknut.				
Injector Adjusting Screw Locknut		61 N•m	45 ft-lb	
Torque Wrench Method		0.7 N•m	6 in-lb	
Cover of Rocker Lever Housing		15 N•m	130 in-lb	
Rocker Lever Assembly (003-009)				
Final Torque Rocker Lever Assemblies		183 N•m	135 ft-lb	
Final Torque Rocker Lever Assemblies		183 N•m	135 ft-lb	
Rocker Lever Housing (003-013)				
Initial Torque Rocker Lever Housing		34 N•m	25 ft-lb	
Final Torque Rocker Lever Housing		61 N•m	45 ft-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

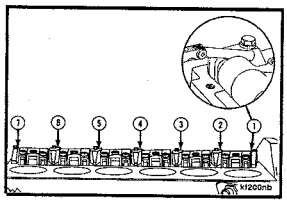
Cam Followers/Tappets - Specifications

Cam Follower Assembly (004-001)



Cam Follower Roller Side Clearance

0.19 mm	MIN	0.007 in
0.65 mm	MAX	0.026 in



Cam Follower Side Clearance Between Supports

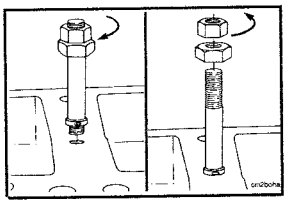
0.76 mm	MIN	0.030 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

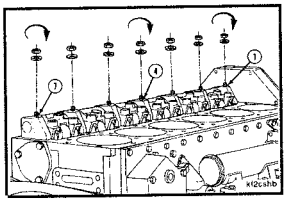
Cam Followers/Tappets - Torque Values

Cam Follower Assembly (004-001)

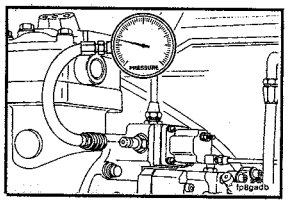
Cam Follower Studs		34 N•m	25 ft-lb



Cam Follower Supports		47 N•m	35 ft-lb



Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

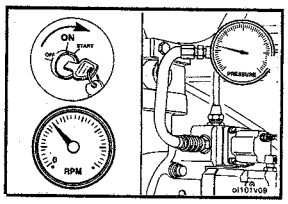


Fuel System - Specifications

Fuel Flow (005-011)

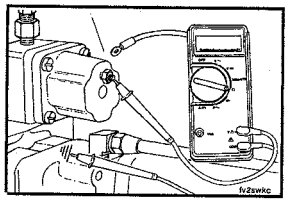
Minimum Cranking Fuel Pressure

172 kPa	MIN	25 psi



Minimum Fuel Pressure at 1200 rpm

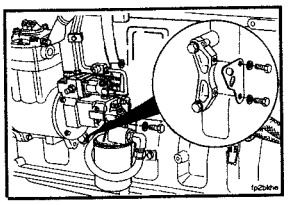
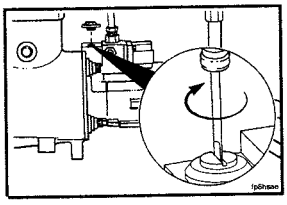
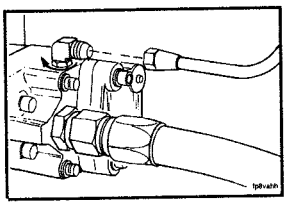
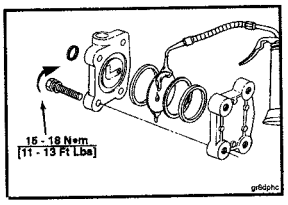
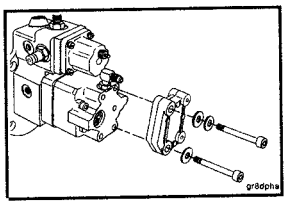
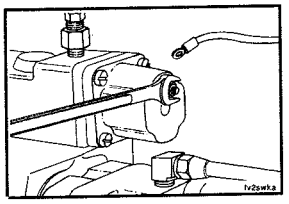
827 kPa	MIN	120 psi



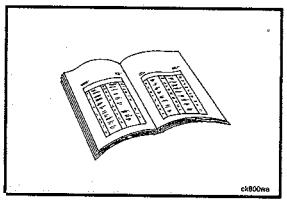
Fuel Shutoff Valve (FSOV) (005-043)

Fuel Shutoff Valve Coil Resistance

Check the coil resistance with a multimeter. The coil resistance **must** be 6 to 10 ohms for 12 VDC solenoids or 26 to 40 ohms for 24 VDC solenoids.

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Fuel System - Torque Values				
Fuel Pump (005-016)				
Fuel Pump Support Bracket Capscrews		47 N•m	35 ft-lb	
Fuel Pump Mounting Capscrews		47 N•m	35 ft-lb	
Fuel Pump Filter Cap		16 N•m	12 ft-lb	
Fuel Pump Gear Pump Check Valve (005-016)				
Check Valve Elbow Jam Nut		6 N•m	50 in-lb	
Fuel Pump Pulsation Damper (005-031)				
Fuel Pump Pulsation Damper		18 N•m	13 ft-lb	
Damper Mounting Capscrews		18 N•m	13 ft-lb	
Fuel Shutoff Valve (005-043)				
Fuel Shutoff Valve Wire Connection Nut		3 N•m	25 in-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

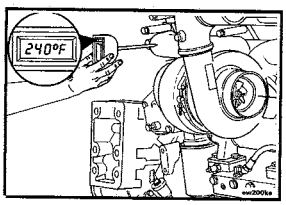


Injectors and Fuel Lines - Specifications

Cylinder Misfires or Smokes (006-005)

Automated Cylinder Performance Test

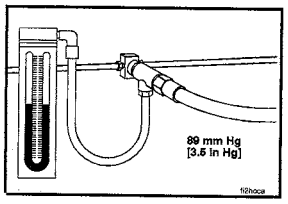
Minimum cylinder contribution is 71 percent.



Warning: To avoid serious burns, wear protective gloves when measuring exhaust manifold surface temperature.

Exhaust Manifold Temperature Test

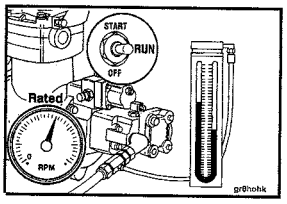
The maximum exhaust manifold surface temperature at idle is 143°C [290°F].



Fuel Drain Line Restriction (006-012)

Fuel Drain Line Restriction

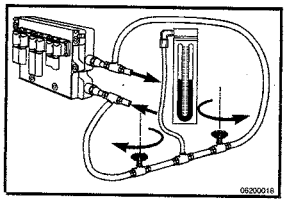
	89 mm Hg	MAX	3.5 in Hg



Fuel Inlet Restriction (006-020)

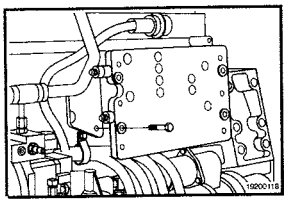
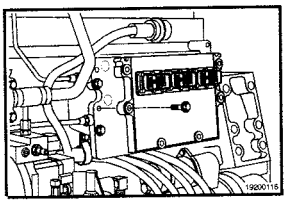
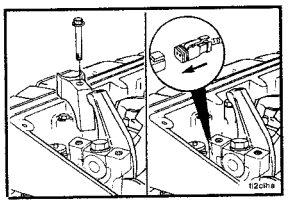
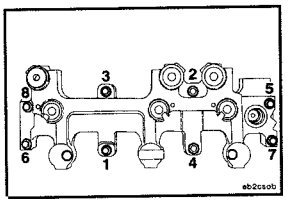
Fuel Inlet Restriction

New Filter	152 mm Hg	MAX	6 in Hg
Used Filter	254 mm Hg	MAX	10 in Hg



Cooling Plate Restriction

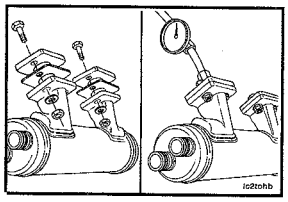
	25 mm Hg	MAX	1 in Hg

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Injectors and Fuel Lines - Torque Values				
ECM Cooling Plate, Fuel Cooled (006-006)				
ECM Cooling Plate Mounting Capscrews		40 N•m	30 ft-lb	
ECM Mounting Capscrews		7 N•m	65 in-lb	
Injector (006-026)				
Injector Hold-Down Capscrew		75 N•m	55 ft-lb	
Rocker Lever Support Capscrews		81 N•m	60 ft-lb	

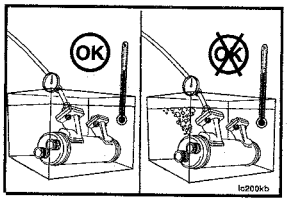
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

Lubricating Oil System - Specifications

Lubricating Oil Cooler (007-003)

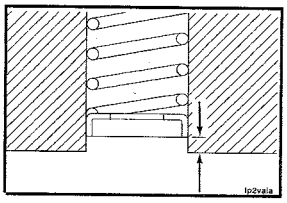


Air Pressure:		414 kPa	60 psi

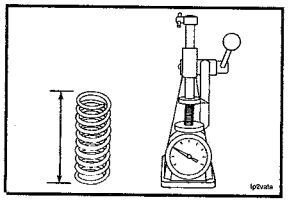


Temperature:		82 °C	180 °F

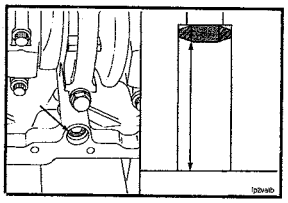
Lubricating Oil High Pressure Relief Valve (007-021)



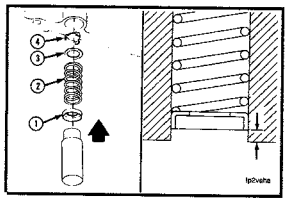
Relief Valve Retainer Installed Depth			
		8.03 mm	MIN 0.316 in
		8.53 mm	MAX 0.336 in



Force Required to Compress Spring to 29.1 mm [1.15 in]			
		263 N	MIN 59 lbf
		322 N	MAX 72 lbf

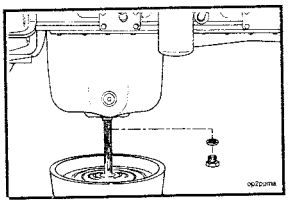


Relief Valve Seat Depth			
		62.62 mm	MIN 2.465 in
		63.62 mm	MAX 2.505 in



Relief Valve Retainer Installed Depth			
		8.03 mm	MIN 0.316 in
		8.53 mm	MAX 0.336 in

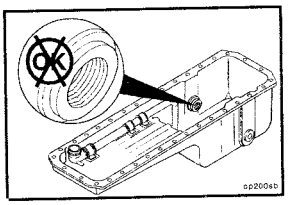
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.



Oil Drain Fitting Specifications

Length	63.50 mm	[2.500 in]
Diameter	41.28 mm	[1.625 in]
Weight	0.363 mm	[0.80 lb]

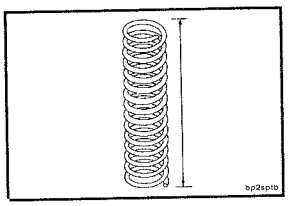
Do **not** use fittings other than the Cummins-supplied fittings in the side drain location.



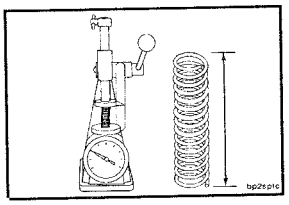
Oil Pan Threaded Holes

Thread Location	Tap Size
Temperature Gauge	3/8 in NPTF
Oil Sump Heater	1-18 NS-3B
Oil Drain	1 in NPTF

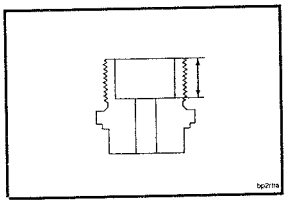
Lubricating Oil Pressure Regulator (Main Rifle) (007-029)



Regulator Spring Free Length	84.1 mm	Nominal	3.31 in

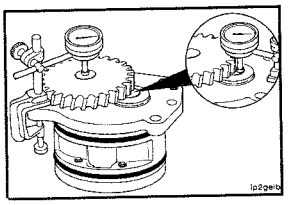


Main Oil Pressure Regulator Spring Load at 48.3 mm [1.90 in]	91.1 N	MIN	20.50 lbf
	94.7 N	MAX	21.30 lbf



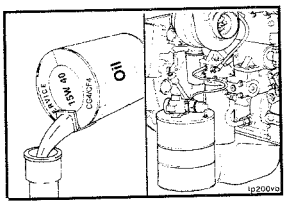
Main Oil Pressure Regulator Retainer Plug	11.1 mm	MIN	0.44 in
	13.4 mm	MAX	0.53 in

Lubricating Oil Pump (007-031)



Driveshaft End Clearance	0.064 mm	MIN	0.0025 in
	0.269 mm	MAX	0.0106 in

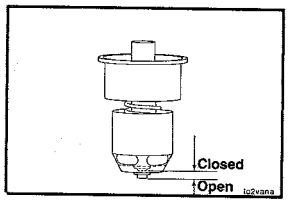
Lubricating Oil System (007-037)



Lubricating Oil System Priming

The oil pressure **must not** exceed the maximum of 276 kPa [40 psi].

