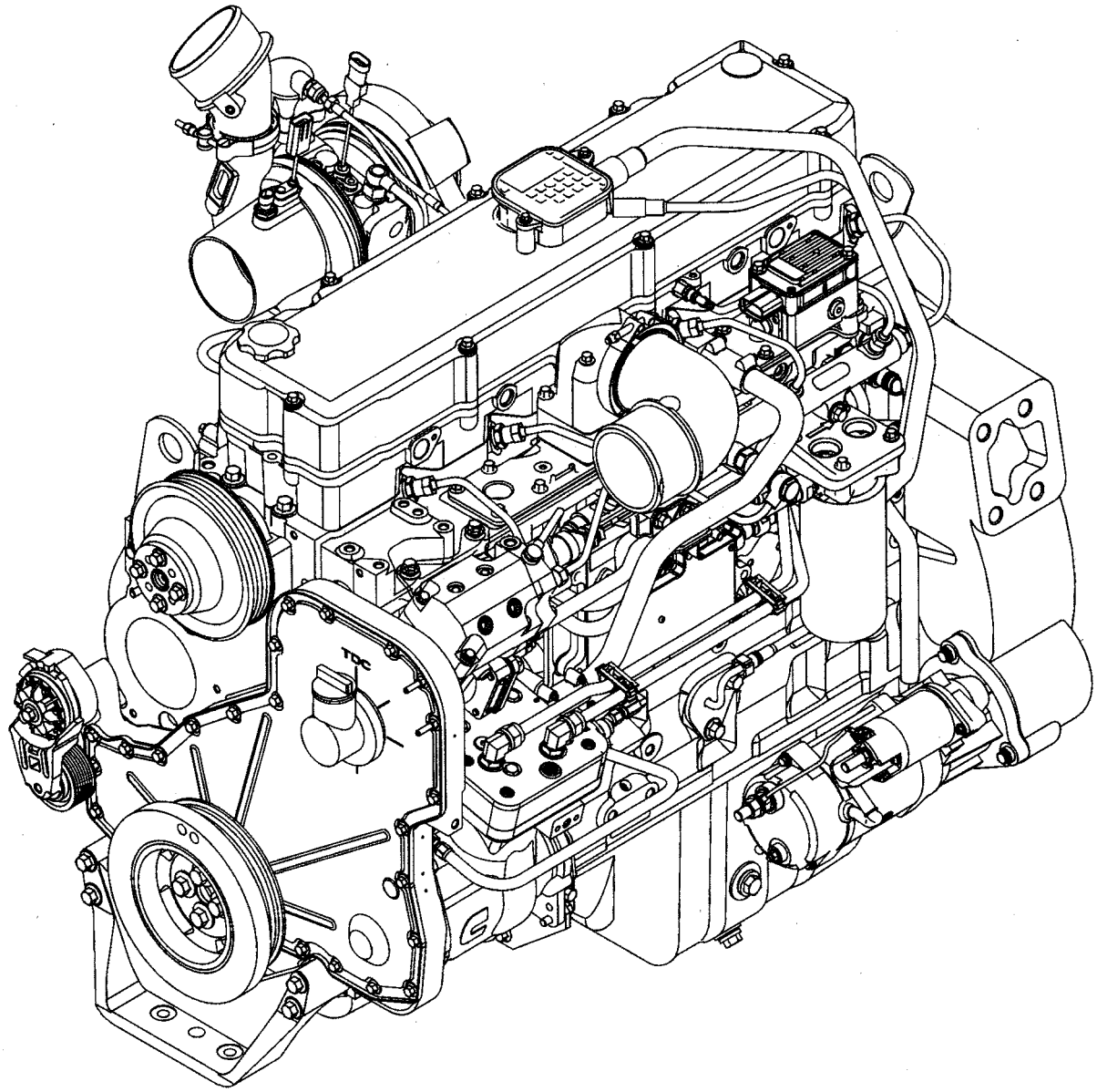
Troubleshooting and Repair Manual ISC, ISC^{e}, QSC8.3, ISL and QSL9 Engines



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Bulletin 4021418
Printed 28-JANUARY-2005

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 Contacting your local area Cummins Regional office. A Cummins Regional office listing is located in Service Literature (Section L).

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

Cummins 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 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:

Cummins® Cummins® ReCon® HOLSET® Fleetguard® NELSON® Premium Blue® Cummins®

Table of Contents

Section i - Introduction

Section Contents

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About the Manual

General Information

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' filmcard system. Some sections contain **reference** numbers and **procedure** numbers. **Reference** numbers provide general information, specifications, diagrams, and service tools where applicable. **Procedure** numbers are used to identify and reference specific repair procedures for correcting the problem.

This manual **does not** contain fuel systems electronic troubleshooting. Use the troubleshooting trees in this manual, if there are no electronic fault codes.

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.

How to Use the Manual

General Information

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:

- The engine has been installed according to the manufacturer's specifications.
- The easiest repairs are done first.
- "Generic" solutions to cover problems with the most common applications and Original Equipment Manufacturer (OEM).

Symbols

General Information

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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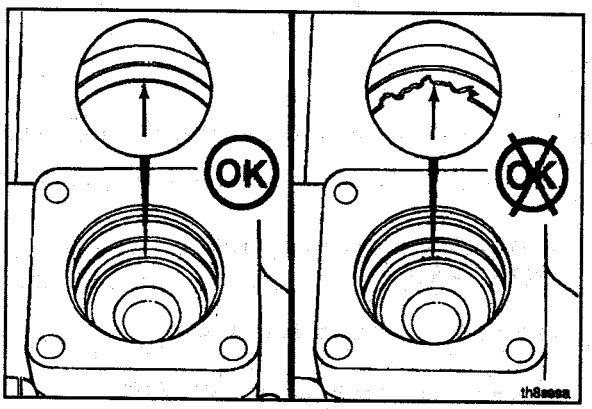
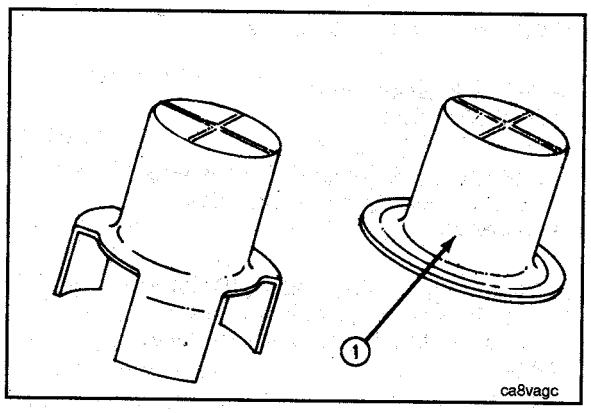


Illustrations

General Information

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, carelessness, or ignoring the warnings can cause burns, cuts, mutilation, asphyxiation or other personal 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.

- Work in an area surrounding the product that 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 slowly loosening the filler cap to relieve the pressure from the cooling system.
- **Always** use blocks or proper stands to support the product before performing any service work. Do **not** work on anything that is supported ONLY by lifting jacks or a hoist.
- Relieve all pressure in the air, oil, fuel, and 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 reduce the possibility of suffocation and frostbite, wear protective clothing and ONLY disconnect 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 reduce the possibility of 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 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 reduce the possibility of 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 the tools 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.
- Liquified petroleum gas is heavier than air and can accumulate near the floor, in sumps, and low-lying areas.
- Natural gas is lighter than air and can accumulate under hood and awnings.
- To reduce the possibility of suffocation and frostbite, wear protective clothing and ONLY disconnect natural gas and liquified petroleum gas lines in a well ventilated area.
- Coolant is toxic. If **not** reused, dispose of in accordance with local environmental regulations.

General Repair Instructions

General Information

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 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:**

1. **Air Compressor**
2. **Air Controls**
3. **Air Shutoff Assemblies**
4. **Balance Weights**
5. **Cooling Fan**
6. **Fan Hub Assembly**
7. **Fan Mounting Bracket(s)**
8. **Fan Mounting Capscrews**
9. **Fan Hub Spindle**
10. **Flywheel**
11. **Flywheel Crankshaft Adapter**
12. **Flywheel Mounting Capscrews**
13. **Fuel Shutoff Assemblies**
14. **Fuel Supply Tubes**
15. **Lifting Brackets**
16. **Throttle Controls**
17. **Turbocharger Compressor Casing**
18. **Turbocharger Oil Drain Line(s)**
19. **Turbocharger Oil Supply Line(s)**
20. **Turbocharger Turbine Casing**
21. **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 reduce the possibility of 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 or damage to the engine or components can result.

General Cleaning Instructions

Definition of Clean

Parts **must** be free of debris that can contaminate any engine system. This does **not** necessarily mean they have to appear as new.

Sanding gasket surfaces until the factory machining marks are disturbed adds no value and is often harmful to forming a seal. It is important to maintain surface finish and flatness tolerances to form a quality sealing surface. Gaskets are designed to fill small voids in the specified surface finish.

Sanding gasket surfaces where edge-molded gaskets are used is most often unnecessary. Edge-molded gaskets are those metal carriers with sealing material bonded to the edges of the gasket to seal while the metal portion forms a metal to metal joint for stability. Any of the small amounts of sealing material that can stick to the parts are better removed with a blunt-edged scraper on the spots rather than spending time polishing the whole surface with an air sander or disc.

For those gaskets that do **not** have the edge molding, nearly all have a material that contains release agents to prevent sticking. Certainly this is **not** to say that some gaskets are **not** difficult to remove because the gasket has been in place a long time, has been overheated or the purpose of the release agent has been defeated by the application of some sealant. The object however is just to remove the gasket without damaging the surfaces of the mating parts without contaminating the engine (don't let the little bits fall where they can not be removed).

Bead blasting piston crowns until the dark stain is removed is unnecessary. All that is required is to remove the carbon build-up above the top ring and in the ring grooves. There is more information on bead blasting and piston cleaning later in this document.

Cummins Inc. does **not** recommend sanding or grinding the carbon ring at the top of cylinder liners until clean metal is visible. The liner will be ruined and any signs of a problem at the top ring reversal point (like a dust-out) will be destroyed. It is necessary to remove the carbon ring to provide for easier removal of the piston assembly. A medium bristle, high quality, steel wire wheel that is rated above the rpm of the power tool being used will be just as quick and there will be less damage. Yes, one **must** look carefully for broken wires after the piston is removed but the wires are more visible and can be attracted by a magnet.

Oil on parts that have been removed from the engine will attract dirt in the air. The dirt will adhere to the oil. If possible, leave the old oil on the part until it is ready to be cleaned, inspected and installed, and then clean it off along with any attracted dirt. If the part is cleaned then left exposed it can have to be cleaned again before installation. Make sure parts are lubricated with clean oil before installation. They do **not** need to be oiled all over but do need oil between moving parts (or a good lube system priming process conducted before cranking the engine).

Bead blasting parts to remove exterior paint is also usually unnecessary. The part will most likely be painted again so all that needs happen is remove any loose paint.

Abrasive Pads and Abrasive Paper

The keyword here is "abrasive". There is no part of an engine designed to withstand abrasion. That is they are all supposed to lock together or slide across each other. Abrasives and dirt particles will degrade both functions.

⚠WARNING⚠

Abrasive material must be kept out of or removed from oil passages and parts wear points. Abrasive material in oil passages can cause bearing and bushing failures that can progress to major component damage beyond reuse. This is particularly true of main and rod bearings.

Cummins Inc. does **not** recommend the use of emery cloth or sand paper on any part of an **assembled** engine or component including but **not** limited to removing the carbon ridge from cylinder liners or to clean block decks or counterbores.

Great care **must** be taken when using abrasive products to clean engine parts, particularly on partially assembled engines. Abrasive cleaning products come in many forms and sizes. All of them contain aluminum oxide particles, silicon carbide, or sand or some other similar hard material. These particles are harder than most of the parts in the engine. Since they are harder, if they are pressed against softer material they will either damage the material or become embedded in it. These materials fall off the holding media as the product is used. If the products are used with power equipment the particles are thrown about the engine. If the particles fall between two moving parts, damage to the moving parts is likely.

If particles that are smaller than the clearance between the parts while they are at rest (engine stopped), but larger than the running clearance then damage will occur when the parts move relative to each other (engine started). While the engine is running and there is oil pressure, particles that are smaller than the bearing clearance are likely to pass between the parts without damage and be trapped in the oil filter. However, particles larger than the bearing clearance

will remove material from one part and can become embedded in one of the parts. Once embedded in one part it will abrade the other part until contact is no longer being made between the two parts. If the damage sufficiently degrades the oil film, the two parts will come into contact resulting in early wear-out or failure from lack of effective lubrication.

Abrasive particles can fly about during cleaning it is **very** important to block these particles from entering the engine as much as possible. This is particulary true of lubricating oil ports and oil drilling holes, especially those located downstream of the lubricating oil filters. Plug the holes instead of trying to blow the abrasive particles and debris with compressed air because the debris is often simply blown further into the oil drilling.

All old gasket material **must** be removed from the parts gasket surfaces. However, it is **not** necessary to clean and polish the gasket surface until the machining marks are erased. Excessive sanding or buffing can damage the gasket surface. Many newer gaskets are of the edge molded type (a steel carrier with a sealing member bonded to the steel). What little sealing material that can adhere is best removed with a blunt-edged scraper or putty knife. Cleaning gasket surfaces where an edge-molded gasket is used with abrasive pads or paper is usually a waste of time.

⚠WARNING⚠

Excessive sanding or grinding the carbon ring from the top of the cylinder liners can damage the liner beyond reuse. The surface finish will be damaged and abrasive particles can be forced into the liner material which can cause early cylinder wear-out or piston ring failures.

Tape off or plug all openings to any component interior before using abrasive pads or wire brushes. If really necessary because of time to use a power tool with abrasive pads, tape the oil drillings closed or use plug and clean as much of the surface as possible with the tool but clean around the oil hole/opening by hand so as to prevent contamination of the drilling. Then remove the tape or plug and clean the remaining area carefully and without the tool. DO NOT use compressed air to blow the debris out of oil drilling on an assembled engine! More likely than **not**, the debris can be blown further into the drilling. Using compressed air is fine if both ends of the drilling are open but that is rarely the case when dealing with an assembled engine.

Gasket Surfaces

The object of cleaning gasket surfaces is to remove any gasket material, not refinish the gasket surface of the part.

Cummins Inc. does **not** recommend any specific brand of liquid gasket remover. If a liquid gasket remover is used, check the directions to make sure the material being cleaned will **not** be harmed.

Air powered gasket scrapers can save time but care must be taken to **not** damage the surface. The angled part of the scraper must be against the gasket surface to prevent the blade from digging into the surface. Using air powered gasket scrapers on parts made of soft materials takes skill and care to prevent damage.

Do **not** scrape or brush across the gasket surface if at all possible.

Solvent and Acid Cleaning

Several solvent and acid-type cleaners can be used to clean the disassembled engine parts (other than pistons. See Below). Experience has shown that the best results can be obtained using a cleaner that can be heated to 90° to 95° Celsius (180° to 200° Fahrenheit). Kerosene emulsion based cleaners have different temperature specifications, see below. A cleaning tank that provides a constant mixing and filtering of the cleaning solution will give the best results. Cummins 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⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturers recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Experience has shown that kerosene emulsion based cleaners perform the best to clean pistons. These cleaners should **not** be heated to temperature in excess of 77°C (170°F). The solution begins to break down at temperatures in excess of 82°C (180°F) and will be less effective.

Do **not** use solutions composed mainly of chlorinated hydrocarbons with cresols, phenols and/or cresylic components. They often do **not** do a good job of removing deposits from the ring groove and are costly to dispose of properly.

Solutions with a pH above approximately 9.5 will cause aluminum to turn black; therefore do **not** use high alkaline solutions.

Chemicals with a pH above 7.0 are considered alkaline and those below 7.0 are acidic. As you move further away from the neutral 7.0, the chemicals become highly alkaline or highly acidic.

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 to **not** damage any gasket surfaces. When possible use hot high pressure water or steam clean the parts before putting them in the cleaning tank. Removing the heaviest dirt before placing in the tank will allow the cleaner to work more effectively and the cleaning agent will last longer.

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

If the parts are **not** to be used immediately after cleaning, dip them in a suitable rust proofing compound. The rust proofing compound **must** be removed from the parts before assembly or 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 method for cleaning the oil drillings and coolant passages

⚠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.