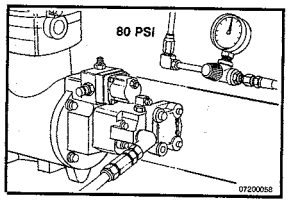
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.



Lubricating Oil Thermostat (007-039)

Thermostat Inspect for Reuse

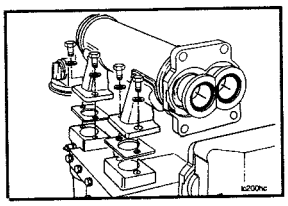
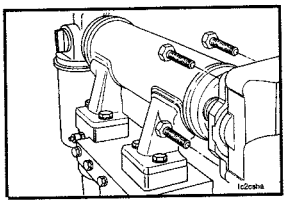
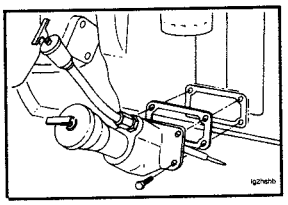
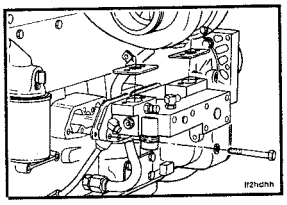
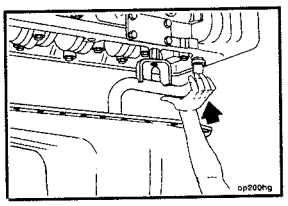
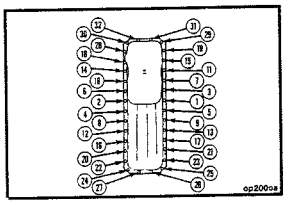
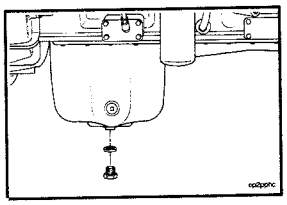
Write down the temperature at which the valve is fully extended. The valve **must** be fully extended to at least 6 mm [0.250 in] from the closed position when the temperature reaches 116°C [240°F].

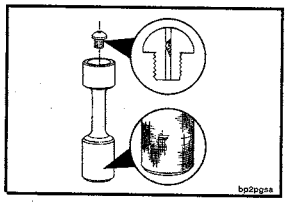
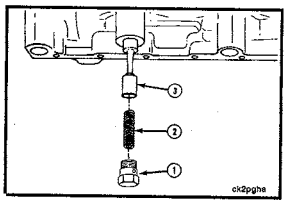
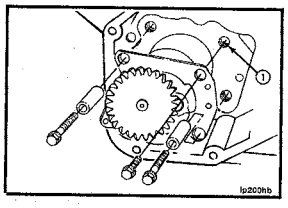
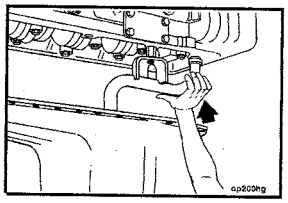
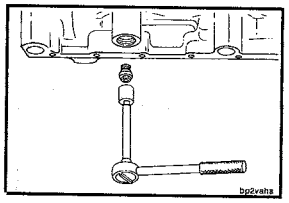
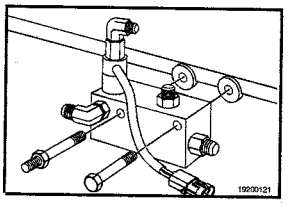


Lubricating Oil Contamination (007-044)

Fuel Pressure Test

Apply air pressure to the cylinder head. The maximum air pressure is 552 kPa [80psi].

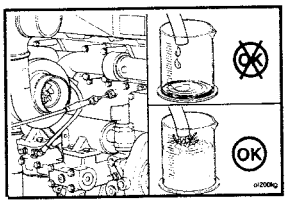
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Lubricating Oil System - Torque Values				
Lubricating Oil Cooler (007-003)				
Lubricating Oil Cooler Mounting Pad Capscrews		47 N•m	35 ft-lb	
Lubricating Oil Cooler Flange Mounting Capscrews		47 N•m	35 ft-lb	
Lubricating Oil Dipstick Housing (007-010)				
Lubricating Oil Dipstick Housing Mounting Capscrews		47 N•m	35 ft-lb	
Lubricating Oil Filter Head (007-015)				
Lubricating Oil Filter Head Mounting Capscrews		47 N•m	35 ft-lb	
Lubricating Oil Pan (007-025)				
Block Mounted Front Sump Suction Tube Retaining Capscrew		61 N•m	45 ft-lb	
Lubricating Oil Pan Capscrews		47 N•m	35 ft-lb	
Oil Drain Plug		88 N•m	65 ft-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	**Lubricating Oil Pressure Regulator (Main Rifle) (007-029)**		
	Viscosity Sensor Orifice	1 N•m	6 in-lb
	**Lubricating Oil Pressure Regulator Plug (Main Rifle)**		
	Rear Sump Oil Pan	75 N•m	55 ft-lb
	Front Sump Oil Pan	122 N•m	90 ft-lb
	**Lubricating Oil Pump (007-031)**		
	Lubricating Oil Pump Mounting Capscrews	41 N•m	30 ft-lb
	**Lubricating Oil Transfer Tube (007-040)**		
	Block Mounted Front Sump Suction Tube Retaining Capscrew	61 N•m	45 ft-lb
	**Lubricating Oil Viscosity Sensor (007-041)**		
	Lubricating Oil Viscosity Sensor	24 N•m	18 ft-lb
	**Centinel™ System (ISM Engines) (007-071)**		
	Integrated Centinel Control Valve Capscrews	47 N•m	35 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

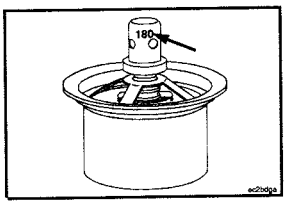
Cooling System - Specifications

Coolant Thermostat (008-013)



Thermostat Initial Opening Temperature

81 °C	MIN	178 °F
83 °C	MAX	182 °F

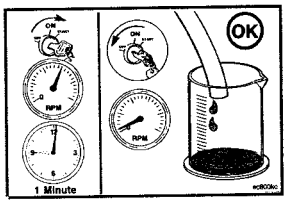


Coolant Thermostat Operating Temperature

The nominal operating temperature is stamped on the thermostat.

- Thermostat **must** begin to open within 1°C [2°F] of nominal temperature.
- Thermostat **must** be fully open within 12°C [22°F] of nominal temperature.

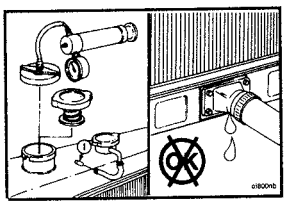
The fully open distance between the thermostat flange and housing is 11 mm [0.435 in].



Coolant Thermostat Leak Test

The amount of coolant collected **must not** be more than 100 cc [3.3 fl oz].

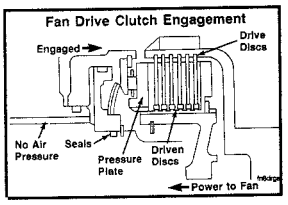
Cooling System (008-018)



Air Pressure for Coolant System Pressure Test

138 kPa	20 psi

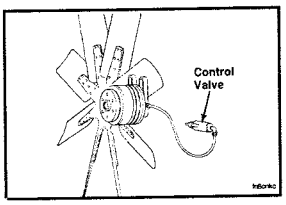
Fan Clutch, Air-Disengaged (008-024)



Air-Disengaged Fan Clutch

Air pressure of 480 to 830 kPa [70 to 120 psi] is required to override the clutch spring tension to disengage the fan.

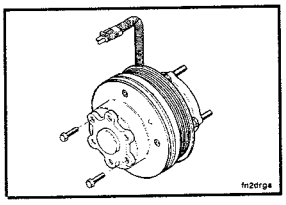
Fan Clutch, Air-Engaged (008-025)



Air-Engaged Fan Clutch

Air pressure of 620 to 830 kPa [90 to 120 psi] is required to override the clutch spring tension to engage the fan.

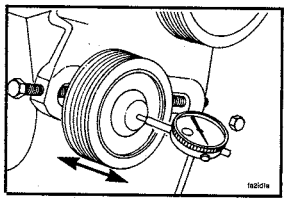
Fan Clutch, Electric (008-026)



Cummins Electric Fan Clutch

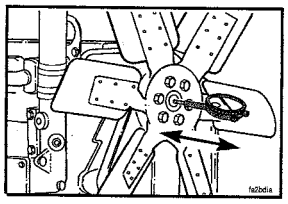
This type of fan clutch is activated when 12 VDC from the vehicle electrical system is applied.

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.



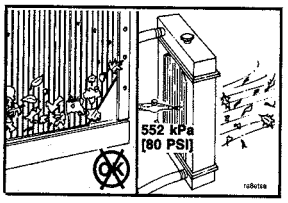
Fan Drive Idler Pulley Assembly (008-030)

Idler Pulley End Clearance				
		0.025 mm	MIN	0.0010 in
		0.250 mm	MAX	0.0100 in



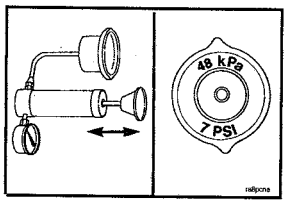
Fan Hub, Belt Driven (008-036)

Fan Hub End Clearance				
		0.08 mm	MIN	0.003 in
		0.41 mm	MAX	0.016 in



Radiator (008-042)

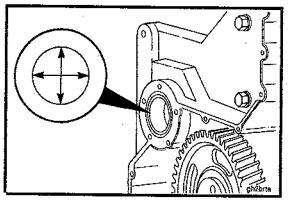
Compressed Air Pressure for Cleaning Radiator		552 kPa		80 psi



Radiator Pressure Cap (008-047)

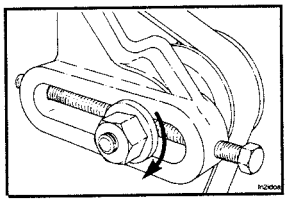
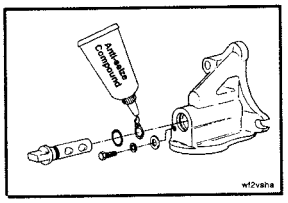
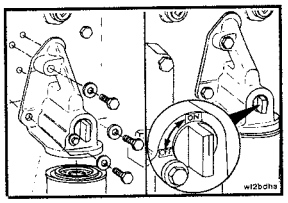
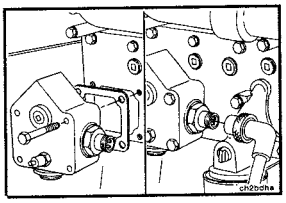
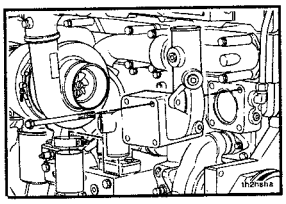
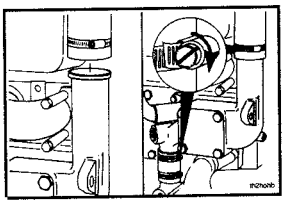
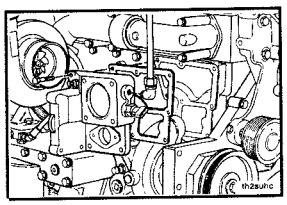
Radiator Pressure Cap

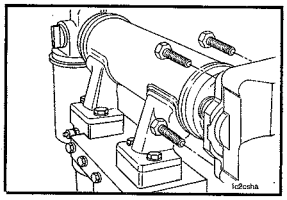
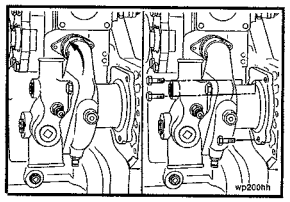
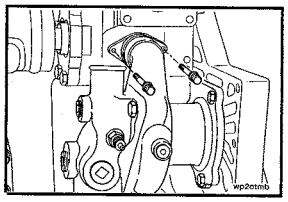
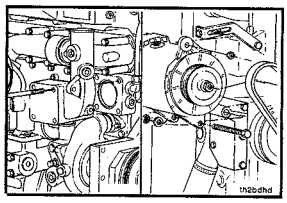
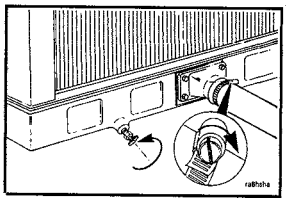
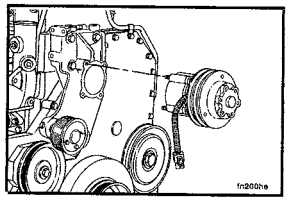
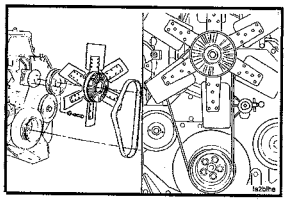
The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.

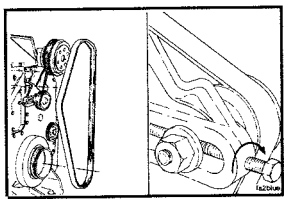
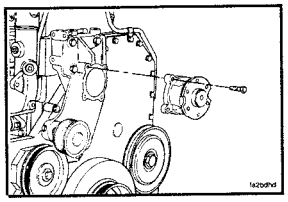
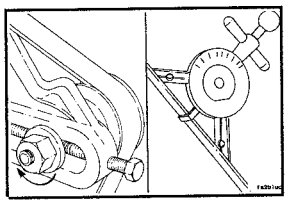
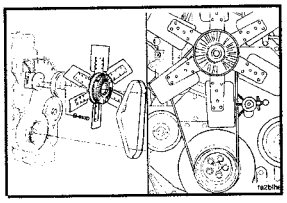
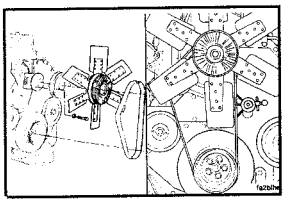
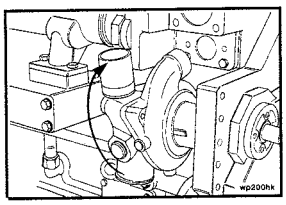
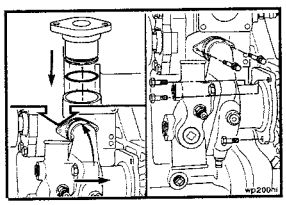


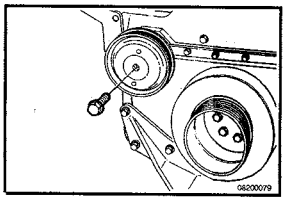
Water Pump (008-062)

Needle Bearing Bore Inside Diameter (Gear Housing)				
		36.967 mm	MIN	1.4553 in
		36.992 mm	MAX	1.4564 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Cooling System - Torque Values				
Cooling Fan Drive Belt (008-002)				
Idler Pulley Shaft Locknut		190 N•m	140 ft-lb	
Coolant Filter Head (008-007)				
Coolant Filter Head Valve Retaining Capscrew		10 N•m	90 in-lb	
Coolant Filter Head Mounting Capscrews		54 N•m	40 ft-lb	
Coolant Heater Housing (008-012)				
Heater Housing Capscrews		54 N•m	40 ft-lb	
Coolant Thermostat (008-013)				
Thermostat Housing Mounting Capscrews		54 N•m	40 ft-lb	
Upper Coolant Hose Clamps		3 N•m	30 in-lb	
Coolant Thermostat Housing Support (008-015)				
Coolant Thermostat Housing Support Mounting Capscrews		54 N•m	40 ft-lb	

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	**Mounting Flange Capscrews**		47 N•m	35 ft-lb
	**Water Pump Mounting Capscrews**		47 N•m	35 ft-lb
	**Water Transfer Tube Mounting Capscrews**		24 N•m	18 ft-lb
	**Coolant Thermostat Seal (008-016)**			
	Thermostat Housing Capscrews		54 N•m	40 ft-lb
	**Cooling Systeml (008-018)**			
	Lower Radiator Hose Clamp		5 N•m	40 in-lb
	**Fan Clutch, Electric (008-026)**			
	Electric Fan Clutch Mounting Capscrews		47 N•m	35 ft-lb
	**Fan Clutch, Viscous (008-028)**			
	Viscous Fan Clutch Mounting Capscrews		68 N•m	50 ft-lb

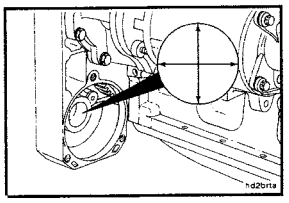
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Fan Drive Idler Pulley Assembly (008-030)				
Fan Idler Pulley Shaft Locknut		190 N•m	140 ft-lb	
Fan Hub, Belt Driven (008-036)				
Belt Driven Fan Hub		47 N•m	35 ft-lb	
Fan Idler Pulley Shaft Locknut		190 N•m	140 ft-lb	
Fan Spacer and Pulley (008-039)				
Fan Pulley		68 N•m	50 ft-lb	
Fan, Cooling (008-040)				
Cooling Fan Mounting Capscrews		68 N•m	50 ft-lb	
Water Pump (008-062)				
Water Pump Cover		47 N•m	35 ft-lb	
Water Pump Mounting Capscrews		47 N•m	35 ft-lb	
Water Pump Transfer Connection Mounting Capscrews		25 N•m	18 ft-lb	

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	**Pulley Capscrew**	1	75 N•m	55 in-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	

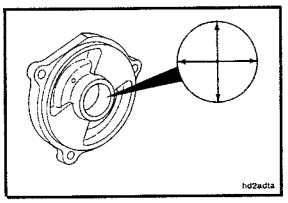
Drive Units - Specifications

Hydraulic Pump Drive (009-016)



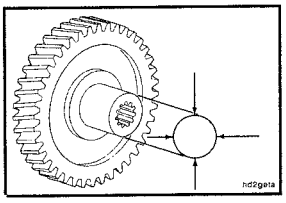
Needle Bearing Bore Inside Diameter (Gear Housing)

41.967 mm	MIN	1.6522 in
41.992 mm	MAX	1.6532 in



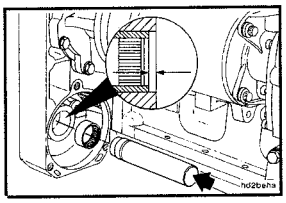
Needle Bearing Bore Inside Diameter (Hydraulic Pump Drive Adapter)

41.967 mm	MIN	1.6522 in
41.992 mm	MAX	1.6532 in



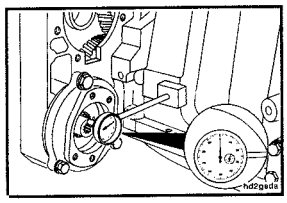
Hydraulic Drive Shaft Outside Diameter

34.984 mm	MIN	1.3773 in
35.000 mm	MAX	1.3780 in



Hydraulic Drive Needle Bearing Installation Specification

The bearing **must** be 0.25 to 0.76 mm [0.010 to 0.030 in] past the outside edge of the gear housing bore surface.

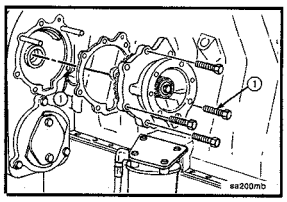


Hydraulic Pump Driveshaft's End Clearance

0.076 mm	MIN	0.003 in
0.635 mm	MAX	0.025 in

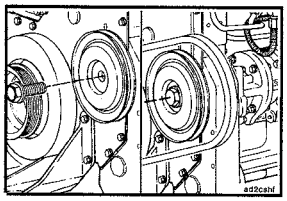
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

Drive Units - Torque Values



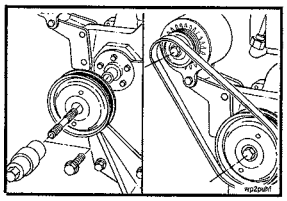
Accessory Drive (009-001)

Accessory Drive Assembly Mounting Capscrews		47 N•m	35 ft-lb



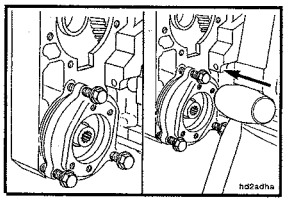
Accessory Drive Pulley (009-004)

Accessory Drive Pulley Mounting Capscrew		542 N•m	400 ft-lb



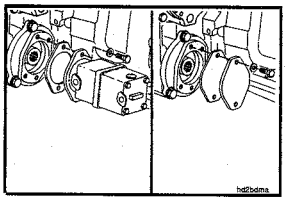
Alternator Drive Pulley (009-010)

Alternator Drive Pulley Retaining Capscrew		75 N•m	55 ft-lb



Hydraulic Pump Drive (009-016)

Hydraulic Drive Adapter Mounting Capscrews		47 N•m	35 ft-lb

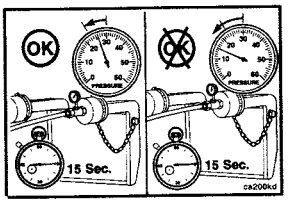


Hydraulic Pump/Cover Plate		27 N•m	20 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

Air Intake System - Specifications

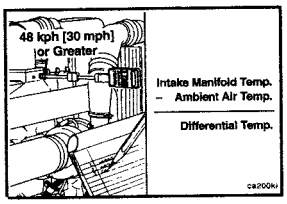
Charge-Air Cooler (CAC) (010-027)



Charge Air Cooler Leak Test

If the pressure drop is 34 kPa [5 psi] or less in 15 seconds, the cooler is functioning properly.

If the pressure drop is greater than 34 kPa [5 psi] in 15 seconds, check all connections again.



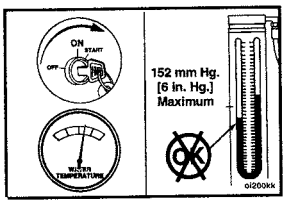
Charge Air Cooler Temperature Differential Test

Perform a road test with the engine at peak power and a vehicle speed of 48 kph [30 mph] or greater.

Intake Manifold Temperature	-	Ambient Air Temperature	=	Differential Temperature
Maximum Differential Temperature: 28°C [50°F]				

Charge Air Cooler Pressure Test

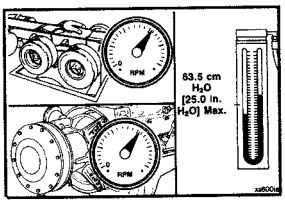
If the differential pressure is greater than 152 mm Hg [6 in Hg], check the charge air cooler and associated piping for plugging. Clean or replace if necessary.



Air Intake Restriction (010-031)

Inlet Air Restriction

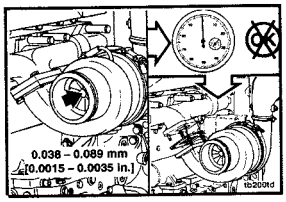
63.5 mm H_2O MAX 25.0 in H_2O



Turbocharger Axial Clearance (010-038)

Axial Clearance

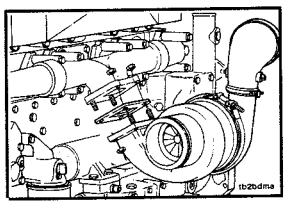
0.038 mm	MIN	0.0015 in
0.089 mm	MAX	0.0035 in



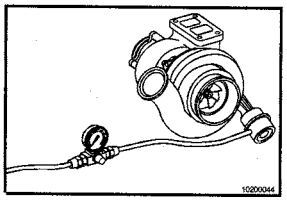
Turbocharger Radial Bearing Clearance (010-047)

Radial Bearing Clearance

0.15 mm	MIN	0.006 in
0.64 mm	MAX	0.025 in



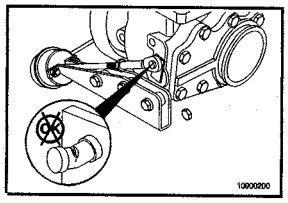
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.



Turbocharger Wastegate Actuator (010-050)

Wastegate Actuator Test

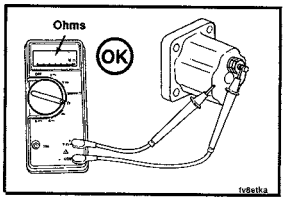
Apply a maximum of 310 kPa [45 psi] to make sure the wastegate is functioning properly.



Turbocharger Wastegate Valve Body (010-055)

Valve Body Shaft and Bushing Clearance

Maximum allowable clearance is 0.003 in.