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

- Electrical Components
- Wiring Harnesses
- Injectors
- Fuel Pump
- Belts and Hoses
- Bearings (ball or taper roller)
- Electronic Control Module (ECM)
- ECM Connectors

Plastic Bead Cleaning

Cummins Inc. does **not** recommend the use of glass bead blast or walnut shell media on **any** engine part. Cummins Inc. recommends using **only** plastic bead media, Part Number 3822735 or equivalent on any engine part. **Never** use sand as a blast media to clean engine parts. Glass and walnut shell media when **not** used to the media manufacturer's recommendations can cause excess dust and can embed in engine parts that can result in premature failure of components through abrasive wear.

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

△CAUTION△

Do not use bead blasting cleaning methods on aluminum pistons skirts or the pin bores in any piston, piston skirt or piston crown. Small particles of the media will embed in the aluminum or other soft metal and result in premature wear of the cylinder liner, piston rings, pins and pin bores. Valves, turbocharger shafts, etc., can also be damaged. Follow the cleaning directions listed in the procedures.

△CAUTION△

Do not contaminate wash tanks and tank type solvent cleaners with the foreign material and plastic beads. Remove the foreign material and plastic beads with compressed air, hot high pressure water or steam before placing them in tanks or cleaners. The foreign material and plastic beads can contaminate the tank and any other engine parts cleaned in the tank. Contaminated parts may cause failures from abrasive wear.

Plastic bead blasting media, Part Number 3822735, can be used to clean all piston ring grooves. Do **not** sure any bead blasting media on piston pin bores or aluminum skirts.

Follow the equipment manufacturer's cleaning instructions. Make sure to adjust the air pressure in the blasting machine to the bead manufacturer's recommendations. Turning up the pressure can move material on the part and cause the plastic bead media to wear out more quickly. The following guidelines can be used to adapt to manufacturer's instructions:

1. Bead size: U.S. size Number 16 — 20 for piston cleaning with plastic bead media, Part Number 3822735
2. Operating Pressure — 270 kPa (40 psd) for piston cleaning. Pressure should not cause beads to break.
3. Steam clean or wash the parts with solvent to remove all of the foreign material and plastic beads after cleaning. Rinse with hot water. Dry with compressed air.

⚠CAUTION⚠

The bead blasting operation must not disturb the metal surface. If the metal surface is disturbed the engine can be damaged due to increased parts clearance or inadequate surface finish on parts that move against other parts.

When cleaning pistons, it is **not** necessary to remove all the dark stain from the piston. All that is necessary is to remove the carbon on the rim and in the ring grooves. This is best done by directing the blast across the part as opposed to straight at the part. If the machining marks are disturbed by the blasting process, then the pressure is too high or the blast is being held on one spot too long. The blast operation **must not** disturb the metal surface.

Walnut shell bead blast material is sometimes used to clean ferrous metals (iron and steel). Walnut shell blasting produces a great amount of dust particularly when the pressure if the air pressure on the blasting machine is increased above media manufacturer's recommendation. Cummins Inc. recommends **not** using walnut shell media to clean engine parts due to the risk media embedment and subsequent contamination of the engine.

Cummins Inc. now recommends glass bead media **NOT** used to clean any engine parts. Glass media is too easily embedded into the material particularly in soft materials and when air pressures greater than media manufacturer's recommend are used. The glass is an abrasive so when it is in a moving part, that part is abrading all the parts in contact with it. When higher pressures are used the media is broken and forms a dust of a very small size that floats easily in the air. This dust is very hard to control in the shop, particularly if **only** compressed air (and not hot water) is used to blow the media after it is removed from the blasting cabinet (blowing the part off inside the cabinet may remove large accumulations but never removes all the media).

Bead blasting is best used on stubborn dirt/carbon build-up that has **not** been removed by first steam/higher pressure washing then washing in a heated wash tank. This is particularly true of pistons. Steam and soak the pistons first then use the plastic bead method to safely remove the carbon remaining in the grooves (instead of running the risk of damaging the surface finish of the groove with a wire wheel or end of a broken piston ring. Make sure the parts are dry and oil free before bead blasting to prevent clogging the return on the blasting machine.

Always direct the bead blaster nozzle "across" rather than directly at the part. This allows the bead to get under the unwanted material. Keep the nozzle moving rather than hold on one place. Keeping the nozzle directed at one-place too long causes the metal to heat up and be moved around. Remember that the spray is **not** just hitting the dirt or carbon. If the machining marks on the piston groove or rim have been disturbed then there has **not** been enough movement of the nozzle and/or the air pressure is too high.

Never bead blast valve stems. Tape or use a sleeve to protect the stems during bead blasting. Direct the nozzle across the seat surface and radius rather than straight at them. The object is to remove any carbon build up and continuing to blast to remove the stain is a waste of time.

Acronyms and Abbreviations

General Information

The following list contains some of the acronyms and abbreviations used in this manual.

API	American Petroleum Institute
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
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
°F	Fahrenheit
FMI	Failure Mode Indentifier
GVW	Gross Vehicle Weight
LPG	Liquified Petroleum Gas
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
MPa	Megapascal
mph	Miles Per Hour
mpq	Miles Per Quart
N•m	Newton-meter
NG	Natural Gas
OEM	Original Equipment Manufacturer
PID	Parameter Identification Descriptions
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
SID	Subsystem Identification Descriptions
VS	Variable Speed
VSS	Vehicle Speed Sensor

Notes

Section E - Engine and System Identification

Section Contents

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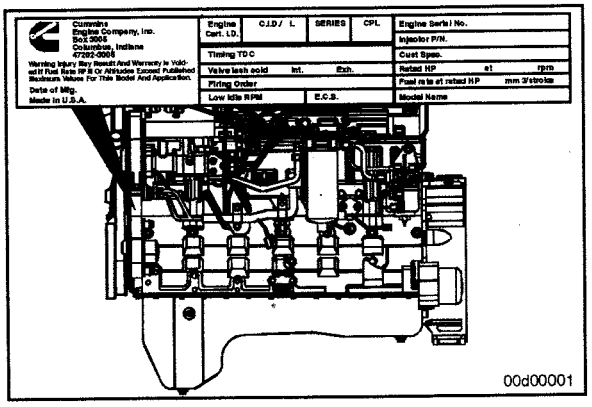
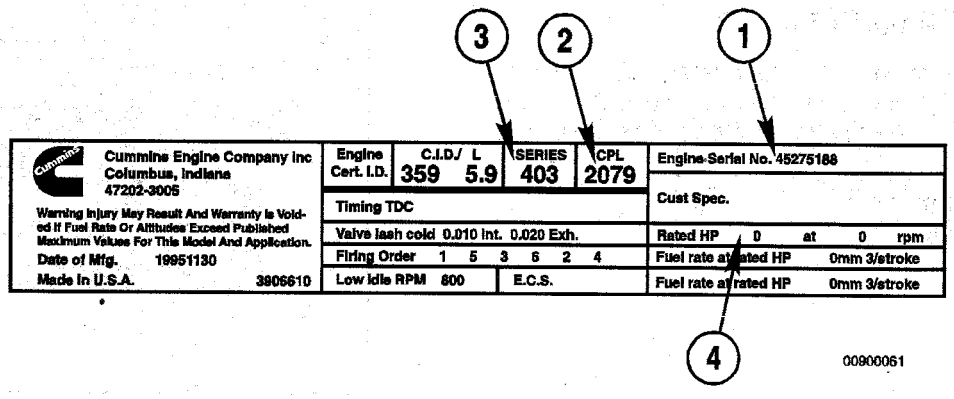
Engine Identification

Engine Dataplate

The engine dataplate provides important facts about the engine. The engine serial number (ESN) and control parts list (CPL) provide information for service and ordering parts. The engine dataplate **must not** be changed unless approved by Cummins Inc.

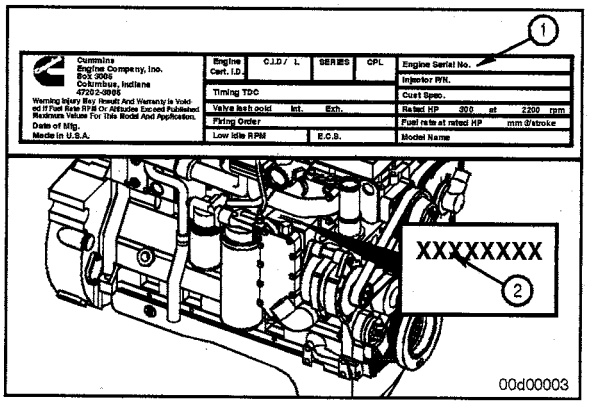




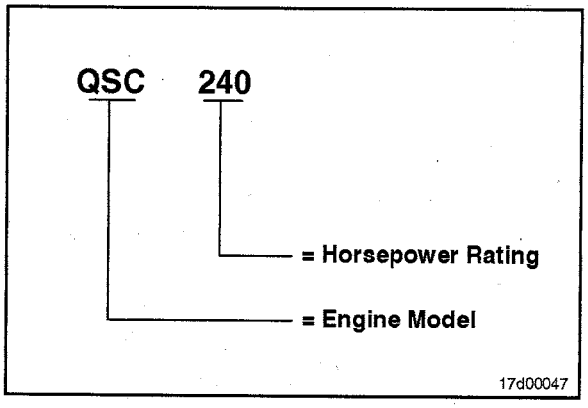
The dataplate is located on the top side of the gear housing.

Have the following engine data available when communicating with a Cummins Authorized Repair Location:

1. Engine serial number (ESN)
2. Control parts list (CPL)
3. Model
4. Horsepower and rpm rating.



NOTE: If the engine dataplate (1) is **not** readable, the ESN (2) can be found on the engine block on top of the lubricating oil cooler housing. Additional engine information is on the electronic control module (ECM) dataplate.



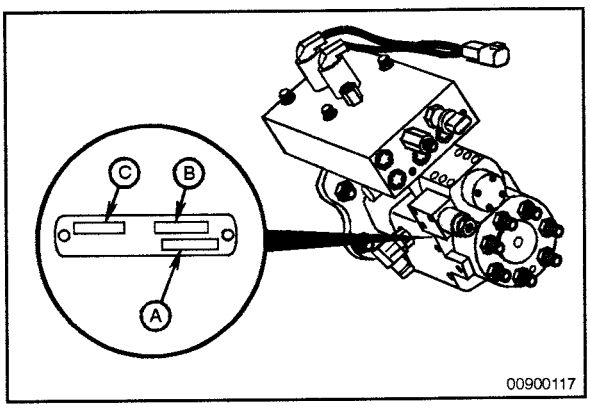
Cummins Engine Nomenclature

The Cummins engine nomenclature provides the engine model and horsepower rating.

Fuel Injection Pump Dataplate

The Cummins Accumulator Pump System (CAPS) fuel injection pump dataplate is located on the side of the injection pump. The dataplate contains the following information:

A. Cummins part number
B. Pump serial number
C. Factory code.

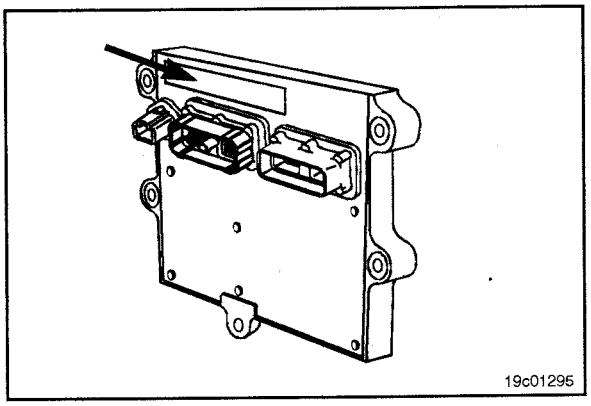


ECM Dataplate

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

The following information is found on the ECM dataplate:

- ECM part number (PN)
- ECM serial number (SN)
- ECM date code (DC)
- Engine serial number (ESN)
- ECM Code (identifies the software in the ECM).

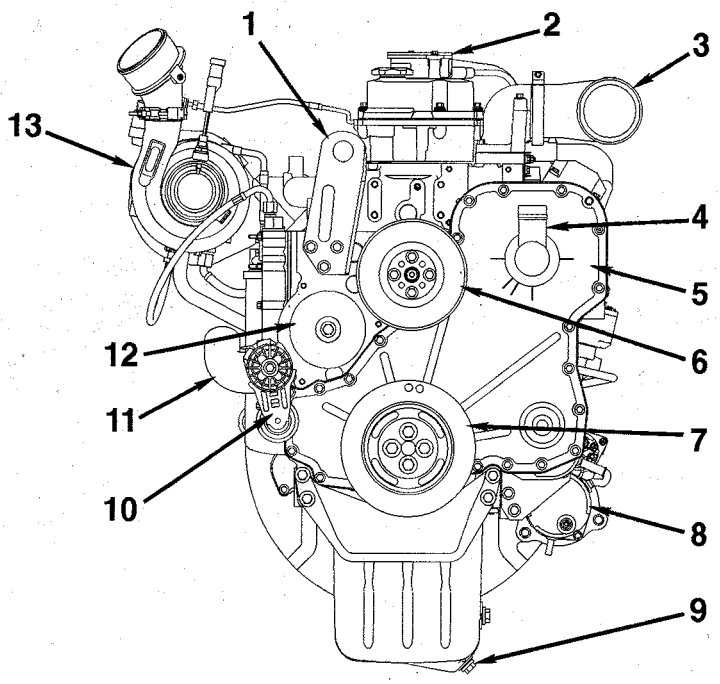


Engine Diagrams

Engine Views

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

NOTE: The illustrations are **only** a reference to show a typical engine.



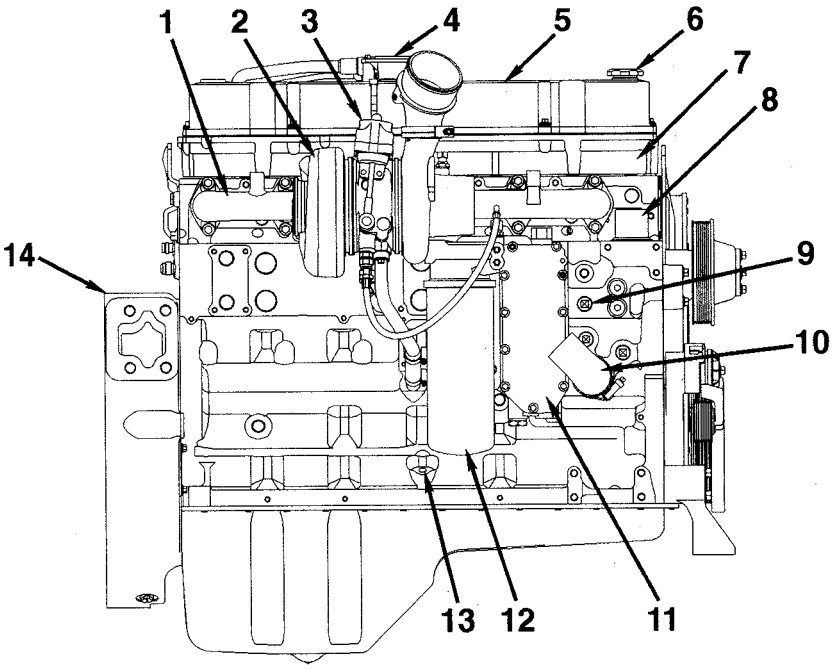
00d00130

Front Engine View (CM850 Electronic Control Module)

1. Engine lifting bracket
2. Crankcase breather
3. Air intake connection
4. Engine oil fill
5. Front gear cover
6. Fan pulley
7. Vibration Damper
8. Starter
9. Engine oil pan drain plug
10. Automatic belt tensioner
11. Coolant inlet connection
12. Water pump
13. Turbocharger (VGT shown)