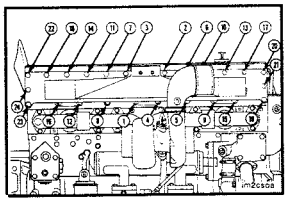
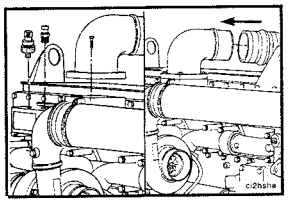
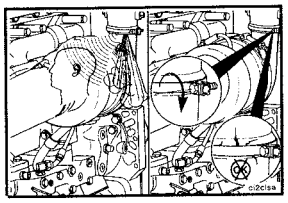
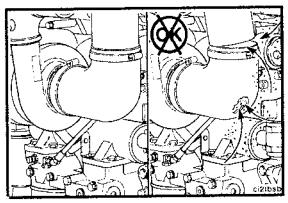
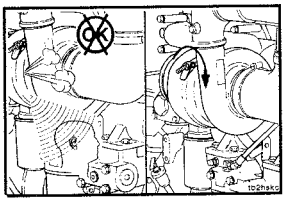
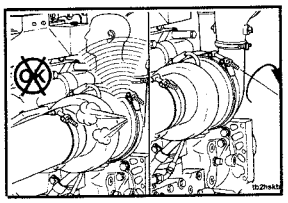
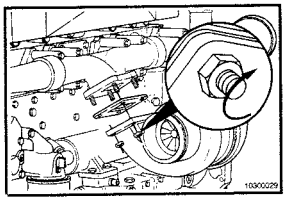


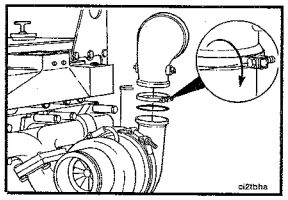
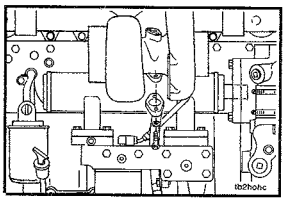
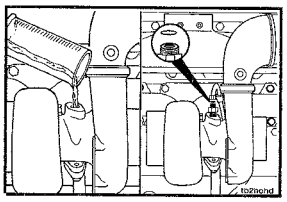
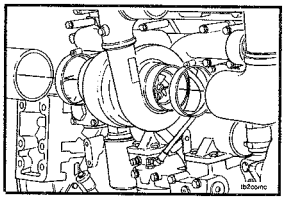
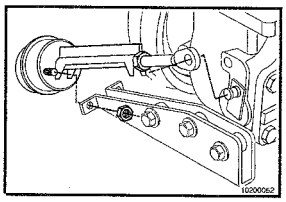
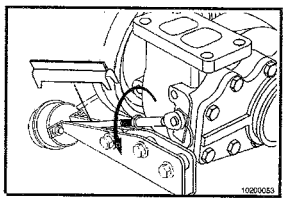
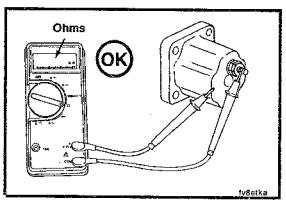
Turbocharger Wastegate Controller (010-109)

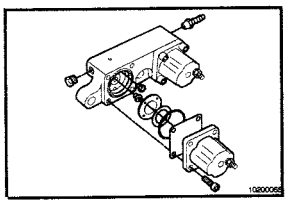
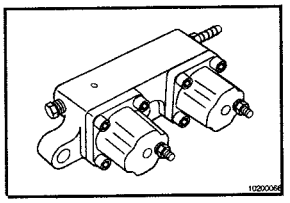
Coil Assembly Ohms Specifications

If the coil assembly shows zero ohms, there is an electrical short in the coil.

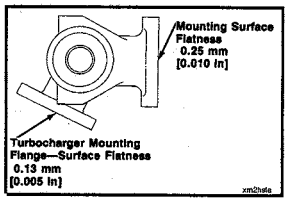
Solenoid	Ohms	Temperature
24 VDC solenoid	26-40 Ohms	-18°C to 100°C [0°F to 212°F]
12 VDC solenoid	6-10 Ohms	-18°C to 100°C [0°F to 212°F]

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Air Intake System - Torque Values				
Air Intake Manifold (010-023)				
Air Intake Manifold Capscrews		47 N•m	35 ft-lb	
Air Intake Manifold Capscrews		41 N•m	30 ft-lb	
Air Leaks, Air Intake and Exhaust Systems (010-024)				
Turbocharger Discharge Elbow Connection Clamp		8 N•m	72 in-lb	
Air Intake Piping Clamps		8 N•m	72 in-lb	
Turbocharger Turbine Housing				
Capscrews		14 N•m	120 in-lb	
V-band		9 N•m	75 in-lb	
Turbocharger Compressor Housing V-band Clamp		9 N•m	75 in-lb	
Turbocharger (010-033)				
Turbocharger Mounting Nuts		61 N•m	45 ft-lb	

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	**Turbocharger Compressor Discharge Elbow**		8 N•m	75 in-lb
	**Turbocharger Oil Drain Line Capscrews**		27 N•m	20 ft-lb
	**Oil Supply Line**		20 N•m	15 ft-lb
	**Intake Pipe Clamp** **Exhaust Pipe Clamp**		8 N•m 8 N•m	72 in-lb 72 in-lb
	**Turbocharger Wastegate Actuator (010-050)**			
	Actuator Mounting Capscrews		8.5 N•m	75 in-lb
	**Control Rod Jam Nut**		8.5 N•m	75 in-lb
	**Turbocharger Wastegate Controller (010-109)**			
	Electrical Connection on Coils		2 N•m	15 in-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Shutoff Shield and Coil		8 N•m	72 in-lb	
Wastegate Controller		47 N•m	35 ft-lb	
Connection Nut		2 N•m	15 in-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

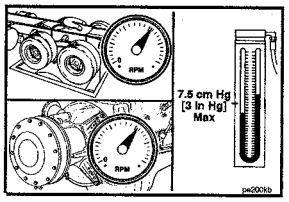


Exhaust System - Specifications

Exhaust Manifold, Dry (011-007)

Exhaust Manifold Mounting Surfaces

The exhaust manifold mounting surface **must** be flat to within 0.25 mm [0.010 in]. The turbocharger mounting flange **must** have a surface flatness of 0.13 mm [0.005 in].



Exhaust Restriction (011-009)

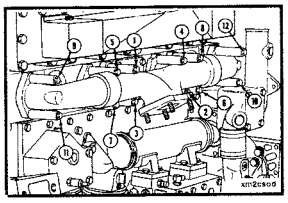
Exhaust Restriction (Without Catalyst)			
Hg	75 mm	MAX	3 in
H_2O	1016 mm	MAX	40 in
Exhaust Restriction (With Catalyst)			
Hg	152 mm	MAX	6 in
H_2O	2082 mm	MAX	82 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

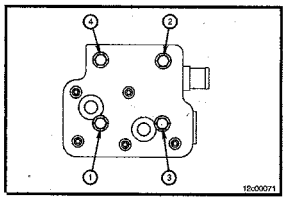
Exhaust System - Torque Values

Exhaust Manifold, Dry (011-007)

Exhaust Manifold Mounting Capscrews	1	27 N•m	20 ft-lb
	2	47 N•m	35 ft-lb



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

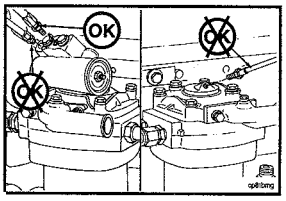


Compressed Air System - Specifications

Air Compressor Carbon Buildup (012-003)

Carbon Deposit Thickness Inside Air Discharge Line

The carbon deposit thickness **must not** exceed 1.6 mm [0.0625 in].



Air Governor (Air Compressor Pumps Continuously) (012-018)

Unloader Port Air Pressure

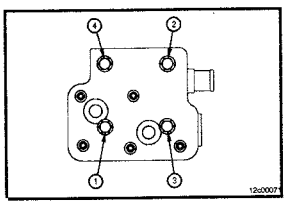
Apply 690 kPa [100 psi] air pressure to the unloader port.

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

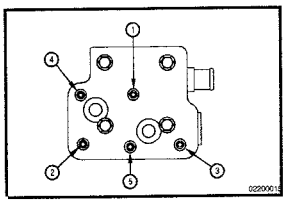
Compressed Air System - Torque Values

Air Compressor Carbon Buildup (012-003)

Cummins Air Compressor Cylinder Head	1	25 N•m	15 ft-lb
	2	Rotate 90 degrees except No. 4 which is rotated only 60 degrees.	

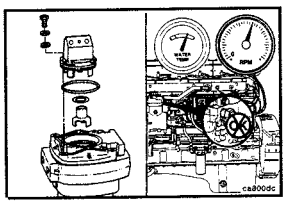


Cummins Air Compressor Cylinder Head	1	6 N•m	53 in-lb
	2	Rotate 90 degrees.	

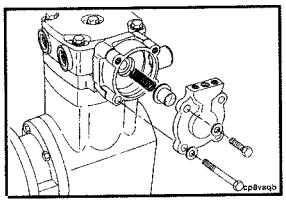


Air Compressor Unloader and Valve Assembly (012-013)

Holset SS, E-Type, and ST Unloader	14 N•m	10 ft-lb

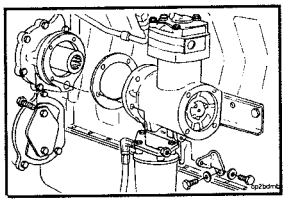


Holset QE Unloader	27 N•m	20 ft-lb

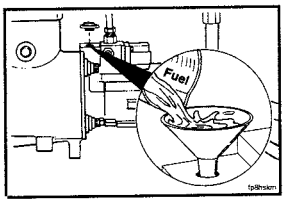


Air Compressor (012-014)

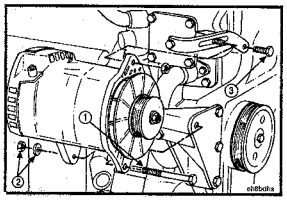
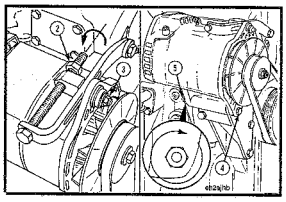
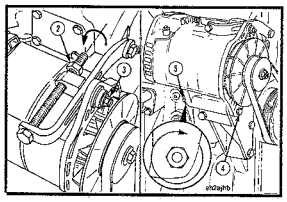
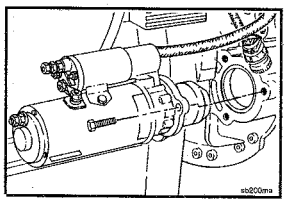
Holset Air Compressor Mounting Capscrews	68 N•m	50 ft-lb
Cummins Air Compressor Mounting Capscrews	44 N•m	33 ft-lb
Holset Air Compressor Support Bracket Mounting Capscrews	47 N•m	35 ft-lb
Cummins Air Compressor Support Bracket Mounting Capscrews	44 N•m	33 ft-lb

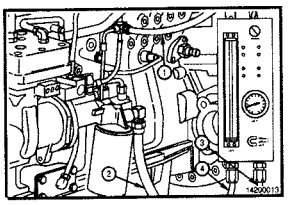
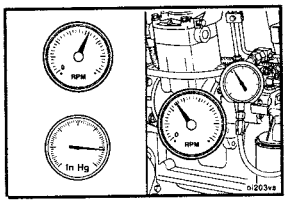
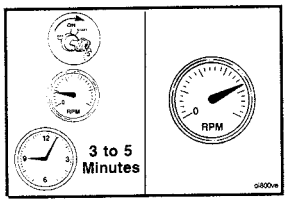
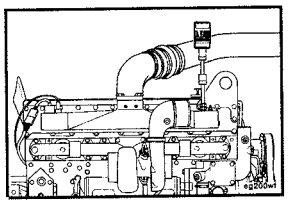
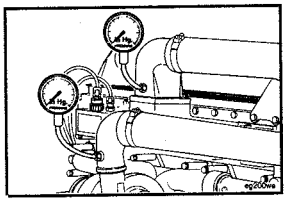
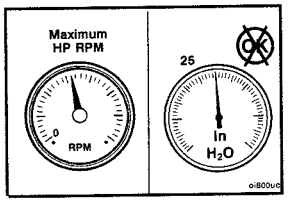
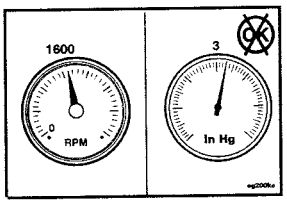


Fuel Pump Filter Cap	18 N•m	13 ft-lb

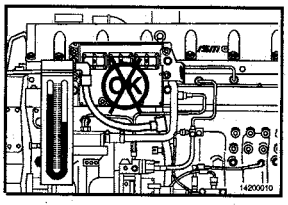


Electrical Equipment - Torque Values

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Alternator (013-001)			
			
Alternator Adjusting Link Mounting Capscrews		47 N•m	35 ft-lb
Drive Belt, Alternator (013-005)			
			
Alternator Belt Adjusting Link Locknut		80 N•m	60 ft-lb
Alternator Mounting Pivot Capscrew		47 N•m	35 ft-lb
			
Alternator Belt Adjustment Link Locking Capscrew		80 N•m	60 ft-lb
Alternator Mounting Pivot Capscrew		47 N•m	35 ft-lb
Starting Motor (013-020)			
			
Starting Motor Mounting Capscrews		90 N•m	140 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Engine Testing - Specifications					
Engine Testing (Chassis Dynamometer) (014-002)					
Inlet Fuel Temperature		15.5 °C 48.9 °C	MIN MAX	60 °F 120 °F	
Fuel Inlet Restriction					
New Filter		152 mm Hg	MAX	6 in Hg	
Used Filter		254 mm Hg	MAX	10 in Hg	
Fuel Drain Line Restriction		89 mm Hg	MAX	3.5 in Hg	
Intake Manifold Air Temperature		66 °C 77 °C	Nominal MAX	150 °F 170 °F	
CAC Restriction		152 mm Hg	MAX	6 in Hg	
Intake Air Restriction		635 mm H_2O	MAX	25 in H_2O	
Exhaust Air Restriction		76 mm Hg	MAX	3.0 in Hg	

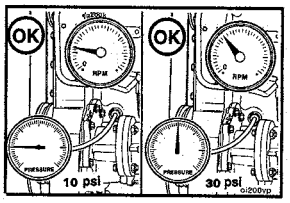
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.



Blowby Specifications

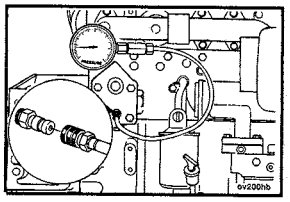
New, Rebuilt Engines*	30.5 cm H_2O [12.0 in H_20]
Used Engines**	46.0 cm H_2O [18.0 in H_20]

*Less than 160,000 km [100,000 mi] or 3600 hours.
**Over 160,000 km [100,000 mi] or 3600 hours.



Lubricating Oil Pressure

Low idle	70 kPa	MIN	10 psi
At 1200 rpm	207 kPa	MIN	30 psi



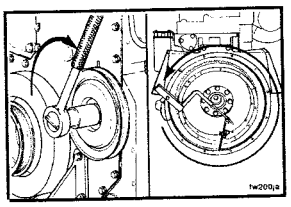
Coolant Pressure

	275 kPa	MAX	40 psi

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

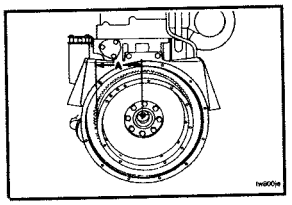
Mounting Adaptations - Specifications

Flywheel (016-005)

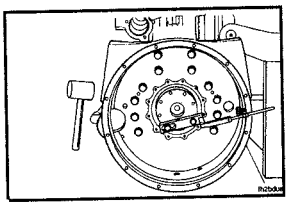


Flywheel Bore Runout

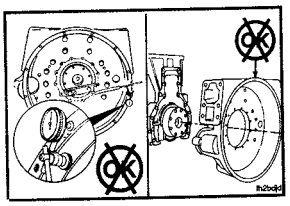
The total indicator reading **must not** exceed 0.127 mm [0.0050 in].



Flywheel Face Runout Total Indicator Reading			
Flywheel Radius (A)		Maximum Total Indicator Reading of Flywheel Face	
mm	in	mm	in
203	8	0.203	0.008
254	10	0.254	0.010
305	12	0.305	0.012
356	14	0.356	0.014
406	16	0.406	0.016

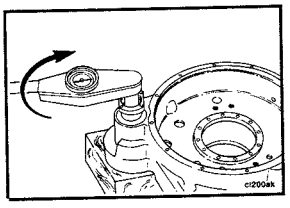


Flywheel Housing Bore Alignment Maximum Total Indicator Reading		
mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008



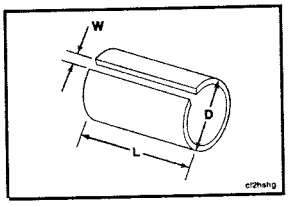
Flywheel Housing Face Alignment Maximum Total Indicator Reading		
mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008

Flywheel Housing, REPTO (016-007)



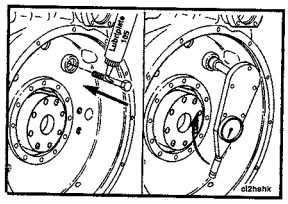
REPTO Output Shaft Rolling Resistance

The rolling resistance **must** be between 0.6 to 1.1 N•m [5 to 10 in-lb].



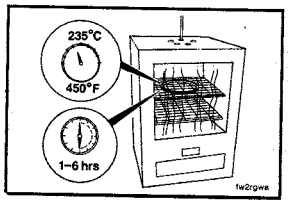
Sleeve Specifications		
Length (L)	25.40 mm	1.00 in
Slot (W)	6.30 mm	0.25 in
Outside Diameter (D)	38.10 mm	1.50 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.



Idler Shaft

The torque needed to draw the idler shaft in place **must not** exceed 88 N•m [65 ft-lb].



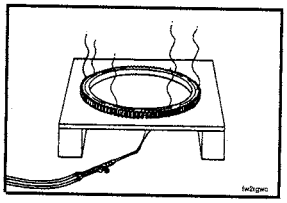
Warning: To avoid severe burns, wear protective gloves when installing the heated ring gear.

Flywheel Ring Gear (016-008)

Flywheel Ring Gear Installation

Use an oven to heat the new ring gear for a minimum of one hour. Do **not** heat the ring gear for more than 6 hours.

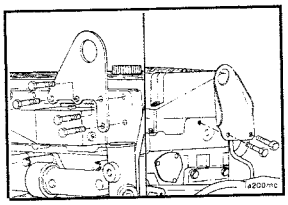
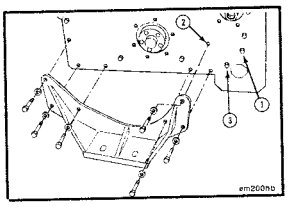
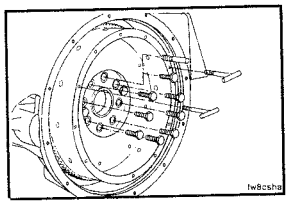
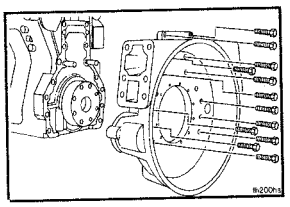
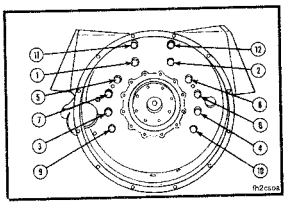
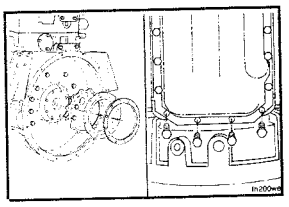
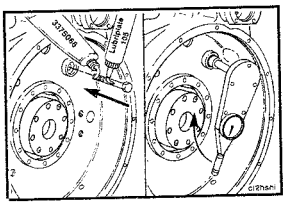
Temperature:	235 °C	450 °F



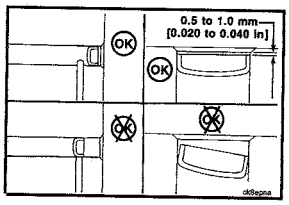
Flywheel Ring Gear Alternate Heating Method

If an oven is **not** available, use a heating torch to heat the gear. Use a Tempilstik crayon, or equivalent, to check the temperature of the gear.

Temperature:	235 °C	450 °F

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Mounting Adaptations - Torque Values				
Engine Lifting Brackets (016-001)				
Front Lifting Bracket Mounting Capscrews		47 N•m	35 ft-lb	
Rear Lifting Bracket Mounting Capscrew		81 N•m	60 ft-lb	
Engine Support Bracket, Front (016-002)				
Front Engine Support Bracket Mounting Capscrews		68 N•m	50 ft-lb	
Flywheel (016-005)				
Flywheel Mounting Capscrews		183 N•m	135 ft-lb	
Flywheel Housing (016-006)				
Flywheel Housing Initial Torque		7 N•m	60 in-lb	
Flywheel Housing Mounting Capscrew Final Torque	1	68 N•m	50 ft-lb	
	2	129 N•m	95 ft-lb	
	3	197 N•m	145 ft-lb	
Oil Pan to Flywheel Housing Mounting Capscrews		47 N•m	35 ft-lb	
Flywheel Housing, REPTO (016-007)				
Idler Shaft Capscrew		102 N•m	75 ft-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

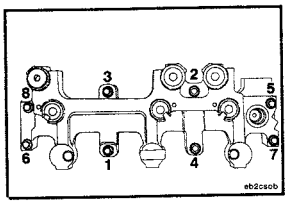
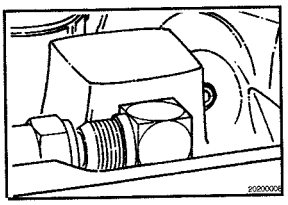
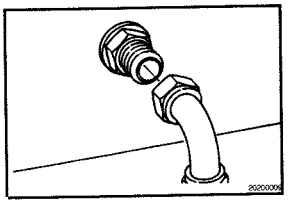


Miscellaneous - Specifications

Cup Plug (017-002)

Cup Plug Installation Depth

The cup plug **must** be installed with the edge of the plug 0.5 to 1.0 mm [0.020 to 0.040 in] deeper than the entrance chamber of the bore.

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Vehicle Braking - Torque Values				
Clutch Switch (020-004)				
Engine Brake Mounting Capscrew		81 N•m	60 ft-lb	
Internal Oil Connector Supply Hose		19 N•m	14 ft-lb	
External Oil Connector Supply Hose		19 N•m	14 ft-lb	

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

NOTE ON SELECTING TAP-DRILL SIZES: The tap drill sizes 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
60%	75%	
		48
		1.95mm
		5/64
	3-48	47
		2.00mm
	M2.5x.45	2.05mm
		46
3-48	3056	45
		2.10mm
M2.5x.45	M2.6x.45	2.15mm
3-56	4-36	44
		2.20mm
M2.6x.45		2.25mm
4-36	4-40	43
		2.30mm
		2.35mm
4-40	4-48	42
		3/32
	M3x.6	2.40mm
4-48		41
		2.45mm
		40
M3x.6	M3x.5	2.50mm
		39
	5-40	38
M3x.5		2.60mm
5-40	5-44	37
		2.70mm
5-44	6-32	36
		2.75mm
		7/64
		35
		2.80mm
		34
6-32	6-40	33
	M3.5x6	2.90mm
		32
M3.5x6		3.00mm
6-40		31
		3.10mm
		1/8
		3.20mm
	M4x.75	3.25mm
		30
	M4x.7	3.30mm
M4x.75		3.40mm
M4x.7	8-32	29
		3.50mm
	8-36	28
8-32		9/64
		3.60mm
8-36		27
		3.70mm
		26
	M4.5x.75	3.75mm
	10-24	25
		3.80mm
		24
M4.5x.75		3.90mm
		23
		5/32
10-24		22
	M5x1	4.00mm
	10-32	21
		20
	M5x.9	4.10mm
M5x1	M5x.8	4.20mm
10-32		19
M5x.9		4.25mm
M5x.8		4.30mm
		18
		11/64
		17

Tap Size		Drill Size
60%	75%	
		4.40mm
	12-24	16
		4.50mm
		15
	M5.5x.9	4.60mm
12-24	12-28	14
		13
		4.70mm
M5.5x.9		4.75mm
12-28		3/16
		12
		4.80mm
		11
		4.90mm
		10
		9
	M6x1	5.00mm
		8
		5.10mm
	1/4-20	7
		13/64
		6
M6x1		5.20mm
		5
	M6x.75	5.25mm
		5.30mm
1/4-20		4
M6x.75		5.40mm
	1/4-28	3
		5.50mm
		7/32
		5.60mm
1/4-28		2
		5.70mm
		5.75mm
		1
		5.80mm
		5.90mm
		A
		15/64
	M7x1	6.00mm
		B
		6.10mm
		C
M7x1		6.20mm
		D
	M7x.75	6.25mm
		6.30mm
		E
		1/4
M7x.75		6.40mm
		6.50mm
	5/16-18	F
		6.60mm
		G
		6.70mm
		17/64
	M8x1.25	6.75mm
5/16-18		H
		6.80mm
		6.90mm
	5.16-24	I
M8x1.25	M8x1	7.00mm
		J
		7.10mm
5/16-24		K
		9/32
M8x1		7.20mm
		7.25mm
		7.30mm
		L
		7.40mm
		M

Tap Size		Drill Size
60%	75%	
		7.50mm
		19/64
		7.60mm
		N
		7.70mm
	M9x1.25	7.75mm
		7.80mm
		7.90mm
	3/8-16	5/16
M9x1.25	M9x1	8.00mm
		O
		8.10mm
M9x1		8.20mm
		P
		8.25mm
		8.30mm
3/8-16	1/8-27NPT	21/64
		8.40mm
	3/8-24	Q
	M10x1.5	8.50mm
		8.60mm
		R
3/8-24		8.70mm
1/8-27NPT		11/32
	M10x1.25	8.75mm
M10x1.5		8.80mm
		S
		8.90mm
M10x1.25	M10x1	9.00mm
		T
		9.10mm
		23/64
M10x1		9.20mm
		9.30mm
	7/16-14	U
		9.40mm
	M11x1.5	9.50mm
		3/8
		V
		9.60mm
		9.70mm
		9.75mm
M11x1.5		9.80mm
7/16-14		W
		9.90mm
	7/16-20	25/64
		10.00mm
7/16-20		X
	M12x1.75	10.20mm
		Y
		13/32
		Z
M12x1.75	M12x1.5	10.50mm
	1/2-13	27/64
M12x1.5	M12x1.25	10.75mm
M12x1.25		11.00mm
1/2-13		7/16
1/4-18NPT		
		11.25mm
		11.50mm
		29/64
		11.75mm
		11.50mm
	1/2-20	29/64
	9/16-12	15/32
	M14x2	12.00m
		12.25mm
9/16-12		31/64
M14x2	M14x1.5	12.50mm
	9/16-18	1/2
M14x1.5	M14x1.25	12.75mm
M14x1.25		13.00mm
9/16-18		33/64