Engine Diagrams

Engine Views



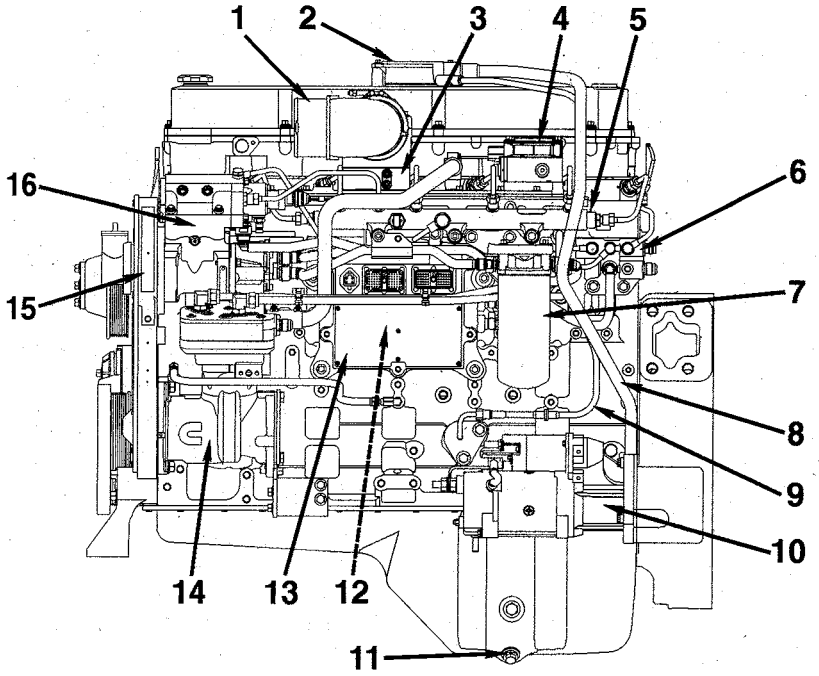
00d00131

Exhaust Side Engine View (CM850 Electronic Control Module)

1. Exhaust manifold
2. Turbocharger (VGT shown)
3. Variable geometry turbocharger actuator
4. Crankcase breather
5. Rocker lever cover
6. Engine oil fill
7. Rocker lever housing
8. Coolant outlet connection
9. Coolant heater port
10. Coolant inlet connection
11. Lubricating oil cooler
12. Lubricating oil filter
13. Dipstick location
14. Flywheel housing

Engine Diagrams

Engine Views

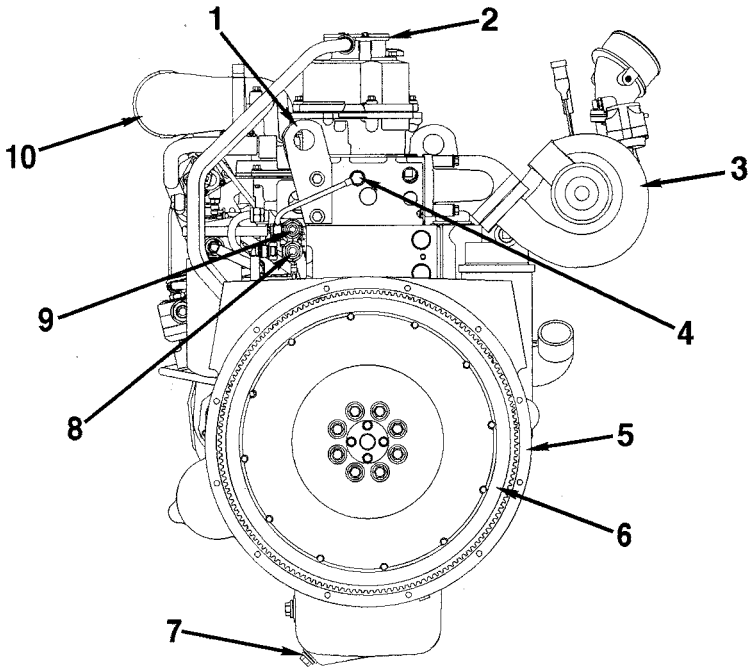


Intake Side Engine View (CM850 Electronic Control Module)

1. Air intake connection
2. Crankcase breather
3. Intake air heater
4. Turbocharger control valve
5. Fuel rail
6. Fuel drain manifold
7. Fuel filter
8. Crankcase breather draft tube
9. Crankcase breather oil drain tube
10. Starter
11. Engine oil drain plug
12. Fuel lift pump
13. Electronic control module (ECM)
14. Air compressor
15. Engine data plate
16. High-pressure pump

Engine Diagrams

Engine Views



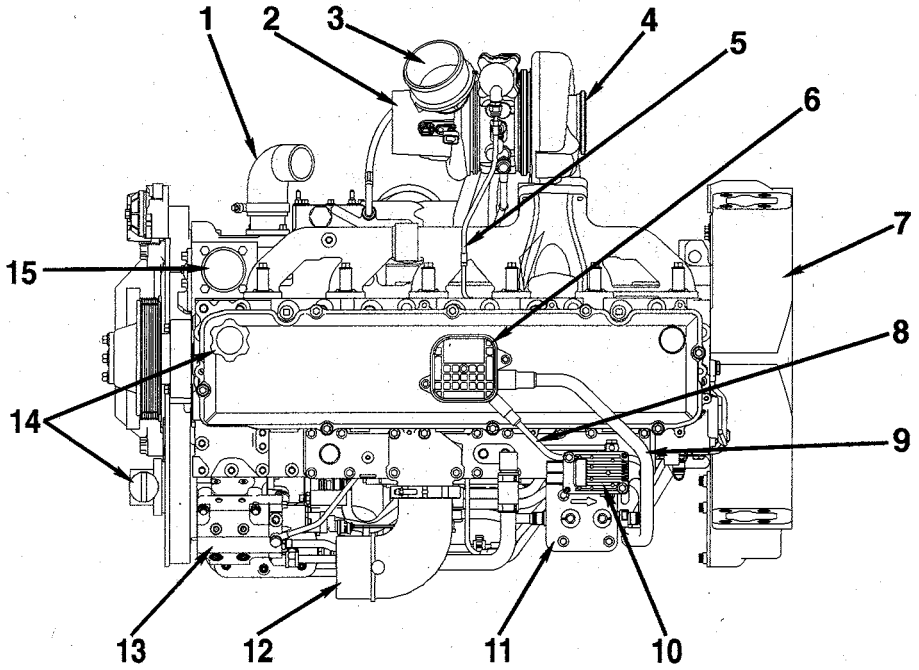
00d00133

Rear Engine View (CM850 Electronic Control Module)

1. Engine lifting bracket
2. Crankcase breather
3. Turbocharger (VGT shown)
4. Injector drain line connection
5. Flywheel housing
6. Flywheel
7. Engine oil drain plug
8. OEM fuel supply line connection
9. OEM fuel drain line connection
10. Air intake connection

Engine Diagrams

Engine Views

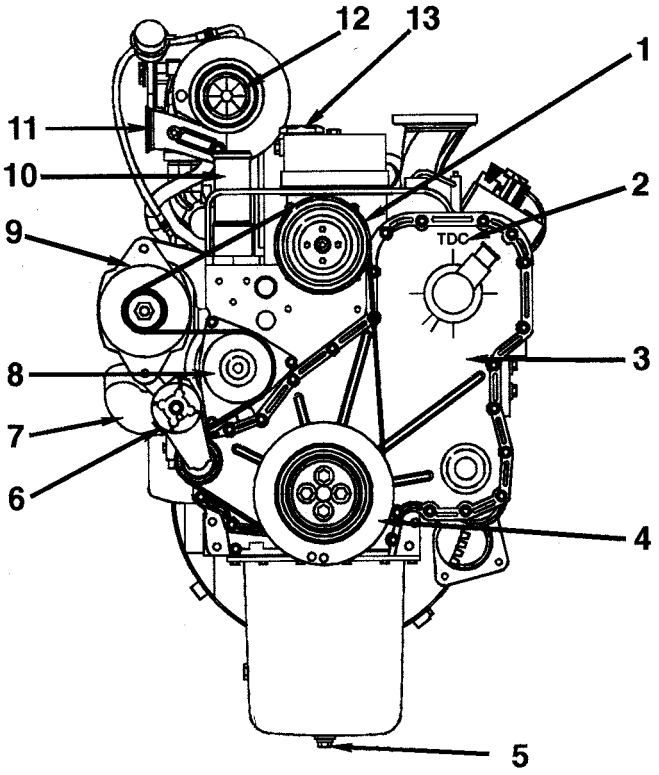


Top Engine View (CM850 Electronic Control Module)

1. Coolant inlet connection
2. Turbocharger air inlet
3. Turbocharger air outlet
4. Turbocharger exhaust outlet
5. Turbocharger actuator air line
6. Crankcase breather
7. Flywheel housing
8. Crankcase breather oil drain tube
9. Crankcase breather draft tube
10. Turbocharger control valve
11. Fuel filter bracket
12. Air inlet connection
13. High-pressure pump
14. Engine oil fill
15. Coolant outlet connection

Engine Diagrams

Engine Views



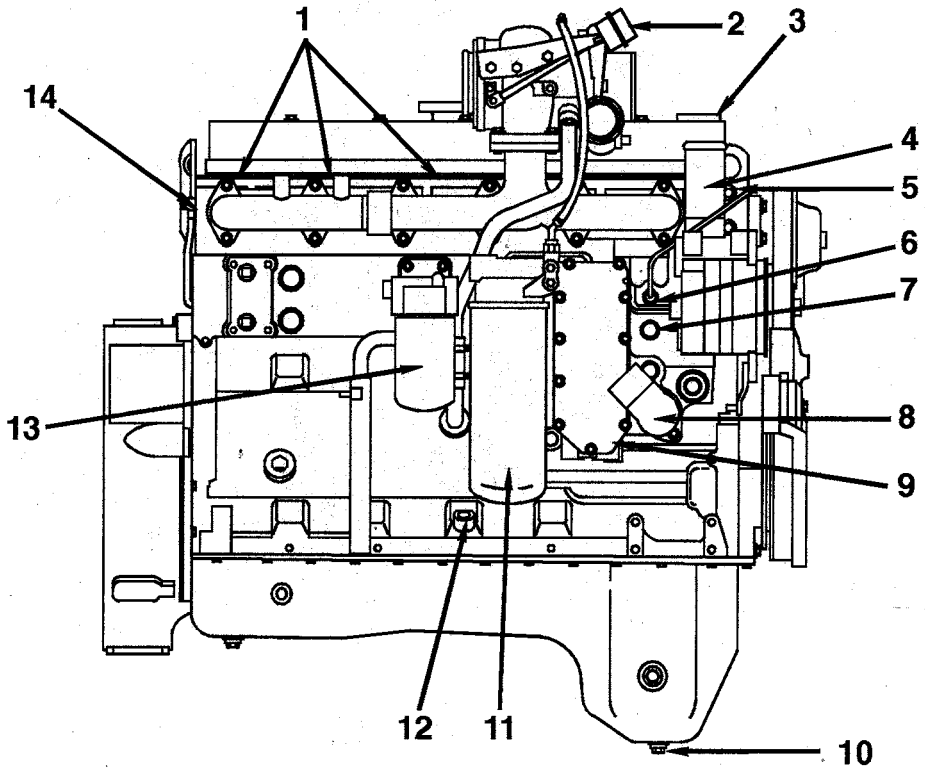
00900121

Front View (Without CM850 Electronic Control Module)

1. Fan pulley
2. Top dead center (TDC) mark
3. Front gear cover
4. Vibration damper
5. Engine oil pan drain plug
6. Automatic belt tensioner
7. Water inlet
8. Water pump
9. Alternator
10. Water outlet
11. Turbocharger air outlet
12. Turbocharger air inlet
13. Engine oil fill

Engine Diagrams

Engine Views

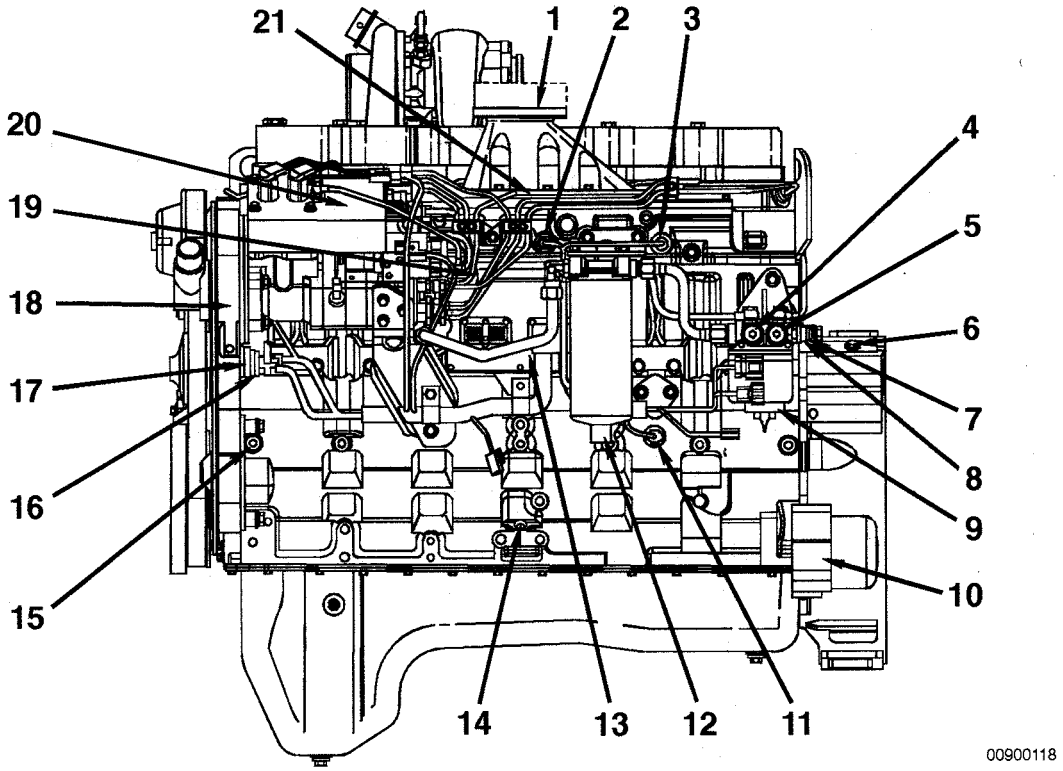


Exhaust Side View (Without CM850 Electronic Control Module)

1. 1/2-inch (NPTF) coolant taps
2. Turbocharger wastegate actuator
3. Engine oil fill
4. Coolant outlet
5. Front engine lifting bracket
6. Coolant temperature sensor
7. Coolant heater port
8. Coolant inlet
9. Lubricating oil cooler
10. Engine oil pan drain plug
11. Lubricating oil filter
12. Dipstick location
13. Coolant filter
14. Injector drain fuel outlet connection

Engine Diagrams

Engine Views

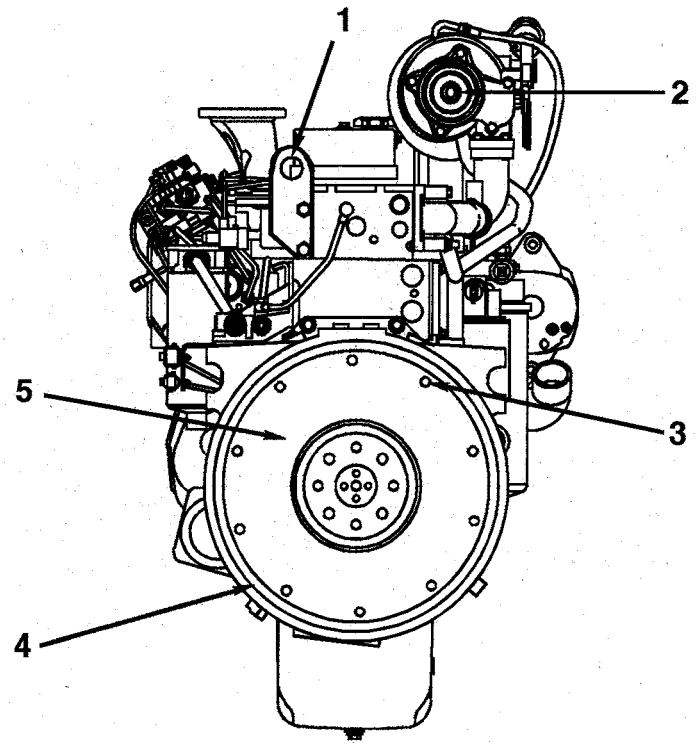


Fuel Pump Side View (Without CM850 Electronic Control Module)

1. Engine air inlet
2. Intake manifold pressure sensor
3. Intake manifold temperature sensor
4. M10 (STOR) fuel pressure after-lift pump
5. M10 (STOR) fuel pressure before-lift pump
6. Magnetic pickup location 3/4-16 UNF
7. Fuel return connection
8. Fuel inlet connection
9. Fuel lift pump
10. Starter mounting flange
11. Oil pressure sensor
12. Fuel filter/water separator
13. Electronic control module (ECM)
14. Dipstick location
15. M10 (STOR) oil pressure port
16. Engine position sensor (EPS) - (inboard)
17. Engine speed sensor (ESS) - (outboard)
18. Engine dataplate
19. High-pressure fuel lines
20. Cummins Acumulator Pump System (CAPS) injection pump
21. Intake air heater

Engine Diagrams

Engine Views



00900119

Rear View (Without CM850 Electronic Control Module)

1. Rear engine lifting bracket
2. Turbocharger exhaust outlet
3. Clutch mounting holes
4. Flywheel housing
5. Flywheel

Section F - Familiarization

Section Contents

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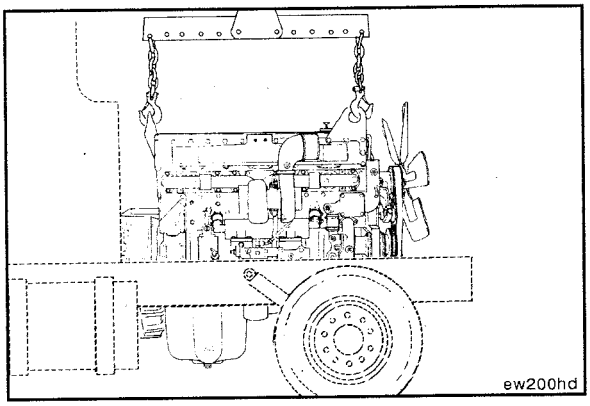
Complete Engine - Overview (000-999)

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.

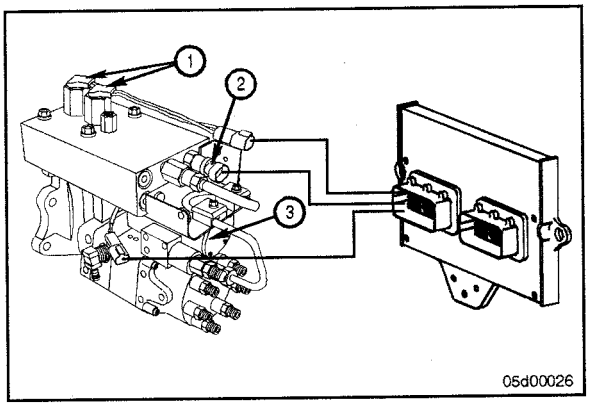


Fuel System - Overview (005-999)

General Information

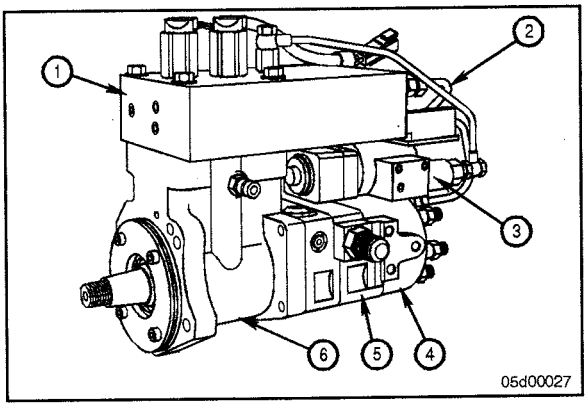
CAPS Fuel System

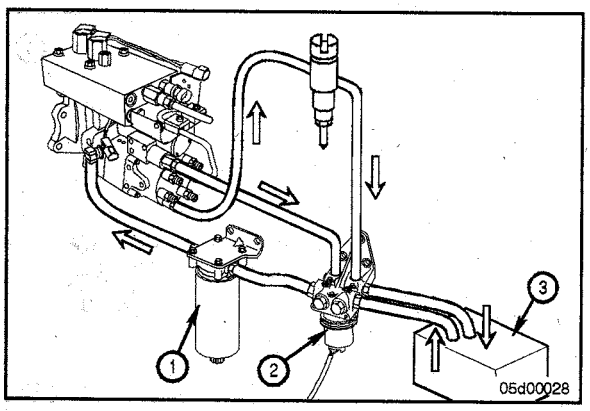
The CAPS fuel system is a distributor-type injection system. CAPS stands for Cummins Accumulator Pump System. An accumulator is used to store pressurized fuel for the injection event. There are four components that provide or receive input to the electronic control module (ECM). There are two pumping control valves (1) that are controlled by the ECM. These valves control the pressure in the accumulator. The accumulator fuel pressure/ temperature (2) sensor is located on the accumulator and provides the ECM with pressure and temperature information. The injection control valve (3) is also controlled by the ECM and regulates fuel injected into the cylinder.



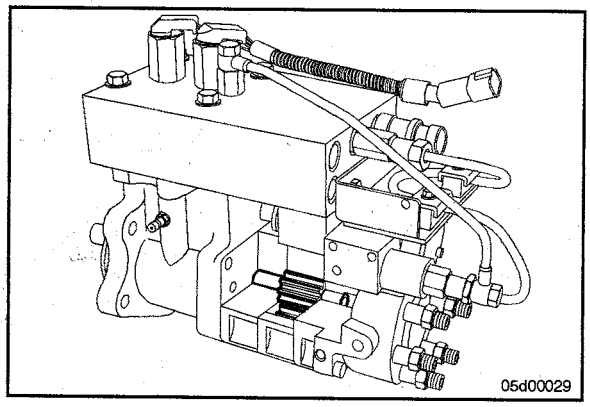
The CAPS injection pump can be divided into six distinct units/modules. They are the gear pump, cam housing, accumulator, rate shape tube, injection control valve (ICV), and distributor. Fuel flows through the modules in the following order:

gear pump - 5
cam housing - 6
accumulator - 1
rate shape tube - 2
injector control valve (ICV) - 3
distributor - 4.

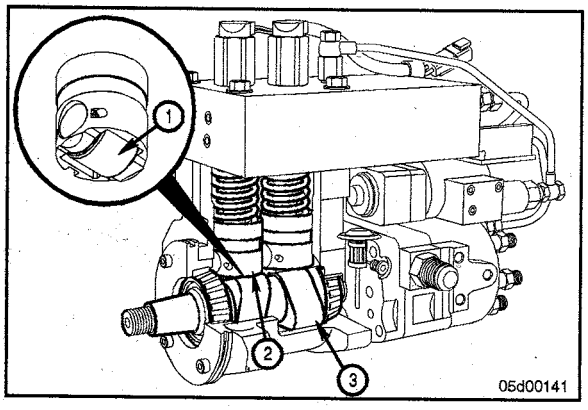




A lift pump is used for priming the pump at start-up. The lift pump runs for approximately 30 seconds after key-on. Once the engine is started, the gear pump is able to maintain prime without any assistance from the lift pump.

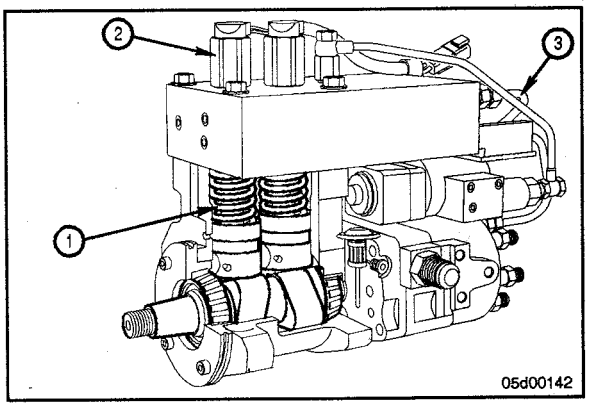


The gear pump supplies fuel to the pumping plungers through internal drillings in the cam housing. The gear pump also supplies fuel to the distributor for lubrication. The fuel pressure is regulated to approximately 160 psi at rated engine rpm. The gear pump has an internal filter to catch any debris generated downstream of the main, external fuel filter. The pump camshaft is driven off the engine camshaft; therefore, pump rpm is one-half engine rpm. The gear pump is driven by the pump camshaft through an internal coupling. The gear pump shaft then turns the distributor rotor through a second internal coupling.

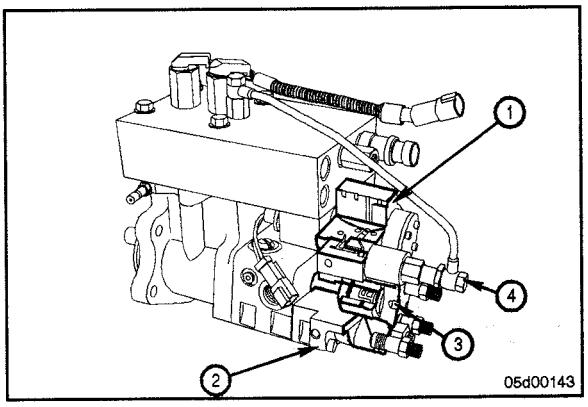


Each of the two pumping plungers is driven by a three lobed camshaft (3). The camshaft is located in the cam housing module by tapered roller bearings. The bearings that support the camshaft, as well as the tappets (2), rollers (1), and camshaft itself are lubricated with engine oil. These are the **only** components in the pump lubricated with engine oil.

A pumping control valve (2) is located above each pumping plunger (1). The supply fuel from the gear pump flows around the plunger of this normally open valve into the chamber above the plunger. The volume above each pumping plunger is filled, by the gear pump, as the plungers travel downward. As the plunger starts to move upward, the fuel is pushed backward into the gear pump. When the pumping control valve closes, the fuel is pushed into the accumulator and then held by check valves. The time when the pumping control valve is energized (closed) is based on engine speed, accumulator pressure, and throttle position. A 0- to 24,000-psi pressure sensor is located in the accumulator. The pressure sensor provides direct feedback to the ECM, so the desired accumulator pressure is maintained. This pressure sensor also has temperature sensing capabilities built into it. Fuel moves from the accumulator to the distributor and through the rate shape tube (3).

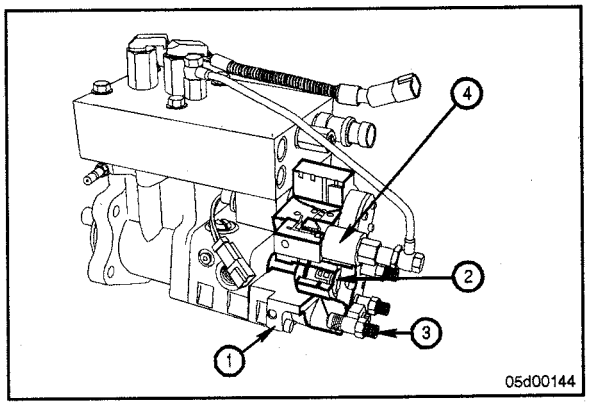


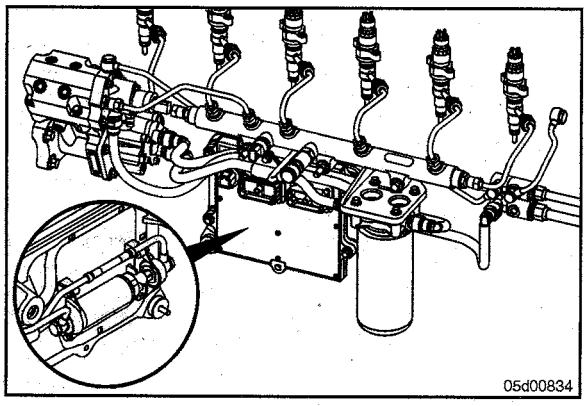
Fuel is delivered to the injection control valve (1) by the rate shape tube and through a drilling in the distributor (2). The ICV controls both fueling and timing. The injection control valve contains an inner pin and outer valve. The outer valve is moved by magnetic force generated inside the ICV by a current from the ECM. The inner pin is moved by spring force and fuel pressure. When the two pins are in the closed position, no fuel flows through the control valve. The position of these internal parts controls fuel flow to the distributor rotor (3) and to the drain (4). The injection control valve opens and closes once for each injection event.



The distributor (1) directs the fuel to the correct injector using the rotor. The drain fuel from the ICV is routed through the ICV pressure regulator (4) and is returned to the tank.

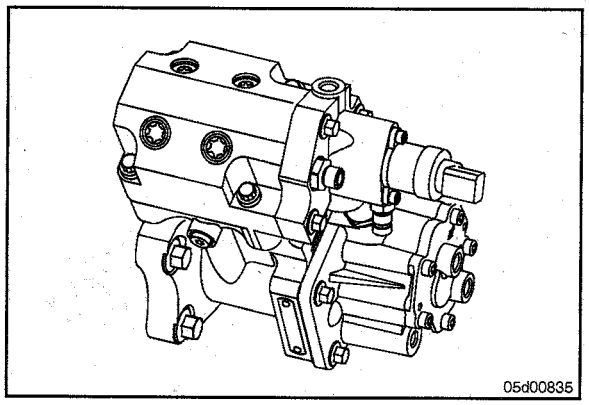
The position of the rotor directs the fuel to one of six drillings in the distributor housing. These drillings communicate the fuel to six fuel pump delivery valves (3). There is one injector line per delivery valve. The injection line carries the fuel to the injector.



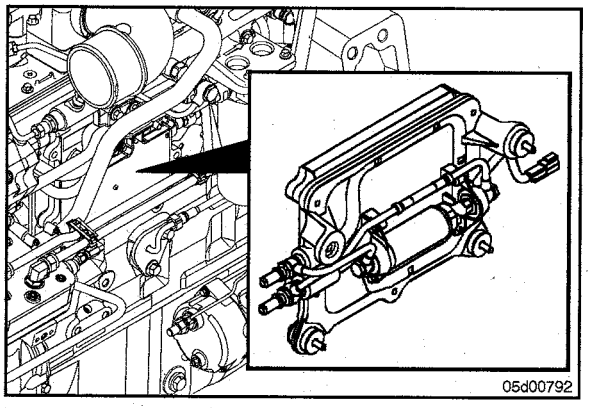


Cummins Common Rail Fuel System

The Cummins Common Rail Fuel System is a high-pressure common rail injection system. A fuel rail is used to store pressurized fuel for fuel injection. There are four components that provide or receive input to the electronic control module (ECM). The ECM powers the electric fuel lift pump (located behind the ECM) for approximately 30 seconds at key on to make sure the fuel system is primed. The normally open fuel pump actuator receives a PWM signal from the ECM to open or close in response to the signal from the fuel rail pressure. The injectors have individual solenoids. The ECM powers each injector individually to provide fueling to each cylinder.

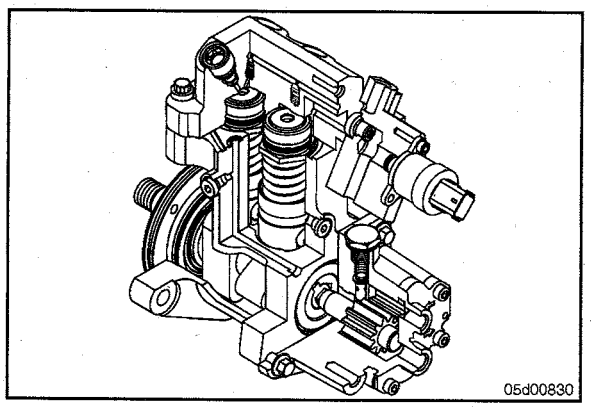


The high-pressure fuel pump can be divided into four distinct assemblies. They are the fuel gear pump, fuel pump actuator housing, cam housing, and high-pressure fuel pump head. Fuel flows through the gear pump to a 3-micron pressure side filter. After the pressure side filter, fuel enters the fuel pump actuator housing. The fuel pump actuator housing includes an air-bleed fitting and the fuel pump actuator. Some fuel continuously returns to drain through the air-bleed orifice fitting. Fuel that is metered through the fuel pump actuator enters the high-pressure fuel pump head where it is pumped to fuel rail pressure and exits at the high-pressure outlet fitting.



A lift pump is used for priming the pump at start-up. The lift pump runs for approximately 30 seconds after key on. Once the engine is started, the gear pump is able to maintain prime without any assistance from the lift pump.

The ECM and ECM cooling plate **must** be removed for access to the lift pump and lift pump fuel lines. This is accomplished by disconnecting the engine harnesses and the quick disconnect style fuel lines first. Removal of the ECM cooling plate capscrews allows the ECM, cooling plate, lift pump and lift pump plumbing to be removed as one assembly.