Tap Size		Drill Size
60%	75%	
		13.25mm
	5/8-11	17/32
	M15x1.5	13.50mm
M15x1.5		13.75mm
5/8-11		35/64
	M16x2	14.00mm
		14.25mm
	5/8-18	9/16
M16x2	M16x1.5	14.50mm
5/8-18		37/64
		14.75mm
M16x1.5		15.00mm
		19.32
		15.25mm
		39/64
	M17x1.5	15.50mm
M17x1.5	M18x2.5	15.75mm
		5/8
M18x2.5	M18x2	16.00mm
M18x2		16.25mm
	3/4-10	41/64
	M18x1.5	16.50mm
3/4-10	M19x2.5	21/32
M18x1.5		16.75mm
M19x2.5		17.00mm
		43/64
		17.25mm
3/4-16	3/4-16	11/16
	M20x2.5	17.50mm
		17.75mm
		45/64
M20x2.5	M20x2	18.00mm
M20x2		18.25mm
		23/32
	M20x1.5	18.50mm
		47/64
M20x1.5		18.75mm
		19.00mm
		3/4
		19.25mm
	7/8-9	49/64
	M22x2.5	19.50mm
7/8-9		25/32
		19.75mm
M22x2.5	M22x2	20.00mm
	7/8-14	51/64
M22x2		20.25mm
	M22x1.5	20.50mm
7/8-14		13/16
		20.75mm
M22x1.5	M24x3	21.00mm
		53/64
		21/25mm
		27/32
M24x3		21.50mm
		21.75mm
		55/64
	M24x2	22.00mm
	1"-8	7/8
M24x2		22.25mm
	M24x1.5	22.50mm
1"-8		57/64
M24x1.5		22.75mm
	M25x2	23.00mm
	1"-12	29/32
M25x2		23.25mm
1"x12	1"-14	59/64
	M25x1.5	23.50mm
M20x1.5		23.75mm
1"-14		15/16

17800013

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

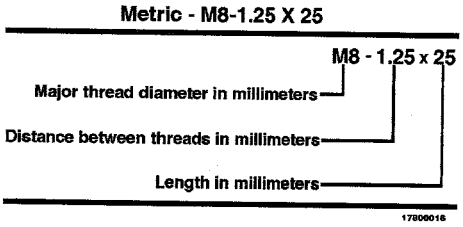
Capscrew Markings and Torque Values

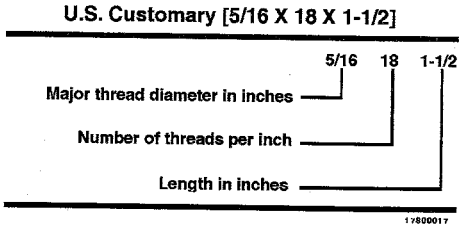
△ CAUTION △

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:

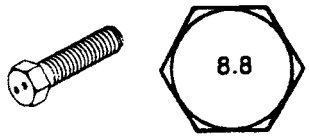
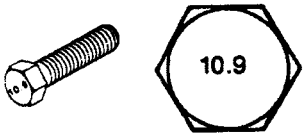
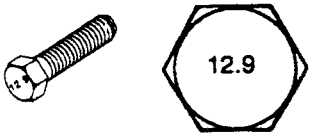




NOTES:

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

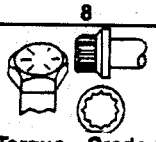
Commercial Steel Class	8.8	10.9	12.9
Capscrew Head Markings			

Body Size	Torque				Torque				Torque			
Diameter	Cast Iron		Aluminum		Cast Iron		Aluminum		Cast Iron		Aluminum	
mm	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	29	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 Body Size	Capscrew Torque - Grade 5 Capscrew				Capscrew Torque - Grade 8 Capscrew			
	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
1/4 - 28	12	9	9	7	18	13	9	7
5/16 - 18	20	15	16	12	30	22	16	12
5/16 - 24	23	17	19	14	33	24	19	14
3/8 - 16	40	30	25	20	55	40	25	20
3/8 - 24	40	30	35	25	60	45	35	25
7/16 - 14	60	45	45	35	90	65	45	35
7/16 - 20	65	50	55	40	95	70	55	40
1/2 - 13	95	70	75	55	130	95	75	55
1/2 - 20	100	75	80	60	150	110	80	60
9/16 - 12	135	100	110	80	190	140	110	80
9/16 - 18	150	110	115	85	210	155	115	85
5/8 - 11	180	135	150	110	255	190	150	110
5/8 - 18	210	155	160	120	290	215	160	120
3/4 - 10	325	240	255	190	460	340	255	190
3/4 - 16	365	270	285	210	515	380	285	210
7/8 - 9	490	360	380	280	745	550	380	280
7/8 - 14	530	390	420	310	825	610	420	310
1 - 8	720	530	570	420	1100	820	570	420
1 - 14	800	590	650	480	1200	890	650	480

Newton-Meter to Foot-Pound Conversion Chart

N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1	9 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
11	97 in-lb	90	66	190	140
12	106 in-lb	95	70	195	144
14	124 in-lb	100	74	200	148
15	133 in-lb	105	77	205	151
16	142 in-lb	110	81	210	155
18	159 in-lb	115	85	215	159
20	15 ft-lb	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.

Weights 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	Abbreviation		
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_2O	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_2O	millimeters of water	mm H_2O	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	(1.8 x °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

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

Drive Belt Tension

SAE Belt Size	Belt Tension Gauge Part No.		Belt Tension New		Belt Tension Range Used*	
	Click-type	Burroughs	N	lbf	N	lbf
0.380 in	3822524		620	140	270 to 490	60 to 110
0.440 in	3822524		620	140	270 to 490	60 to 110
1/2 in	3822524	ST-1138	620	140	270 to 490	60 to 110
11/16 in	3822524	ST-1138	620	140	270 to 490	60 to 110
3/4 in	3822524	ST-1138	620	140	270 to 490	60 to 110
7/8 in	3822524	ST-1138	620	140	270 to 490	60 to 110
4 rib	3822524	ST-1138	620	140	270 to 490	60 to 110
5 rib	3822524	ST-1138	670	150	270 to 530	60 to 120
6 rib	3822525	ST-1293	710	160	290 to 580	65 to 130
8 rib	3822525	ST-1293	890	200	360 to 710	80 to 160
10 rib	3822525	3823138	1110	250	440 to 890	100 to 200
12 rib	3822525	3823138	1330	300	530 to 1070	120 to 240
12 rib K section	3822525	3823138	1330	300	890 to 1070	200 to 240

Note: This chart does not apply to automatic belt tensioners.

* A belt is considered used if it has been in service for ten minutes or longer.

* If used belt tension is less than the minimum value, tighten the belt to the maximum used belt value.

About the Manual i-1
Accessory Drive 9-2
Clean 9-3
Install 9-3
Remove 9-2
Accessory Drive Pulley 9-5
Inspect for Reuse 9-5
Install 9-6
Remove 9-5
Accessory Drive Seal 1-5
Clean 1-6
Install 1-6
Remove 1-5
Acronyms and Abbreviations i-7
Additional Service Literature L-1
Air Compressor 12-23
Inspect for Reuse 12-25
Install 12-25
Remove 12-23
Air Compressor Carbon Buildup 12-11
Initial Check 12-11
Air Compressor Pin Bore Wear 12-16
Initial Check 12-16
Air Compressor Unloader and Valve Assembly 12-19
Clean 12-21
Initial Check 12-19
Inspect for Reuse 12-21
Install 12-21
Remove 12-20
Air Governor (Air Compressor Pumps Continuously) 12-28
Initial Check 12-28
Air Governor (Air Compressor Will Not Pump) 12-27
Initial Check 12-27
Air in Fuel 6-9
Test 6-9
Gear Pump Drain Method 6-10
Sightglass Method 6-9
Air Intake Manifold 10-4
Clean 10-4
Inspect for Reuse 10-4
Install 10-5
Remove 10-4
Air Intake Restriction 10-13
Measure 10-13
Air Intake System - General Information 10-1
General Information 10-1
Air Intake System - Specifications V-39
Air Intake Restriction V-39
Charge-Air Cooler (CAC) V-39
Turbocharger Axial Clearance V-39
Turbocharger Radial Bearing Clearance V-39
Turbocharger Wastegate Actuator V-40
Turbocharger Wastegate Controller V-40
Turbocharger Wastegate Valve Body V-40
Air Intake System - Torque Values V-41
Air Intake Manifold V-41
Air Leaks, Air Intake and Exhaust Systems V-41
Turbocharger V-41
Turbocharger Wastegate Actuator V-42
Turbocharger Wastegate Controller V-42
Air Leaks, Air Intake and Exhaust Systems 10-6
Maintenance Check 10-6
Air Leaks, Compressed Air System 12-30
Initial Check 12-30
Alternator 13-4
Initial Check 13-4
Install 13-5
Remove 13-5
Alternator Drive Pulley 9-6
Inspect for Reuse 9-7
Install 9-7
Remove 9-6
Alternator Drive Seal 1-4
Clean 1-4
Install 1-4
Remove 1-4
Batteries 13-9
Initial Check 13-9
Battery Cables and Connections 13-10
Initial Check 13-10
Bearings, Connecting Rod 1-6
Clean 1-8
Inspect for Reuse 1-8
Install 1-9
Remove 1-6
Bearings, Main 1-11
Clean 1-12
Inspect for Reuse 1-12
Install 1-13
Remove 1-11
Bearings, Thrust 1-16
Install 1-17
Remove 1-16
Cam Follower Assembly 4-2
Assemble 4-5
Clean 4-3
Disassemble 4-3
Inspect for Reuse 4-3
Install 4-6
Remove 4-2
Cam Followers/Tappets - Specifications V-20
Cam Follower Assembly V-20
Cam Followers/Tappets - Torque Values V-21
Cam Follower Assembly V-21
Camshaft 1-19
Clean 1-22
Inspect for Reuse 1-23
Install 1-24
Remove 1-19
Camshaft Bushings 1-28
Clean 1-28
Inspect for Reuse 1-29
Install 1-29
Remove 1-28
Camshaft End Clearance 1-117
Measure 1-117
Camshaft Gear (Camshaft Installed) 1-32
Inspect for Reuse 1-33
Install 1-35
Remove 1-32
Camshaft Gear (Camshaft Removed) 1-38
Install 1-38
Remove 1-38
Capscrew Markings and Torque Values V-58
Capscrew Markings and Torque Values - Metric V-59
Capscrew Markings and Torque Values - U.S. Customary V-60
Centinel System (ISM Engines) 7-51
General Information 7-51
Install 7-52
Prime 7-53
Remove 7-52
Charge Air Cooler (CAC) 10-8
Clean 10-8
Inspect for Reuse 10-9
Leak Test 10-9
Pressure Differential Test 10-11
Temperature Differential Test 10-10
Clutch Switch 20-1
Adjust 20-8
Clean 20-5
Initial Check 20-1
Inspect for Reuse 20-5
Install 20-6
Remove 20-4
Complete Engine - General Information 0-1
General Information 0-1
Component Manufacturers' Addresses M-1
Air Compressors M-1
Air Cylinders M-1
Air Heaters M-1
Air Starting Motors M-1
Alternators M-1
Auxiliary Brakes M-1
Belts M-1