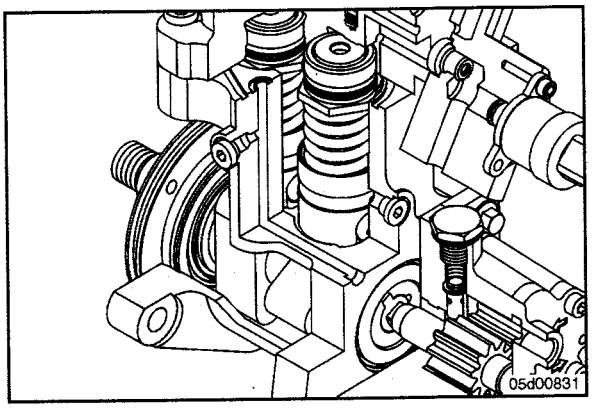


The gear pump output is routed to a 2-micron fuel filter. The filtered fuel returns to the fuel pump actuator housing.

The high-pressure pump is driven by the engine camshaft. The gear pump is driven by the pump camshaft through an internal coupling.

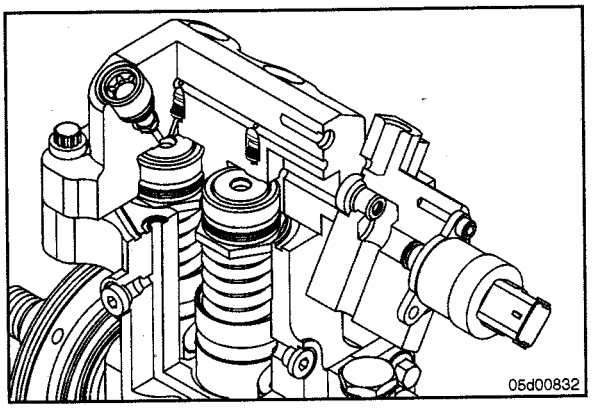
Each of the two pumping plungers is driven by a three lobed camshaft. The camshaft is located in the cam housing module by tapered roller bearings. The bearings that support the camshaft, as well as the tappets, rollers and camshaft itself are lubricated with engine oil. These are the only components in the pump lubricated with engine oil.

Engine oil to the high-pressure pump is supplied through a drilling in the engine gear housing. The oil passes from the engine gear housing to the high-pressure pump cam housing. A small o-ring in a recess on the back of the engine gear housing is used to seal this passage.

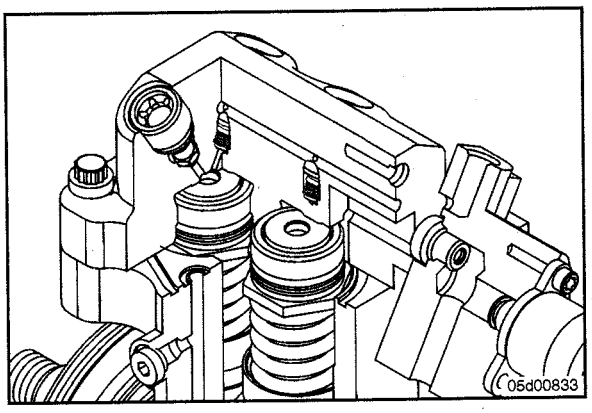


Pressurized fuel from the gear pump is supplied to the fuel pump actuator. The fuel pump actuator is opened or closed by the ECM to maintain the appropriate fuel rail pressure.

An air-bleed orifice fitting in the fuel pump actuator housing aids in purging air from the fuel supply. Because of the air-bleed orifice fitting, some fuel that is supplied by the gear pump will return to drain at all times.

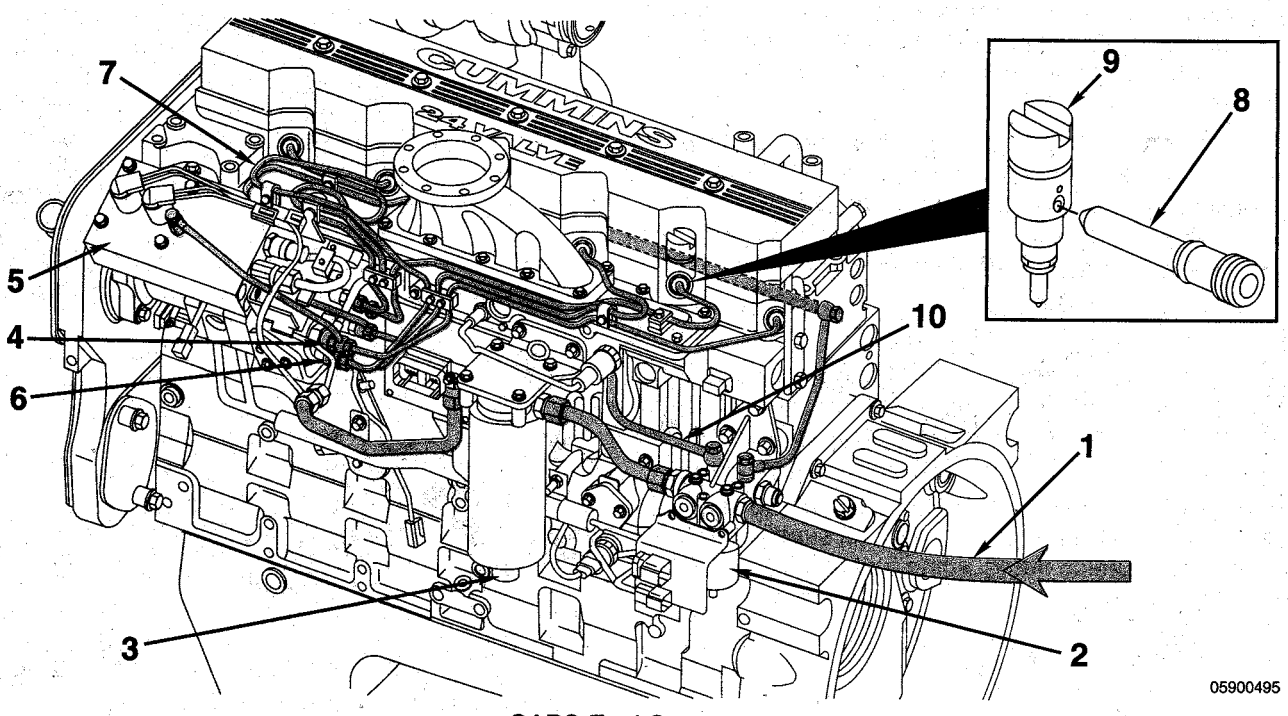


Fuel that is metered past the fuel pump actuator will enter inlet drilling in the high pressure fuel pump inlet drilling and pass the inlet check valve and fill the pumping chamber by pressing the pumping plunger downward. When the camshaft pushes the pumping plunger upward, fuel will reach rail pressure and cause the outlet check valve to lift. Fuel will then enter the outlet drilling of the fuel pump and exit the high pressure fuel line to the fuel rail.



Flow Diagram, Fuel System

General Information

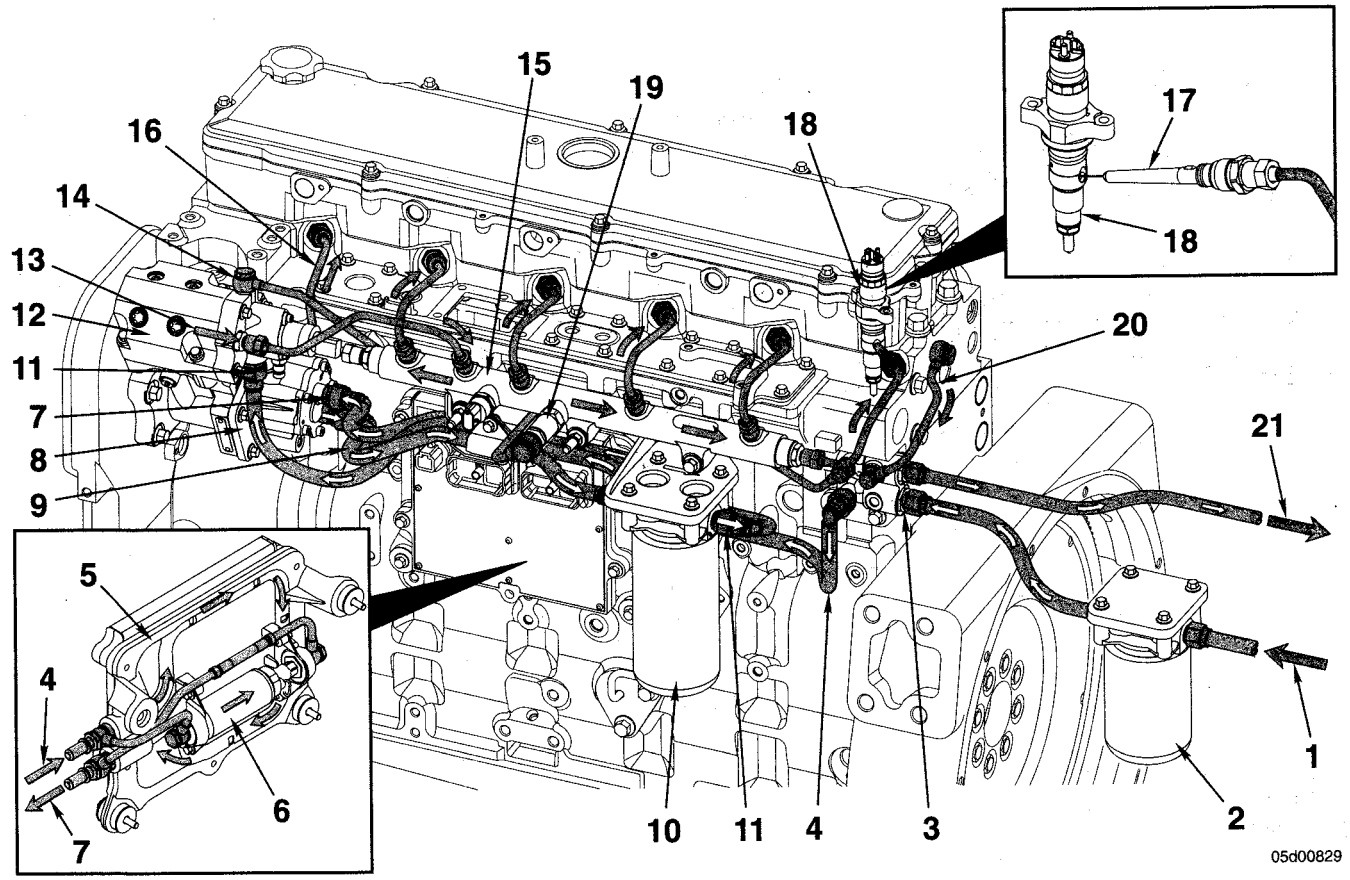


CAPS Fuel System

1. Fuel from supply tank
2. Electronic lift pump
3. Fuel filter and water separator
4. Fuel drain line
5. CAPS injection pump
6. Distributor outlet fitting
7. High-pressure supply lines
8. Fuel connector
9. Injectors
10. Fuel return to supply tank

Flow Diagram, Fuel System

General Information

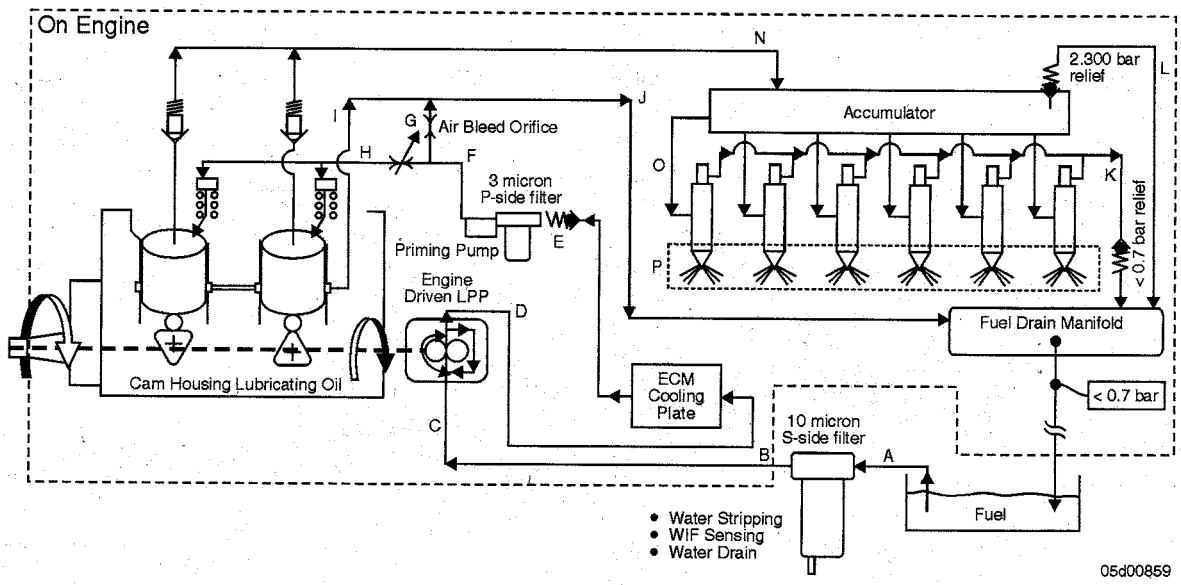


Cummins Common Rail Fuel System

1. Fuel from supply tank
2. Fuel filter and water separator
3. OEM fuel supply connection
4. Fuel supply to ECM mounted fuel lift pump
5. ECM cooling plate
6. ECM mounted fuel lift pump
7. Fuel outlet from ECM mounted fuel lift pump
8. Fuel gear pump
9. Fuel from gear pump to fuel filter
10. Primary fuel filter
11. Fuel inlet to fuel pump actuator
12. High-pressure fuel pump
13. Fuel outlet from high-pressure pump
14. High-pressure pump drain flow connection
15. Fuel rail
16. High-pressure injector supply lines
17. High-pressure fuel connector
18. Fuel injector
19. Fuel pressure relief valve
20. Fuel injector drain flow line
21. Fuel return to supply tanks

Flow Diagram, Fuel System

General Information



Cummins Common Rail Fuel System

Injectors and Fuel Lines - Overview (006-999)

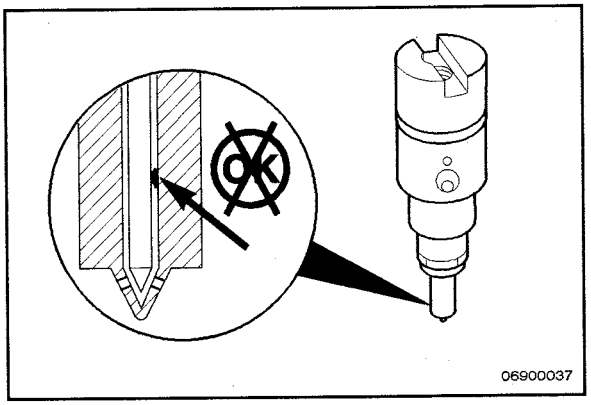
General Information

CAPS Fuel System

⚠WARNING⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

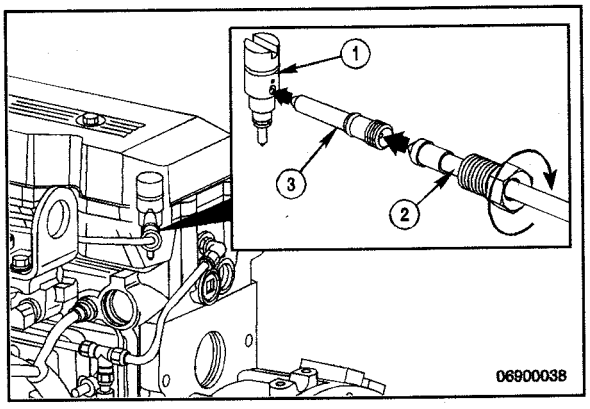
Injectors used in the ISC and ISL engines have hole type nozzles. High pressure fuel flows into the side of the injector and causes the needle to lift and fuel to be injected. The clearances in the nozzle bore are extremely small and any sort of dirt or contaminants will cause the injector needle valve to stick. This is why it is important to clean the area around any fuel connection before servicing it. Also, cap or cover any open fuel connections before a fuel system repair is performed.