Index
Page 2

Catalytic Convertors M-1
Clutches M-1
Coolant Heaters M-2
Coolant Level Switches M-1
Drive Plates M-2
Electric Starting Motors M-2
Electronic Switches M-2
Engine Protection Controls M-2
Fan Clutches M-2
Fans M-2
Fault Lamps M-2
Filters M-2
Flexplates M-2
Fuel Coolers M-2
Fuel Pumps M-2
Fuel Warmers M-2
Gauges M-3
Governors M-3
Heat Sleeves M-3
Hydraulic and Power Steering Pumps M-3
In-Line Connectors M-3
Oil Heaters M-3
Prelubrication Systems M-3
Radiators M-3
Throttle Assemblies M-3
Torque Converters M-3
Compressed Air System - General Information 12-1
General Information 12-1
Compressed Air System - Specifications V-46
Air Compressor Carbon Buildup V-46
Air Governor (Air Compressor Pumps Continuously) V-46
Compressed Air System - Torque Values V-47
Air Compressor V-47
Air Compressor Carbon Buildup V-47
Air Compressor Unloader and Valve Assembly V-47
Connecting Rod 1-41
Clean 1-41
Inspect for Reuse 1-41
Install 1-43
Remove 1-41
Coolant Filter 8-16
Install 8-17
Remove 8-16
Coolant Filter Head 8-19
Clean 8-19
Inspect for Reuse 8-19
Install 8-20
Remove 8-19
Coolant Heater Housing 8-21
Clean 8-22
Inspect for Reuse 8-22
Install 8-22
Remove 8-21
Coolant Temperature Gauge 8-16
Initial Check 8-16
Coolant Thermostat 8-23
Inspect for Reuse 8-26
Install 8-27
Leak Test 8-23
Remove 8-25
Coolant Thermostat Housing Support 8-28
Clean 8-30
Inspect for Reuse 8-30
Install 8-30
Remove 8-28
Coolant Thermostat Seal 8-33
Clean 8-33
Inspect for Reuse 8-33
Install 8-34
Remove 8-33
Coolant Vent Lines 8-35
Initial Check 8-35
Cooling System 8-36
Clean 8-36
Drain 8-36
Fill 8-39
Pressure Test 8-41
Cooling System - Air or Combustion Gas Test 8-42
Initial Check 8-42
Air in Cooling System 8-42
Leak Test 8-43
Air Compressor 8-44
Combustion Gas Leak 8-45
Fan, Shutter, or Heater Air Control Valve 8-43
Cooling System - General Information 8-1
General Information 8-1
Cooling System - Specifications V-31
Coolant Thermostat V-31
Cooling System V-31
Fan Clutch, Air-Disengaged V-31
Fan Clutch, Air-Engaged V-31
Fan Clutch, Electric V-31
Fan Drive Idler Pulley Assembly V-32
Fan Hub, Belt Driven V-32
Radiator V-32
Radiator Pressure Cap V-32
Water Pump V-32
Cooling System - Torque Values V-33
Coolant Filter Head V-33
Coolant Heater Housing V-33
Coolant Thermostat V-33
Coolant Thermostat Housing Support V-33
Coolant Thermostat Seal V-34
Cooling Fan Drive Belt V-33
Cooling Systeml V-34
Fan Clutch, Electric V-34
Fan Clutch, Viscous V-34
Fan, Cooling V-35
Fan Drive Idler Pulley Assembly V-35
Fan Hub, Belt Driven V-35
Fan Spacer and Pulley V-35
Water Pump V-35
Cooling System Diagnostics 8-48
Analyzing the Data 8-52
General Information 8-48
Setup 8-49
Test 8-50
Operational Worksheet 8-51
Cooling System Precharge 8-53
Customer Precharge Method 8-54
Factory Precharge Method 8-53
General Information 8-53
Crankcase Breather (Internal) 3-2
Clean 3-2
Inspect for Reuse 3-2
Install 3-3
Remove 3-2
Crankshaft 1-43
Rotation Check 1-43
Crankshaft Gear, Front (Crankshaft Installed) 1-43
Clean 1-44
Inspect for Reuse 1-44
Install 1-45
Remove 1-43
Crankshaft Pulley 1-46
Inspect for Reuse 1-47
Install 1-47
Remove 1-46
Crankshaft Seal, Front 1-48
Clean 1-49
Install 1-49
Remove 1-48
Crankshaft Seal, Rear 1-50
Clean 1-51
Install 1-51
Remove 1-50
Cup Plug 17-1
Clean 17-1
Inspect for Reuse 17-2
Install 17-2
Remove 17-1
Cylinder Block - Specifications V-1
Bearings, Connecting Rod V-1
Bearings, Main V-1

Bearings, Thrust V-1
Camshaft V-1
Camshaft Bushings V-1
Camshaft End Clearance V-9
Camshaft Gear (Camshaft Installed) V-2
Connecting Rod V-2
Crankshaft Gear, Front (Crankshaft Installed) V-3
Cylinder Block and Liner Seats V-3
Cylinder Liner V-3
Cylinder Liner Protrusion V-8
Gear Housing, Front V-4
Idler Gear, Camshaft V-4
Idler Gear, Hydraulic Pump V-5
Idler Gear, Water Pump V-6
Piston V-7
Piston and Connecting Rod Assembly V-8
Piston Cooling Nozzle V-7
Piston Rings V-7
Vibration Damper V-7
Cylinder Block - Torque Values V-10
Accessory Drive Seal V-10
Alternator Drive Seal V-10
Bearings, Connecting Rod V-10
Bearings, Main V-10
Camshaft V-10
Crankshaft Pulley V-10
Crankshaft Seal, Front V-11
Crankshaft Seal, Rear V-11
Cylinder Liner Protrusion V-13
Gear Cover, Front V-11
Gear Housing, Front V-12
Idler Gear, Camshaft V-12
Idler Gear, Hydraulic Pump V-12
Idler Gear, Water Pump V-12
Piston and Connecting Rod Assembly V-13
Piston Cooling Nozzle V-13
Water Header Plate, Cylinder Block V-13
Cylinder Block and Liner Seats 1-52
Leak Test 1-52
Cylinder Head 2-2
Clean 2-6
Inspect for Reuse 2-7
Install 2-13
Leak Test 2-12
Pressure Test 2-10
Remove 2-2
Cylinder Head - Specifications V-14
Cylinder Head V-14
Cylinder Head - Torque Values V-15
Cylinder Head V-15
Cylinder Liner 1-53
Clean 1-55
Inspect for Reuse 1-56
Install 1-58
Remove 1-53
Cylinder Liner Protrusion 1-112
Measure 1-113
Preparatory 1-112
Cylinder Misfires or Smokes 6-12
Automated Cylinder Performance Test 6-12
ISM 6-12
Cylinder Cutout Test 6-12
ISM 6-12
Exhaust Manifold Temperature Test 6-13
Exhaust Manifold Tilt-back Method 6-13
General Information 6-12
Drive Belt, Alternator 13-6
Adjust 13-8
Install 13-6
Remove 13-6
Drive Belt, Cooling Fan 8-14
Inspect for Reuse 8-14
Install 8-15
Remove 8-14
Drive Belt Tension V-64
Drive Units - Specifications V-37
Hydraulic Pump Drive V-37
Drive Units - Torque Values V-38
Accessory Drive V-38
Accessory Drive Pulley V-38
Alternator Drive Pulley V-38
Hydraulic Pump Drive V-38
Dynamometer Worksheet 14-10
Worksheet 14-10
ECM Cooling Plate, Fuel Cooled 6-14
Install 6-15
Remove 6-14
Electrical Equipment - General Information 13-1
General Information 13-1
Electrical Equipment - Torque Values V-48
Alternator V-48
Drive Belt, Alternator V-48
Starting Motor V-48
Engine Diagrams E-6
Engine Views E-6
Engine Identification E-1
Cummins Engine Nomenclature E-2
ECM Dataplate E-2
Engine Dataplate E-1
Engine Installation 0-5
Install 0-5
Engine Lifting Brackets 16-2
Clean 16-2
Inspect for Reuse 16-2
Install 16-2
Remove 16-2
Engine Mounts 16-28
Install 16-28
Engine Removal 0-3
Remove 0-3
Engine Run-in (Chassis Dynamometer) 14-20
Run-In Instructions 14-20
Engine Run-in (Without Dynamometer) 14-23
Run-In Instructions 14-23
Off-Highway Applications 14-24
On-Highway Applications 14-23
Engine Support Bracket, Front 16-3
Clean 16-3
Inspect for Reuse 16-3
Install 16-4
Remove 16-3
Engine Testing - General Information 14-1
Fuel Flow Measurement on Engine or Chassis Dynamometer 14-4
General Information 14-1
Engine Testing - Specifications V-49
Engine Testing (Chassis Dynamometer) V-49
Engine Testing (Chassis Dynamometer) 14-11
Setup 14-11
Test 14-13
Exhaust Manifold, Dry 11-5
Assemble 11-6
Clean 11-5
Disassemble 11-5
Inspect for Reuse 11-6
Install 11-6
Remove 11-5
Exhaust Restriction 11-7
Measure 11-7
Exhaust System - General Information 11-1
General Information 11-1
Exhaust System - Specifications V-44
Exhaust Manifold, Dry V-44
Exhaust Restriction V-44
Exhaust System - Torque Values V-45
Exhaust Manifold, Dry V-45
Fan Clutch, Air-Disengaged 8-54
Maintenance Check 8-54
Fan Clutch, Air-Engaged 8-54
Maintenance Check 8-54
Fan Clutch, Electric 8-55
Inspect for Reuse 8-56
Install 8-57
Remove 8-55
Fan Clutch, On-Off 8-58

General Information 8-58
Initial Check 8-59
Fan Clutch, Viscous 8-60
General Information 8-60
Initial Check 8-60
Install 8-64
Remove 8-63
Fan, Cooling 8-69
Inspect for Reuse 8-69
Install 8-70
Remove 8-69
Fan Drive Idler Pulley Assembly 8-64
Initial Check 8-64
Install 8-65
Remove 8-64
Fan Hub, Belt Driven 8-66
Initial Check 8-66
Install 8-67
Remove 8-66
Fan Shroud Assembly 8-67
Initial Check 8-67
Fan Spacer and Pulley 8-68
Inspect for Reuse 8-68
Install 8-68
Remove 8-68
Flow Diagram, Air Intake System 10-2
Flow Diagram 10-2
Flow Diagram, Compressed Air System 12-3
Compressed Air System 12-3
Flow Diagram, Cooling System 8-2
Flow Diagram 8-2
Flow Diagram, Exhaust System 11-3
Flow Diagram 11-3
Flow Diagram, Fuel System 5-4
Fuel System 5-4
Flow Diagram, Lubricating Oil System 7-4
Flow Diagram 7-4
Flywheel 16-4
Clean 16-5
Inspect for Reuse 16-5
Install 16-6
Measure 16-7
Remove 16-4
Flywheel Housing 16-10
Clean 16-12
Inspect for Reuse 16-12
Install 16-13
Measure 16-13
Remove 16-10
Flywheel Housing, REPTO 16-16
Clean 16-19
Inspect for Reuse 16-20
Install 16-21
Measure 16-22
Remove 16-16
Flywheel Ring Gear 16-27
Install 16-28
Remove 16-27
Fraction, Decimal, Millimeter Conversions V-63
Fuel Consumption 5-9
Measure 5-9
Fuel Drain Line Restriction 6-16
Measure 6-16
Fuel Filter (Spin-On Type) 6-17
Install 6-17
Remove 6-17
Fuel Flow 5-12
Initial Check 5-12
Leak Test 5-13
Pressure Test 5-13
Fuel Inlet Restriction 6-19
Measure 6-19
Fuel Pump 5-14
Clean 5-15
Inspect for Reuse 5-15
Install 5-16
ISM 5-16
Prime 5-16
General Information 5-16
ISM 5-17
Remove 5-14
Rotation Check 5-18
Fuel Pump Gear Pump Check Valve 5-19
Install 5-19
Remove 5-19
Fuel Pump Pressure Regulator 5-26
Initial Check 5-26
Fuel Pump Pulsation Damper 5-20
Inspect for Reuse 5-20
Fuel Shutoff Valve (FSOV) 5-21
Inspect for Reuse 5-21
Fuel Supply Lines 6-21
Inspect for Reuse 6-21
Remove 6-21
Fuel System - General Information 5-1
Installation Recommendations 5-1
Fuel System - Specifications V-22
Fuel Flow V-22
Fuel Shutoff Valve (FSOV) V-22
Fuel System - Torque Values V-23
Fuel Pump V-23
Fuel Pump Gear Pump Check Valve V-23
Fuel Pump Pulsation Damper V-23
Fuel Shutoff Valve V-23
Gear Cover, Front 1-60
Clean 1-62
Inspect for Reuse 1-62
Install 1-63
Remove 1-60
Gear Housing, Front 1-67
Clean 1-69
Inspect for Reuse 1-70
Install 1-70
Remove 1-67
General Cleaning Instructions i-6
Glass or Plastic Bead Cleaning i-6
Solvent and Acid Cleaning i-6
Steam Cleaning i-6
General Repair Instructions i-5
Welding on a Vehicle with an Electronic Controlled Fuel System . i-5
General Safety Instructions i-4
Important Safety Notice i-4
How to Use the Manual i-1
Hydraulic Pump Drive 9-7
Clean 9-8
Inspect for Reuse 9-9
Install 9-10
Remove 9-7
Idler Gear, Camshaft 1-74
Clean 1-75
Inspect for Reuse 1-76
Install 1-78
Remove 1-74
Idler Gear, Hydraulic Pump 1-79
Clean 1-80
Inspect for Reuse 1-81
Install 1-83
Remove 1-79
Idler Gear, Water Pump 1-85
Clean 1-86
Inspect for Reuse 1-86
Install 1-88
Remove 1-85
Illustrations i-3
Injector 6-28
Install 6-31
ISM 6-31
Remove 6-28
ISM 6-28
Injectors and Fuel Lines - General Information 6-1
Theory of Operation 6-1
Hydromechanical Subsystem 6-1
Injectors and Fuel Lines - Specifications V-24
Cylinder Misfires or Smokes V-24