High pressure fuel is supplied to the injector (1) from the fuel pump via an injector supply line (2) and a fuel connector (3). The end ferrule on the injector supply line pushes against the fuel connector when the fuel line nut is torqued in the cylinder head. This force provides the sealing pressure between both the injector supply line to the fuel connector and the connector to the injector.

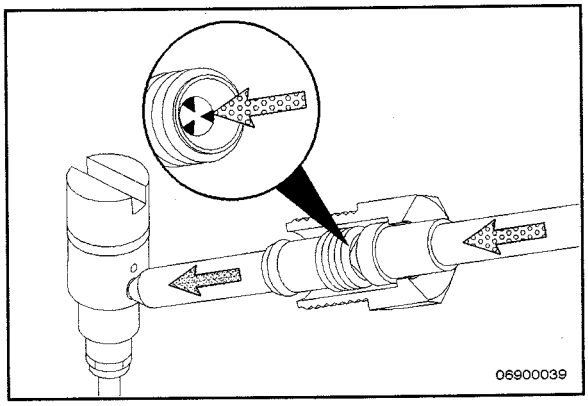
The torque on this line is critical. If the nut is under torqued, the surfaces will **not** seal and a high pressure fuel leak will result. If the nut is over torqued, the connector and injector will deform and also cause a high pressure leak. The leak may result in an injector misfire and low power.

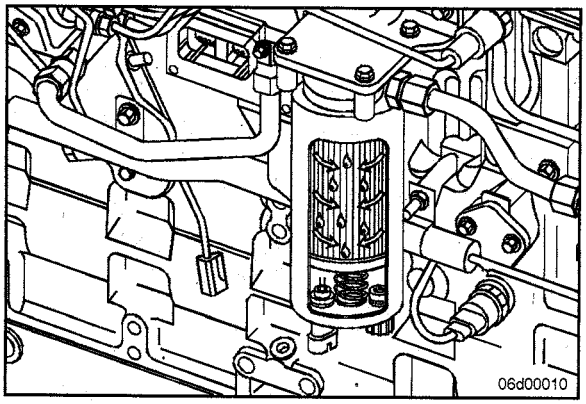
Always lubricate the threads of the high pressure line nuts with engine oil before tightening. Always make sure the proper torque is used on the high pressure line nuts.



The fuel connector contains an edge filter that breaks up small contaminants that enter the fuel system. The edge filter uses the pulsating high pressure to break up most particles so they are small enough to pass through the injector.

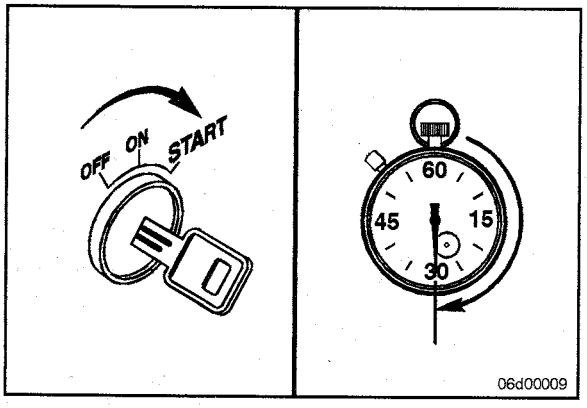
NOTE: The edge filters are **not** a substitute for cleaning and covering all fuel system connections during repair. Edge filters are **not** a substitute for maintaining the recommended engine mounted fuel filter.



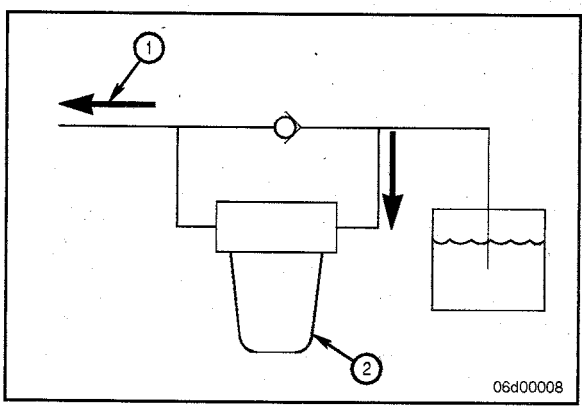


The fuel filter is a spin-on type.

Fuel flows around the outside of the filter and back up through the middle. The filtering media is a 10 micron Stratapore™ design for efficient debris removal. The filter also strips the water and collects it at the bottom of the filter to be drained daily.



The ISC and ISL lift pump will run for 30 seconds after the key is switched on to assist with fuel priming. The lift pump will run during cranking and while the engine is running until the 30 seconds has lapsed. The lift pump will shut off anytime the key is switched "OFF". The 30 second timer is reset after each key switch cycle and ECM power down.



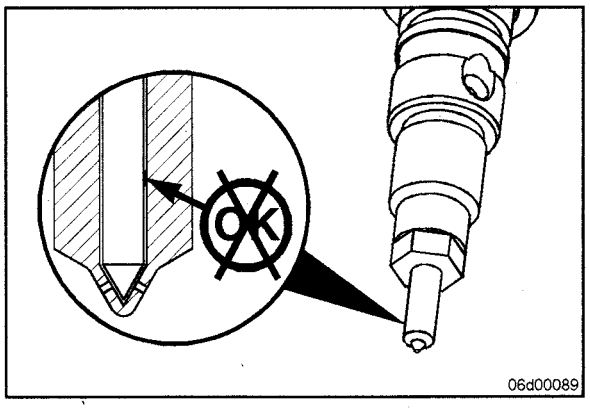
Once the engine is started, additional fuel is drawn through the lift pump head via the gear pump. A valve in the head opens when the gear pump requires more flow than the lift pump can provide or when the lift pump is shut off.

Cummins Common Rail Fuel System

⚠WARNING⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

High-pressure common rail fuel systems use solenoid-actuated injectors. High-pressure fuel flows into the side of the injector. When the solenoid is activated, an internal needle lifts and fuel is injected. The clearances in the nozzle bore are extremely small and any dirt or contaminants will cause the injector to stick. This is why it is important to clean around all fuel connections before servicing the fuel system. Also, cap or cover any open fuel connections before a fuel system repair is performed.

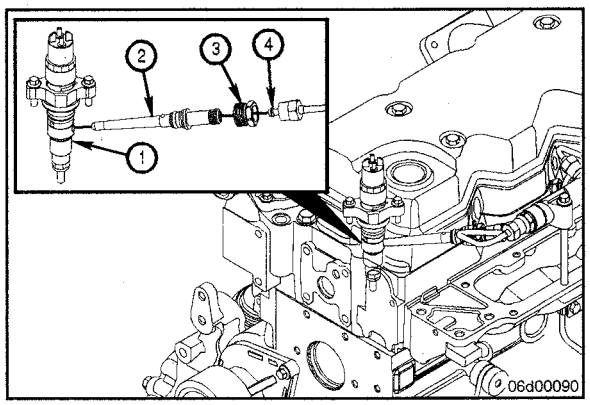


△CAUTION△

To reduce the possibility of engine damage, always use the proper torque on the high-pressure line nuts.

High-pressure fuel is supplied to the injector from the fuel rail by an injector supply line and a fuel connector. The fuel connector pushes against the injector body when the fuel connector nut is tightened. The injector supply line is then connected to the fuel connector.

The torque and sequence for this joint is critical. If the nut or line is undertightened, the surfaces will **not** seal and a high-pressure fuel leak will result. If the nut is overtightened, the connector and injector will deform and cause a high-pressure fuel leak. This leak will be inside the head and will **not** be visible. The result will be a fault code, low power, or no-start.

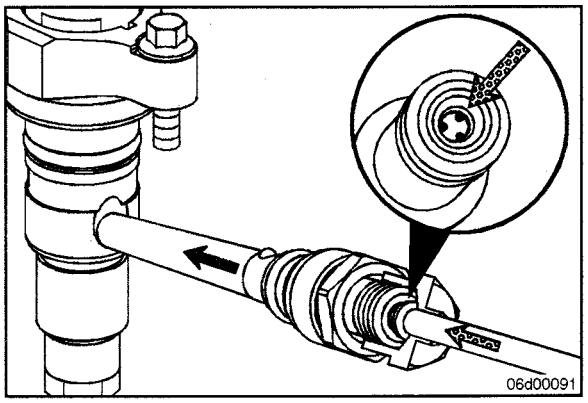


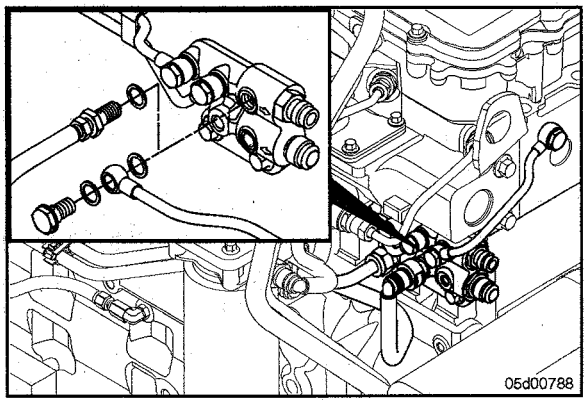
If the injector is **not** fully seated prior to the installation of the high-pressure connector, the joint will **not** seal.

The fuel connector contains an edge filter that breaks up small contaminants that enter the fuel system.

NOTE: The edge filters are **not** a substitute for cleaning and covering all fuel system connections during repair.

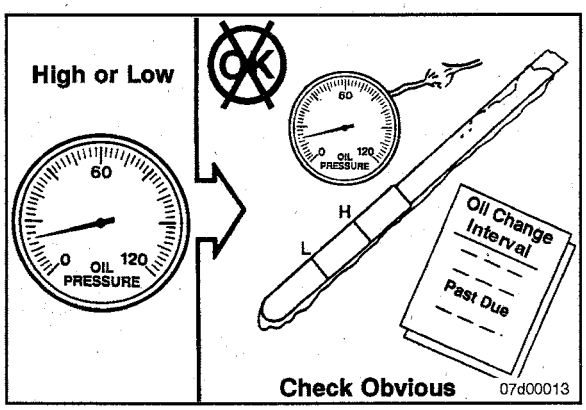
NOTE: Be sure to cap or cover all fuel fittings and ports.





All injectors feed into a common return drilling contained within the cylinder head. Any excess fuel is returned to the tank via this drilling and return line attached to the rear of the cylinder head. A back-pressure valve is located on the back of the cylinder head where the drain line attaches.

The electronic control module (ECM) controls the fueling and timing of the engine by actuating the injector solenoids. An electronic pulse is sent to the solenoids to lift the needle and start the injection event. By electronically controlling the injectors, there is a more precise and accurate control of fueling quantity and timing. Also, multiple injection events can be achieved by electronically controlling the injectors.

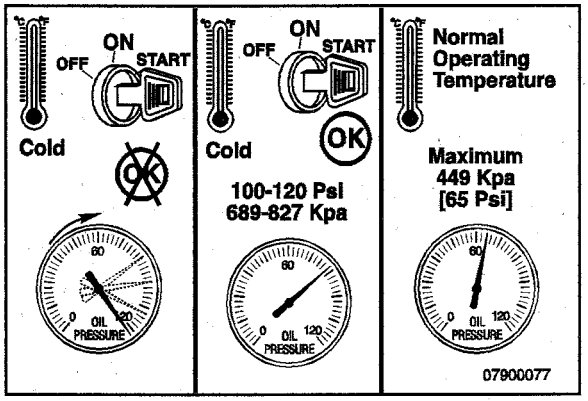


Lubricating Oil System - Overview (007-999)

General Information

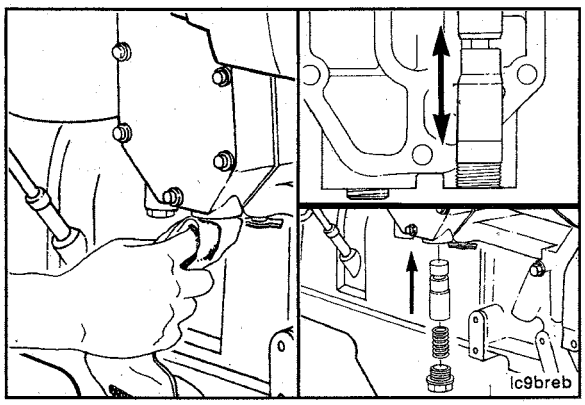
Diagnosing Lubricating System Malfunctions

When diagnosing lubrication system malfunctions, check all obvious items related to oil pressure, such as gauges, high and low oil level, excessive oil contamination, and oil viscosity.



High Lubricating Oil Pressure

High oil pressure usually occurs after the engine is first started in cold weather. Cold start oil pressure typically will be approximately 827 to 1034 kPa [120 to 150 psi]. If the pressure regulator plunger is operating properly, then the oil pressure should drop back to approximately 449 kPa [65 psi] when normal operating temperature is reached.

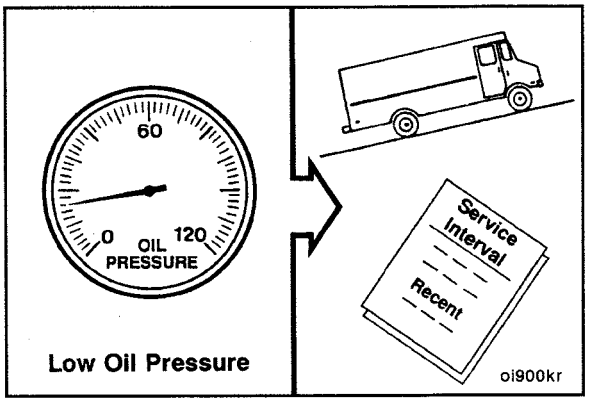


Lubricating Oil Pressure Regulating Valve

The engine will have high oil pressure at the normal operating temperature if the regulator sticks in the closed position. Check the regulator for freedom of movement. Refer to Procedure 007-029.

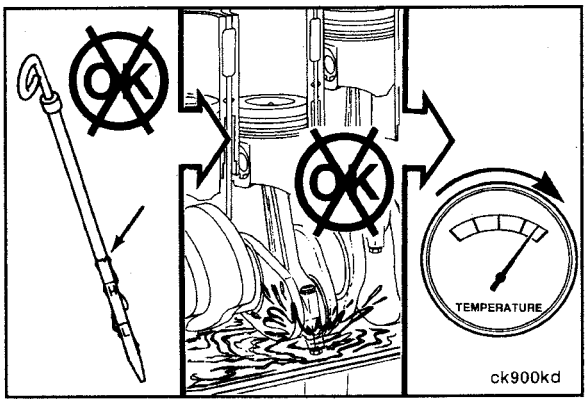
Low Lubricating Oil Pressure

Low lubricating oil pressure (or no oil pressure) can be caused by several lubrication system-related malfunctions. To begin the investigation, determine the engine operating conditions when the low pressure was first observed; for example, following a service interval, at idle **only**, or while operating on a steep grade.

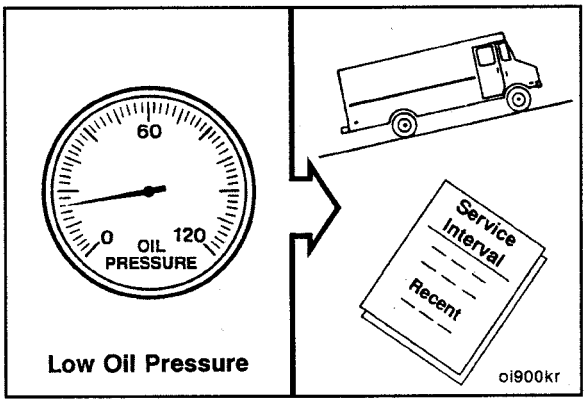


Lubricating Oil Level

High oil level can cause low oil pressure. If the oil level is high enough for the connecting rods to dip into during operation, the oil can become aerated. This will result in low oil pressure and high engine temperature.

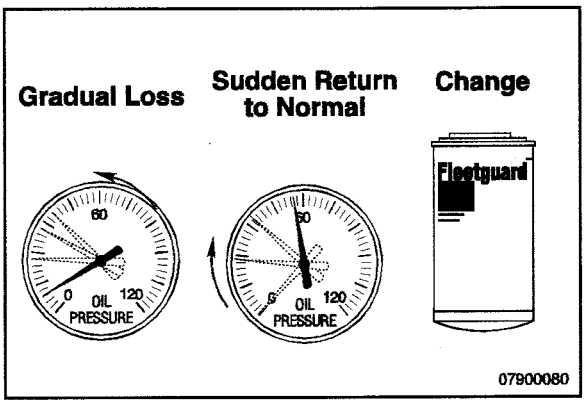


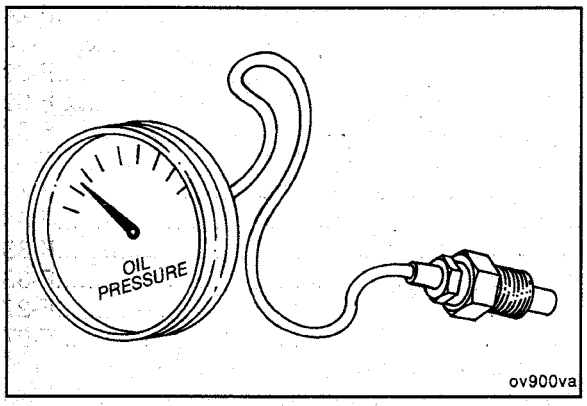
Low lubricating oil level will **not** normally appear as low oil pressure. Typically, it will appear as an intermittent loss of oil pressure when rounding a corner or operating on a steep grade. This condition exists when the oil level is extremely low and the suction tube can **not** pick up oil during all modes of operation.



Lubricating Oil Filter

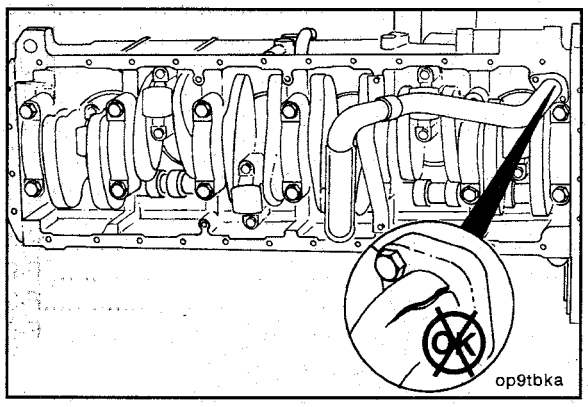
A plugged filter will cause a gradual loss of oil pressure by approximately 69 kPa [10 psi]. The pressure will return to normal when the filter bypass valve opens. If **not** corrected, this will result in severe engine wear, as the engine is running on unfiltered oil when the bypass valve is open.





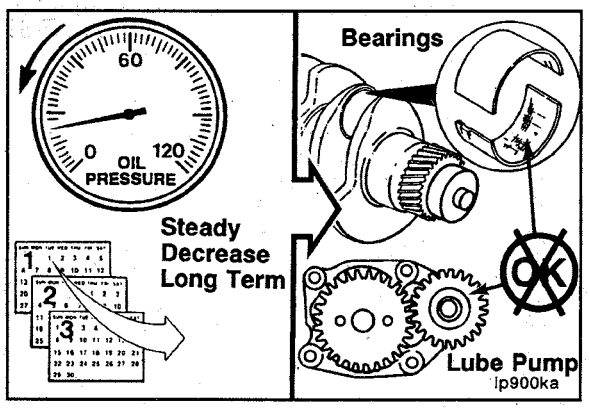
Lubricating Oil Gauge

Check the lubricating oil gauge and sending unit to make sure they are operating correctly by verifying the pressure with a manual gauge.



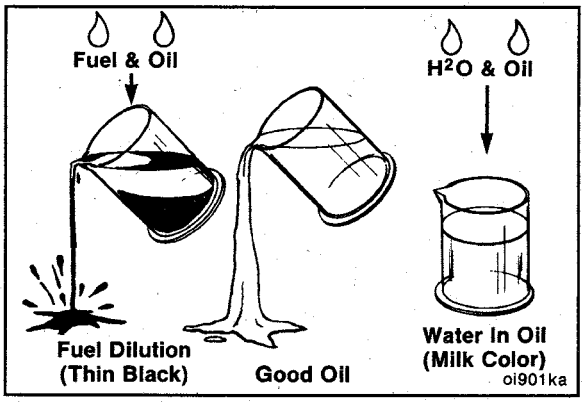
Lubricating Oil Suction Tube

A loose suction tube, damaged gasket, or crack in the suction tube can cause a temporary loss of prime for the oil pump. The engine will have low pressure or no oil pressure at starting, followed by normal oil pressure.



Bearings and Lubricating Oil Pump

A steady decrease in oil pressure over a long period can be an indication of worn bearings or excessive oil pump wear.



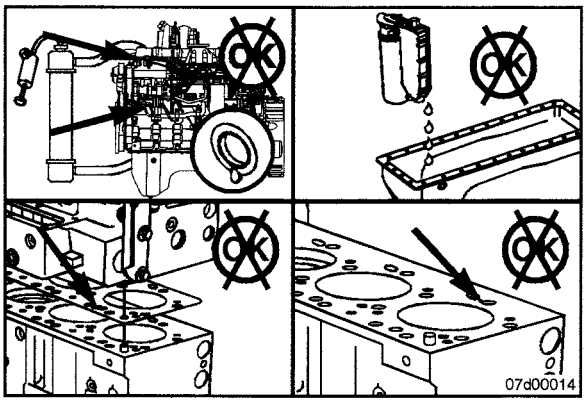
Lubricating Oil Dilution

Check the condition of the lubricating oil.

- Thin, black lubricating oil is an indication of fuel in the lubricating oil.
- Milky discoloration is an indication of coolant in the lubricating oil.

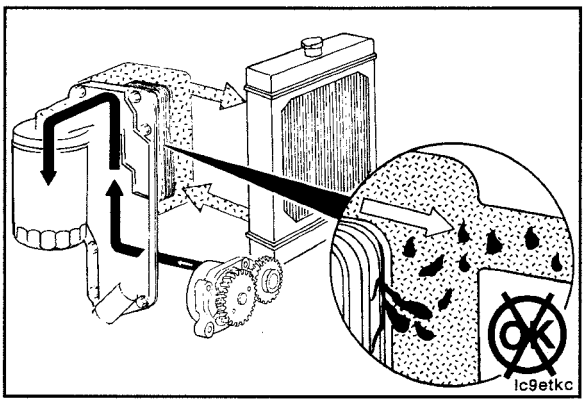
Coolant in the oil can be caused by:

- Expansion plugs that are leaking
- Lubricating oil cooler element that is leaking
- Damaged cylinder head or gasket
- Cracked engine block
- Casting porosity.



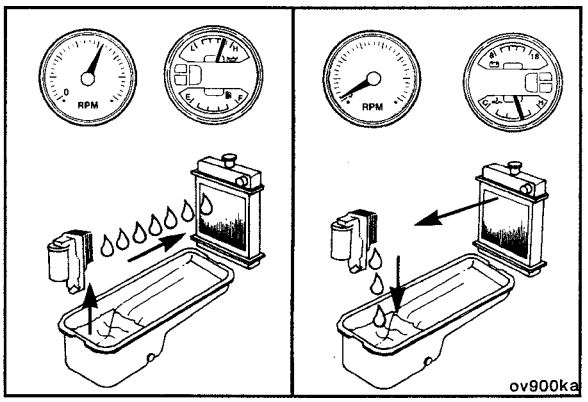
Coolant-Diluted Lubricating Oil

Since the lubricating oil cooler design does **not** require gaskets or seals to maintain the separation of oil and coolant, the element itself **must** leak to allow mixing of the fluids. Refer to Procedure 007-003.



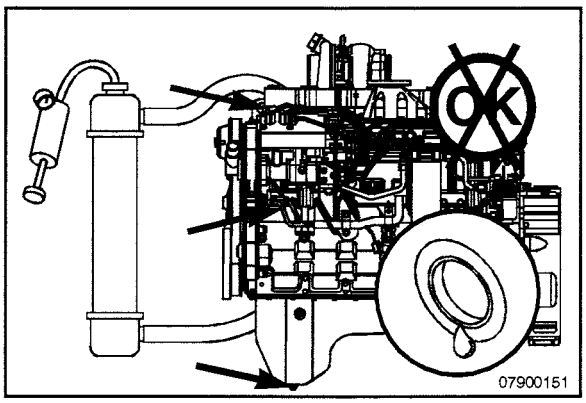
During operation, the lubricating oil pressure will be higher than coolant pressure. A leak in the lubricating oil cooler will appear as lubricating oil in the coolant.

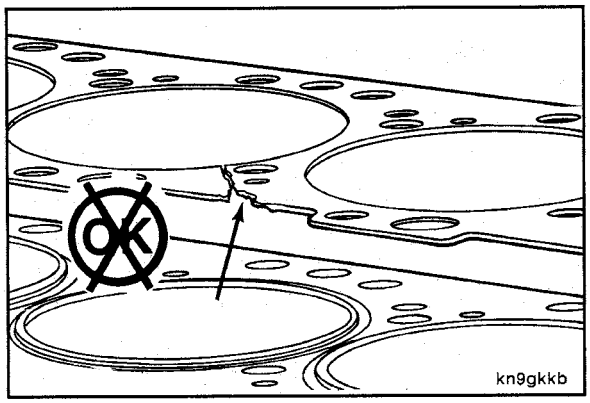
However, following an engine shutdown, the residual pressure in the coolant system can cause coolant to seep through the leak path into the lubricating oil.



To check for leaks, pressurize the cooling system to 140 kPa [20 psi]. With the system pressurized, remove the following components, and inspect for leaks:

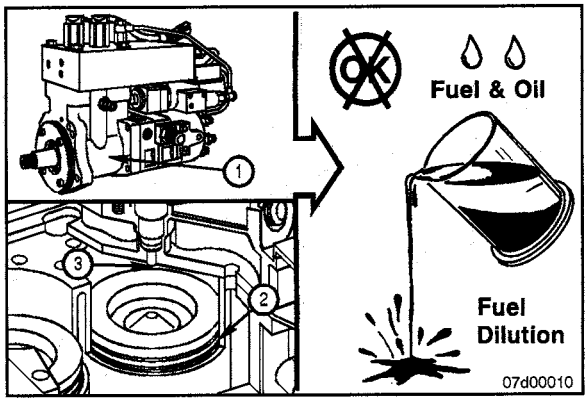
- Valve covers (leaks indicate cracked head)
- Lubricating oil drain plug (leaks indicate defective lubricating oil cooler, head gasket, cracked head, or block).





Coolant in the lubricating oil can be caused by a damaged cylinder head gasket or cracked cylinder head or block.

Remove the cylinder head and gasket, and inspect for cracks or damage. Refer to Procedure 002-004.



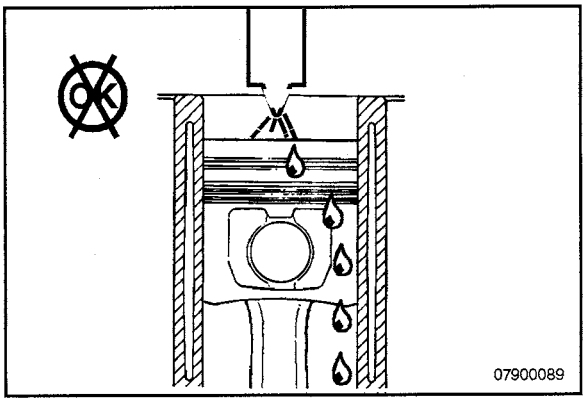
Fuel-Diluted Lubricating Oil

Use the following logic to determine the source of the oil dilution with fuel.

Fuel dilution is limited to three sources:

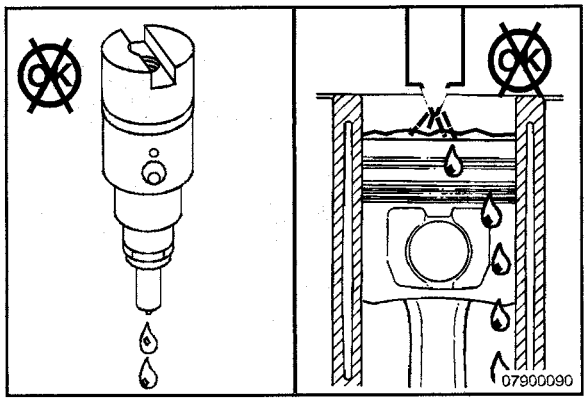
- Injection pump cam housing
- Fuel leaking by the rings
- Injector leakage.

A cracked cam housing can cause fuel to leak into the gear housing and then into the lubrication oil pan.



Incomplete combustion in the cylinders can result in unburned fuel draining into the oil pan.

This condition can be caused by a leaking injector or reduced compression caused by inadequate piston ring sealing.



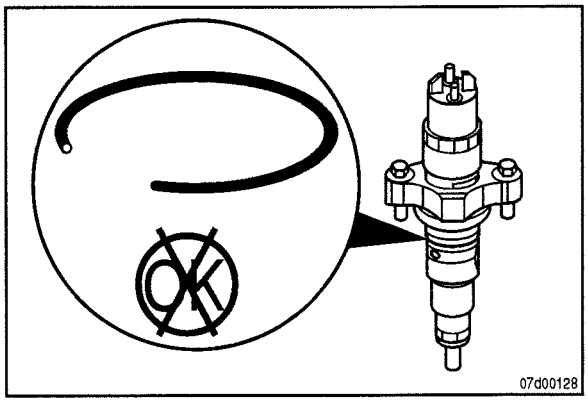
An increase in white exhaust smoke during the first start of the day is a symptom that an injector is leaking.

An injector leak will also cause the engine to run rough and have low power.

Remove, repair, or replace leaking injectors. Refer to Procedure 006-026, for test and repair instructions.

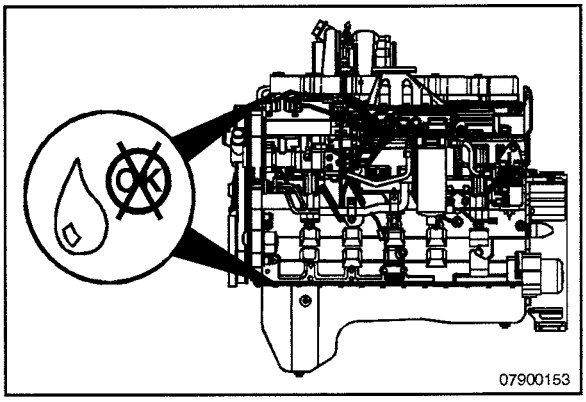
The o-rings in the injectors should be inspected for cracks or wear. A missing or damaged o-ring in an injector can result in improper injection of fuel into the cylinder.

Also, a poor seal between the injector and the high-pressure transfer tube can also cause the injector o-rings to fail or leak into the top of the cylinder head.



Lubricating Oil Leaks

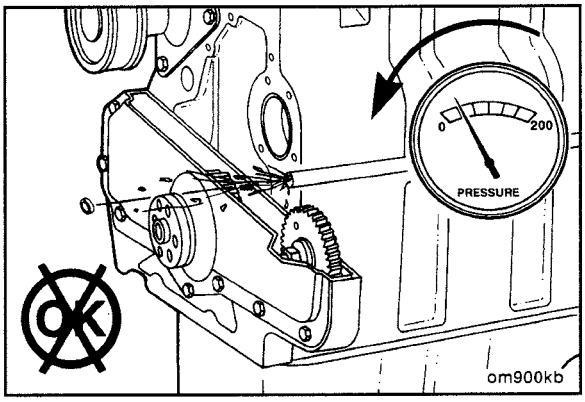
Various gaskets, seals, and plugs are used to contain the lubricating oil. Most leaks can be identified during routine inspection of the engine and vehicle.



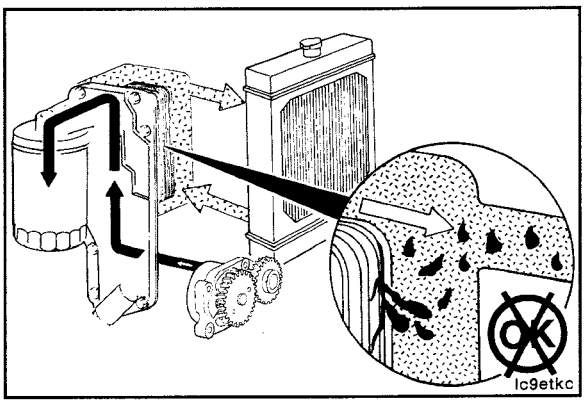
A blown expansion plug can allow a relatively large quantity of lubricating oil to escape, resulting in a sudden drop in the lubricating oil pressure.