Fuel Drain Line Restriction V-24
Fuel Inlet Restriction V-24
Injectors and Fuel Lines - Torque Values V-25
ECM Cooling Plate, Fuel Cooled V-25
Injector V-25
Lubricating Oil and Filters 7-9
Inspect 7-9
Lubricating Oil Contamination 7-46
Fluorescent Dye Tracer 7-46
Fuel Pressure Test 7-48
Lubricating Oil Cooler 7-9
Clean 7-10
Install 7-12
Pressure Test 7-11
Remove 7-9
Lubricating Oil Dipstick 7-13
Calibrate 7-13
Lubricating Oil Dipstick Housing 7-14
Clean 7-15
Inspect for Reuse 7-15
Install 7-15
Remove 7-14
Lubricating Oil Filter (Canister-Type) 7-15
Leak Test 7-15
Lubricating Oil Filter Head 7-18
Clean 7-19
Disassemble 7-18
Inspect for Reuse 7-19
Install 7-20
Remove 7-18
Lubricating Oil Filter (Spin-On) 7-16
General Information 7-16
Install 7-17
Remove 7-16
Lubricating Oil High Pressure Relief Valve 7-21
Initial Check 7-21
Inspect for Reuse 7-22
Install 7-22
Remove 7-21
Lubricating Oil Leaks 7-23
Maintenance Check 7-23
Lubricating Oil Pan 7-25
Clean 7-26
Drain 7-25
Fill 7-29
Inspect for Reuse 7-27
Install 7-27
Front Sump Pan 7-27
Rear Sump Pan 7-29
Remove 7-25
Front Sump Pan 7-25
Rear Sump Pan 7-26
Lubricating Oil Pressure Gauge 7-31
Test 7-31
Lubricating Oil Pressure Regulator (Main Rifle) 7-31
Inspect for Reuse 7-32
Install 7-33
Remove 7-31
Lubricating Oil Pump 7-34
Inspect for Reuse 7-35
Install 7-36
Remove 7-34
Lubricating Oil System 7-38
Prime 7-38
Lubricating Oil System - General Information 7-1
General Information 7-1
Lubricating Oil System - Specifications V-26
Lubricating Oil Contamination V-28
Lubricating Oil Cooler V-26
Lubricating Oil High Pressure Relief Valve V-26
Lubricating Oil Pressure Regulator (Main Rifle) V-27
Lubricating Oil Pump V-27
Lubricating Oil System V-27
Lubricating Oil Thermostat V-28
Lubricating Oil System - Torque Values V-29
Centinel™ System (ISM Engines) V-30
Lubricating Oil Cooler V-29
Lubricating Oil Dipstick Housing V-29
Lubricating Oil Filter Head V-29
Lubricating Oil Pan V-29
Lubricating Oil Pressure Regulator (Main Rifle) V-30
Lubricating Oil Pump V-30
Lubricating Oil Transfer Tube V-30
Lubricating Oil Viscosity Sensor V-30
Lubricating Oil Temperature Gauge 7-39
Test 7-39
Lubricating Oil Thermostat 7-39
Inspect for Reuse 7-40
Install 7-40
Remove 7-39
Lubricating Oil Transfer Tube 7-41
Clean 7-41
Inspect for Reuse 7-42
Install 7-42
Remove 7-41
Lubricating Oil Viscosity Sensor 7-44
Inspect for Reuse 7-45
Install 7-45
Remove 7-44
Miscellaneous - Specifications V-54
Cup Plug V-54
Mounting Adaptations - Specifications V-51
Flywheel V-51
Flywheel Housing, REPTO V-51
Flywheel Ring Gear V-52
Mounting Adaptations - Torque Values V-53
Engine Lifting Brackets V-53
Engine Support Bracket, Front V-53
Flywheel V-53
Flywheel Housing V-53
Flywheel Housing, REPTO V-53
Newton-Meter to Foot-Pound Conversion Chart V-61
Overhead Set 3-3
Adjust 3-7
Measure 3-3
Pipe Plug 17-3
Clean 17-3
Inspect for Reuse 17-3
Install 17-3
Remove 17-3
Pipe Plug Torque Values V-57
Piston 1-90
Assemble 1-93
Clean 1-91
Disassemble 1-91
General Information 1-90
Inspect for Reuse 1-92
Articulated Piston 1-92
Install 1-93
Remove 1-90
Piston and Connecting Rod Assembly 1-101
Assemble 1-106
Clean 1-105
Disassemble 1-104
Inspect for Reuse 1-106
Install 1-108
Remove 1-101
Piston Cooling Nozzle 1-94
Inspect for Reuse 1-94
Install 1-95
Remove 1-94
Piston Rings 1-96
Inspect for Reuse 1-96
Push Rods or Tubes 4-8
Inspect for Reuse 4-9
Install 4-10
Remove 4-8
Radiator 8-70
Initial Check 8-70
Radiator Hoses 8-71
Inspect for Reuse 8-71
Radiator Pressure Cap 8-71
Inspect for Reuse 8-71
Radiator Shutter Assembly 8-72

Initial Check 8-72
Rocker Lever Assembly 3-14
Assemble 3-19
Clean 3-16
Disassemble 3-15
Inspect for Reuse 3-16
Install 3-20
Remove 3-14
Rocker Lever Cover 3-23
Clean 3-23
Inspect for Reuse 3-24
Install 3-24
Remove 3-23
Rocker Lever Housing 3-25
Clean 3-27
Inspect for Reuse 3-28
Install 3-28
Remove 3-25
Rocker Levers - Specifications V-16
Overhead Set V-16
Rocker Lever Assembly V-17
Rocker Levers - Torque Values V-19
Crankcase Breather (Internal) V-19
Overhead Set V-19
Rocker Lever Assembly V-19
Rocker Lever Housing V-19
Service Literature Ordering Location L-2
Service Tools 10-3
Air Intake System 10-3
Cam Followers/Tappets 4-1
Compressed Air System 12-9
Cooling System 8-12
Cylinder Block 1-1
Cylinder Head 2-1
Drive Units 9-1
Electrical Equipment 13-3
Engine Removal and Installation 0-2
Engine Testing 14-8
Fuel System 5-7
Injectors and Fuel Lines 6-7
Lubricating Oil System 7-7
Mounting Adaptations 16-1
Rocker Levers 3-1
Specifications E-3
Air Intake System ..... E-5 , 10-2
Batteries (Specific Gravity) E-5
Compressed Air System 12-5
Cummins 18.7 CFM Model 12-5
Cummins 37.4 CFM Model 12-6
Holset® Compressor Spring Force Specifications 12-8
Holset® SS296/SS296E/QE296 A/C Models 12-5
Holset® SS338/QE338 A/C Models 12-6
Holset® ST676 A/C Model 12-7
Coolant Replacement Requirements 8-11
Cooling System ..... E-4 , 8-3
Cooling System Sealing Additives 8-6
Cooling System Soluble Oils 8-6
Electrical System ..... E-5 , 13-2
Engine Testing 14-6
Exhaust System ..... E-5 , 11-4
Fleetguard® DCA4 Service Filters and Liquid Precharge 8-8
Fuel Recommendations 5-5
Fuel System ..... E-4 , 5-5
Fully Formulated Coolant/Antifreeze 8-5
General Information 8-4
General Specifications E-3
Lubricating Oil System ..... E-4 , 7-6
Supplemental Coolant Additive (SCA) 8-7
Test Intervals 8-10
Testing SCA Concentration Level CC-2602 Test Kit 8-9
Thermo Control Settings 8-4
Stall Speed Check List 5-27
If the Stall Speed is too High, Check the Following: 5-28
If the Stall Speed is Too Low, Check the Following: 5-27
Stall Speed Test 5-22
Stall Speed Check 5-22
Time Speed Check 5-25
Starter Magnetic Switch 13-10
Current Check 13-10
Starter Solenoid 13-13
Voltage Check 13-13
Starter Switch 13-12
Voltage Check 13-12
Starting Motor 13-15
Install 13-16
Remove 13-15
Static Injection Timing 6-22
Measure 6-24
Setup 6-22
Straight Thread Plug 17-4
Clean 17-4
Inspect for Reuse 17-4
Install 17-5
Remove 17-4
Symbols i-2
Tap-Drill Chart - U.S. Customary and Metric V-56
Torque Converter Cooler 8-79
General Information 8-79
Troubleshooting Procedures and Techniques TS-2
Air Compressor Air Pressure Rises Slowly TS-3
Air Compressor Cycles Frequently TS-5
Air Compressor Noise is Excessive TS-7
Air Compressor Pumping Excess Lubricating Oil into the Air System TS-8
Air Compressor Will Not Maintain Adequate Air Pressure (Not Pumping Continuously) TS-10
Air Compressor Will Not Pump Air TS-11
Air Compressor Will Not Stop Pumping TS-12
Alternator Not Charging or Insufficient Charging TS-13
Alternator Overcharging TS-15
Communication Error – Electronic Service Tool or Control Device TS-16
Connecting Rod Bearing Noise TS-113
Coolant in the Lubricating Oil TS-26
Coolant Loss – External TS-18
Coolant Loss – Internal TS-19
Coolant Temperature Above Normal – Gradual Overheat TS-20
Coolant Temperature is Above Normal – Sudden Overheat TS-23
Coolant Temperature is Below Normal TS-24
Crankcase Gases (Blowby) Excessive TS-27
Cranking Fuel Pressure is Low TS-28
Driveability — General Information TS-114
Driveability/Low Power — Customer Complaint Form TS-115
Driveability/Low Power/Excessive Fuel Consumption — Checklist TS-116
Engine Acceleration or Response Poor TS-29
Engine Brake Does Not Operate TS-34
Engine Brake — One or More Cylinders Braking with Power Switch Off TS-38
Engine Brake – Low Retarding Power or Slow to Activate TS-36
Engine Decelerates Slowly TS-39
Engine Difficult to Start or Will Not Start (Exhaust Smoke) TS-40
Engine Difficult to Start or Will Not Start (No Exhaust Smoke) TS-43
Engine Noise Diagnostic Procedures — General Information TS-113
Engine Noise Excessive TS-47
Engine Noise Excessive — Combustion Knocks TS-50
Engine Noise Excessive — Connecting Rod TS-51
Engine Noise Excessive — Main Bearing TS-52
Engine Noise Excessive — Piston TS-53
Engine Noise Excessive — Turbocharger TS-54
Engine Power Output Low TS-55
Engine Runs Rough at Idle TS-61
Engine Runs Rough or Misfires TS-64
Engine Shuts Off Unexpectedly or Dies During Deceleration. TS-67
Engine Speed Surges at Low or High Idle TS-69
Engine Speed Surges Under Load or in Operating Range TS-71
Engine Starts But Will Not Keep Running TS-74
Engine Vibration Excessive TS-76
Engine Will Not Crank or Cranks Slowly (Air Starter) TS-78
Engine Will Not Crank or Cranks Slowly (Electric Starter) TS-80
Engine Will Not Shut Off TS-82
Fuel Consumption Excessive TS-83

Fuel Consumption — Customer Complaint Form TS-118
Fuel Consumption — General Information TS-117
Fuel in Coolant TS-86
Fuel in the Lubricating Oil TS-87
Intake Manifold Air Temperature Above Specification TS-88
Intake Manifold Pressure (Boost) is Below Normal TS-90
Low Idle Adjust Switch Does Not Work TS-92
Lubricating Oil Consumption Excessive TS-93
Lubricating Oil Contaminated TS-95
Lubricating Oil Degradation (Centinel) TS-96
Lubricating Oil Pressure High TS-97
Lubricating Oil Pressure Low TS-98
Lubricating Oil Sludge in the Crankcase Excessive TS-101
Lubricating Oil Temperature Above Specification TS-102
Lubricating or Transmission Oil in the Coolant TS-103
Main Bearing Noise TS-113
Oil Consumption TS-119
Oil Pan Level Incorrect - High (Centinel) TS-105
Oil Pan Level Incorrect - Low (Centinel) TS-104
Operating Fuel Pressure is Low TS-106
Piston Noise TS-113
Response Test TS-122
Smoke, Black — Excessive TS-107
Smoke, White — Excessive TS-110
Turbocharger Leaks Engine Oil or Fuel TS-112
Troubleshooting Symptoms Charts TS-1
Turbocharger 10-14
Check for Correct Component 10-19
Clean 10-15
Inspect for Reuse 10-16
Install 10-17
Remove 10-14
Turbocharger Axial Clearance 10-20
Measure 10-20
Turbocharger Blade Damage 10-20
Inspect for Reuse 10-20
Turbocharger Compressor Seal Leaks 10-21
Leak Test 10-21
Turbocharger Radial Bearing Clearance 10-22
Measure 10-22
Turbocharger Turbine Seal Leaks 10-23
Leak Test 10-23
Turbocharger Wastegate Actuator 10-25
Initial Check 10-25
Install 10-28
Remove 10-26
Test 10-27
Turbocharger Wastegate Controller 10-31
Disassemble 10-31
Inspect for Reuse 10-31
Install 10-32
Remove 10-31
Turbocharger Wastegate Valve Body 10-30
Maintenance Check 10-30
Vehicle Braking - Torque Values V-55
Clutch Switch V-55
Vibration Damper 1-96
Clean 1-96
Eccentricity Check 1-98
Install 1-98
Maintenance Check 1-97
Remove 1-96
Wobble Check 1-99
Water Header Plate, Cylinder Block 1-99
Clean 1-100
Inspect for Reuse 1-100
Install 1-100
Remove 1-99
Water Pump 8-72
Clean 8-75
Inspect for Reuse 8-75
Install 8-76
Remove 8-72
Weights and Measures - Conversion Factors V-62
Wiring Harness, Cummins Electric Fan Clutch 8-80
General Information 8-80
Initial Check 8-80
Install 8-86
Remove 8-84

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