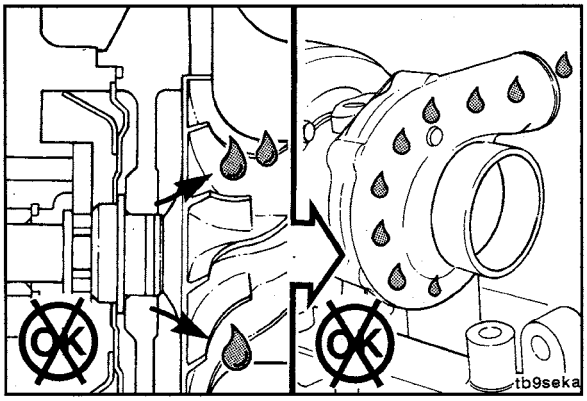
When checking for such a leak, be sure to check all expansion plugs that can obscured by chassis parts.

Lubricating oil blowing out of the breather is a sign of a blown expansion plug.



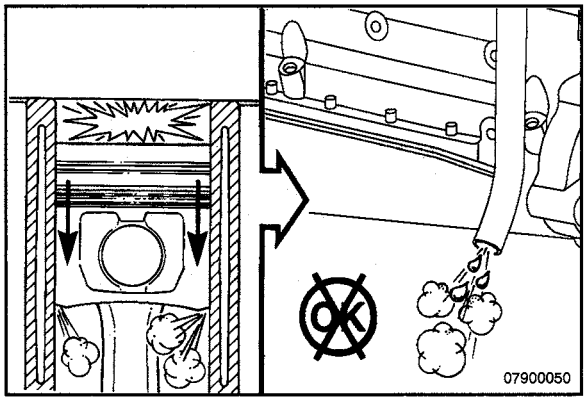
If the lubricating oil cooler element ruptures, the lubricating oil pressure can force lubricating oil into the cooling system. Lubricating oil in the coolant should be visible when the radiator cap is removed. Refer to Procedure 007-003.



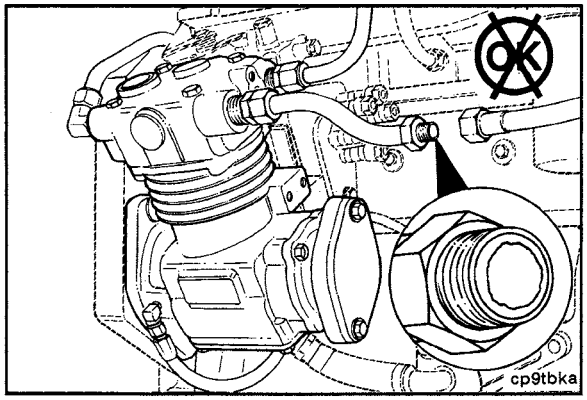


Worn or damaged seals in the turbocharger can also allow lubricating oil to leak into the air crossover pipe and be burned in the engine.

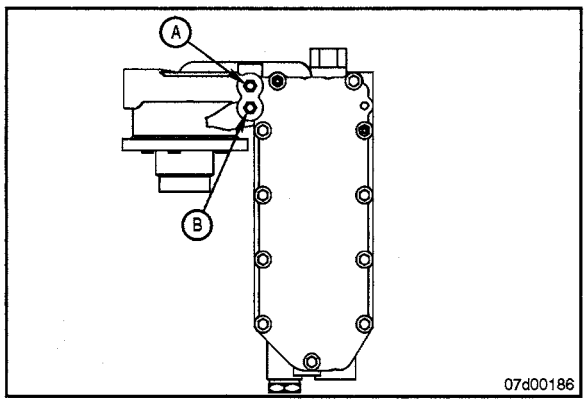
The condition can be verified by removing the air crossover tube or charge air cooler tubing and looking for oil.



Inadequate sealing of the piston rings will result in lubricating oil being blown out the breather tube and/or consumed by the engine. Refer to Procedure 014-002.



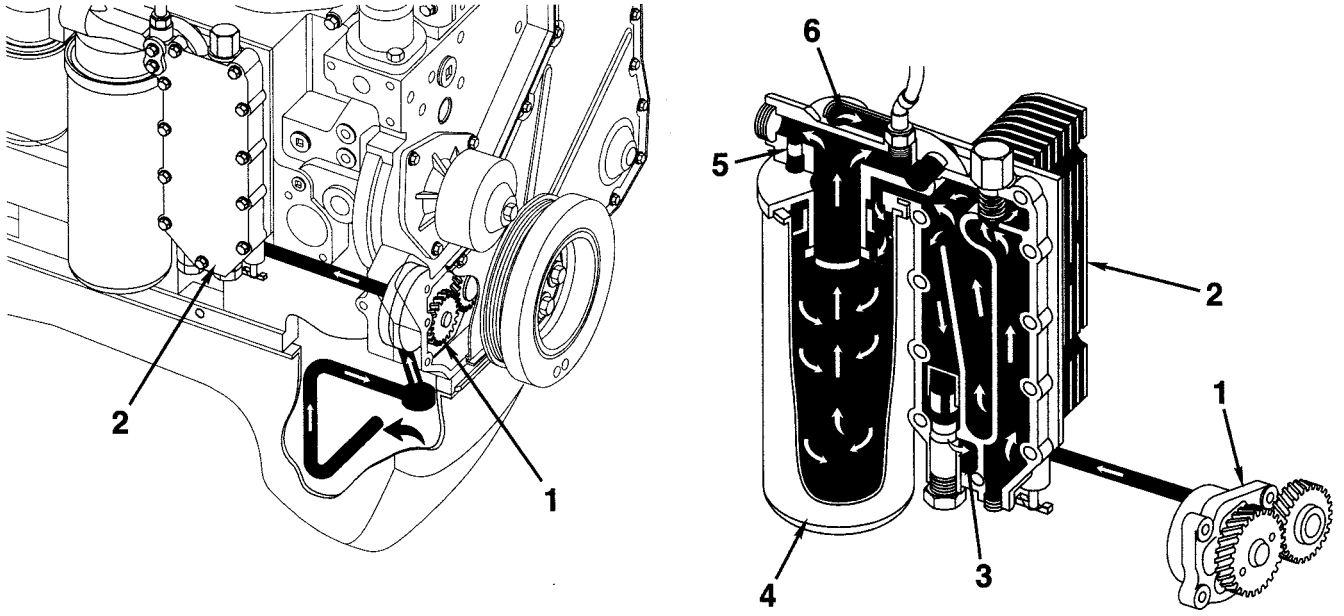
Lubricating oil can also be lost through a worn or malfunctioning air compressor. Look for carbon buildup in the air line from the compressor to the air tank. Also, a failed air compressor head or head gasket can allow oil to leak into the coolant, or coolant to leak into the oil, during hot shutdown.



The lubricating oil cooler contains two ports for measuring oil pressure or recording oil pressure drop across the lubricating oil filter. The top port is after the lubricating oil filter, filtered oil pressure port (A). The bottom port is before the lubricating oil filter, unfiltered oil pressure port (B).

Flow Diagram, Lubricating Oil System

General Information



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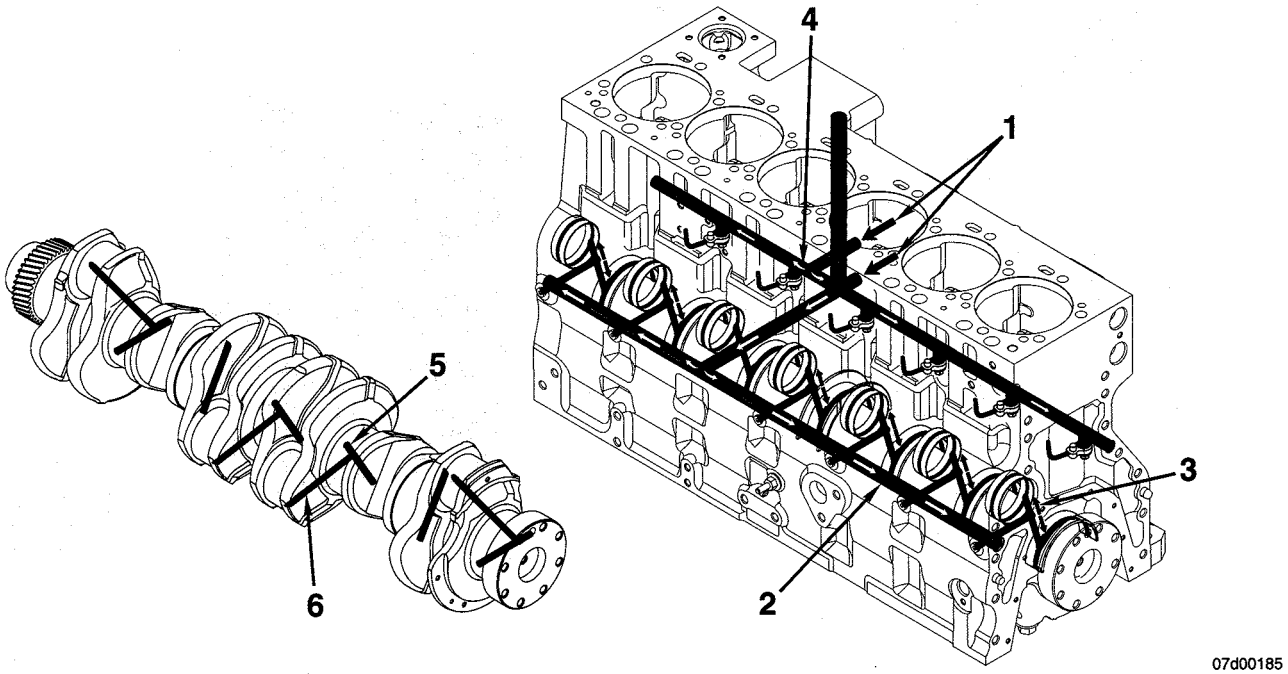
Lubricating Oil Cooler Flow

1. Gerotor lubricating oil pump
2. Lubricating oil cooler
3. To lubricating oil pan
4. Full flow lubricating oil filter
5. Filter bypass valve
6. From lubricating oil filter

Flow Diagram, Lubricating Oil System

General Information

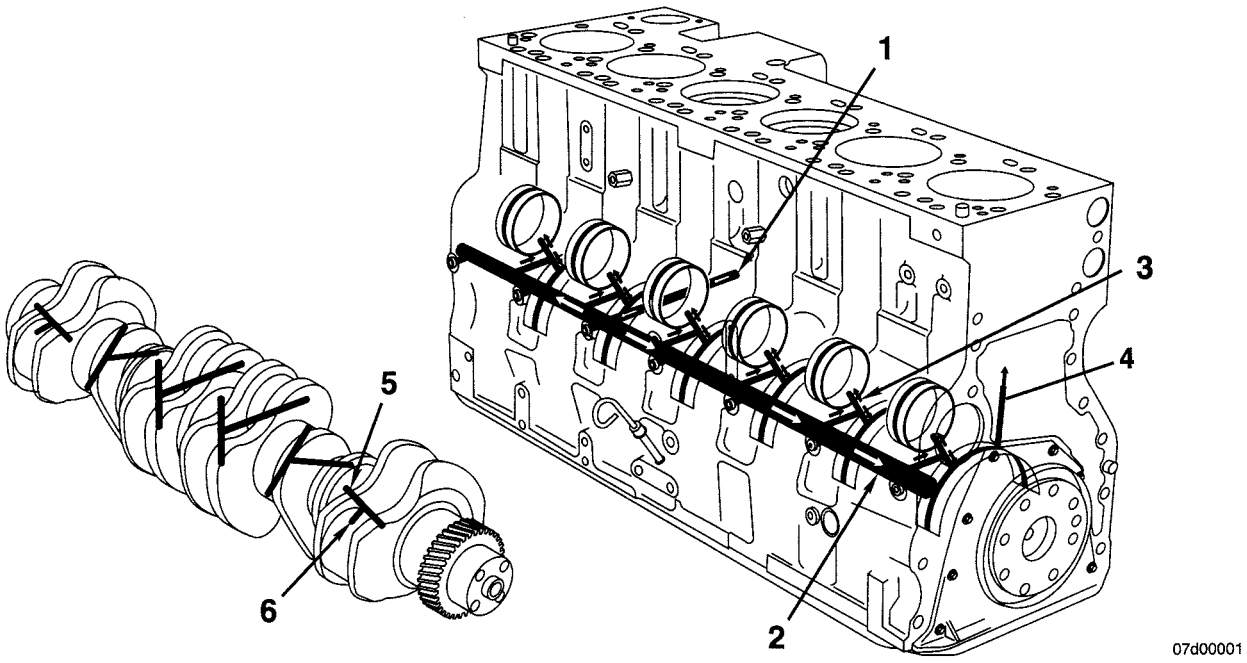


Lubrication for Power Components (All ISL engines and ISC engines with CM850 Electronic Control Module)

1. From lubricating oil cooler
2. Main lubricating oil rifle
3. To camshaft
4. To piston cooling nozzle
5. From main lubricating oil rifle
6. To connecting rod bearing.

Flow Diagram, Lubricating Oil System

General Information

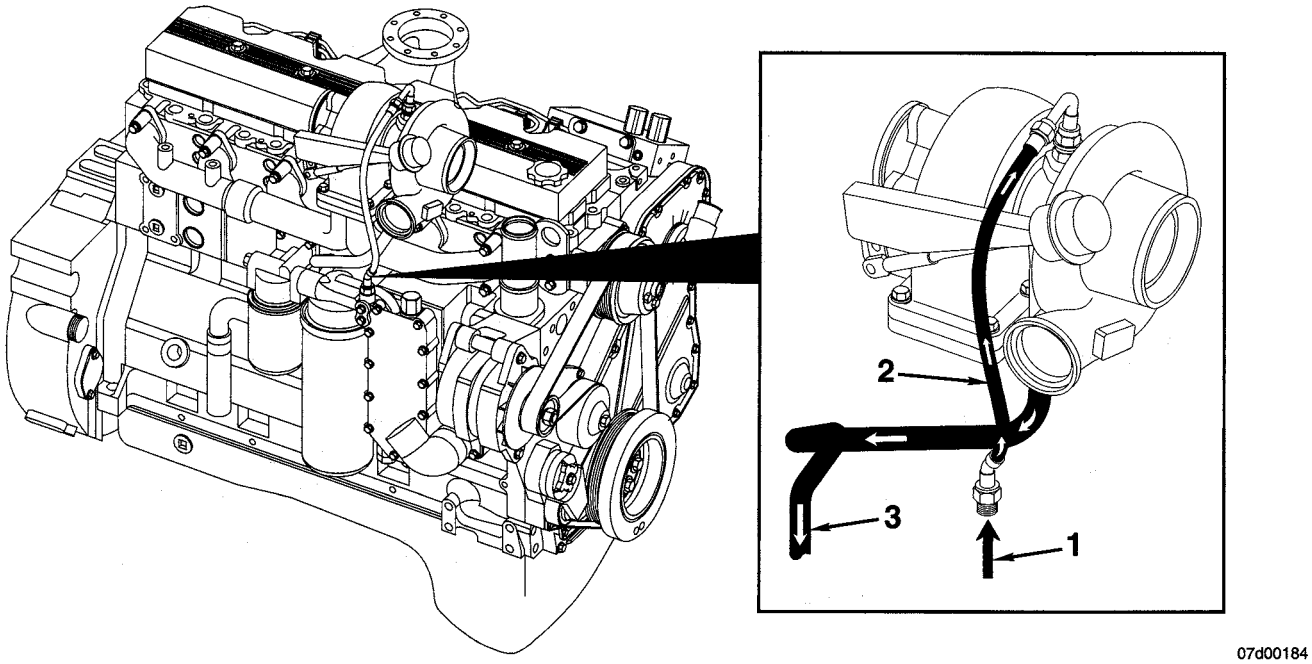


Lubrication for Power Components (ISC engines without CM850 Electronic Control Module)

1. From lubricating oil cooler
2. Main lubricating oil rifle
3. To camshaft
4. To piston cooling nozzle
5. From main lubricating oil rifle
6. To connecting rod bearing.

Flow Diagram, Lubricating Oil System

General Information

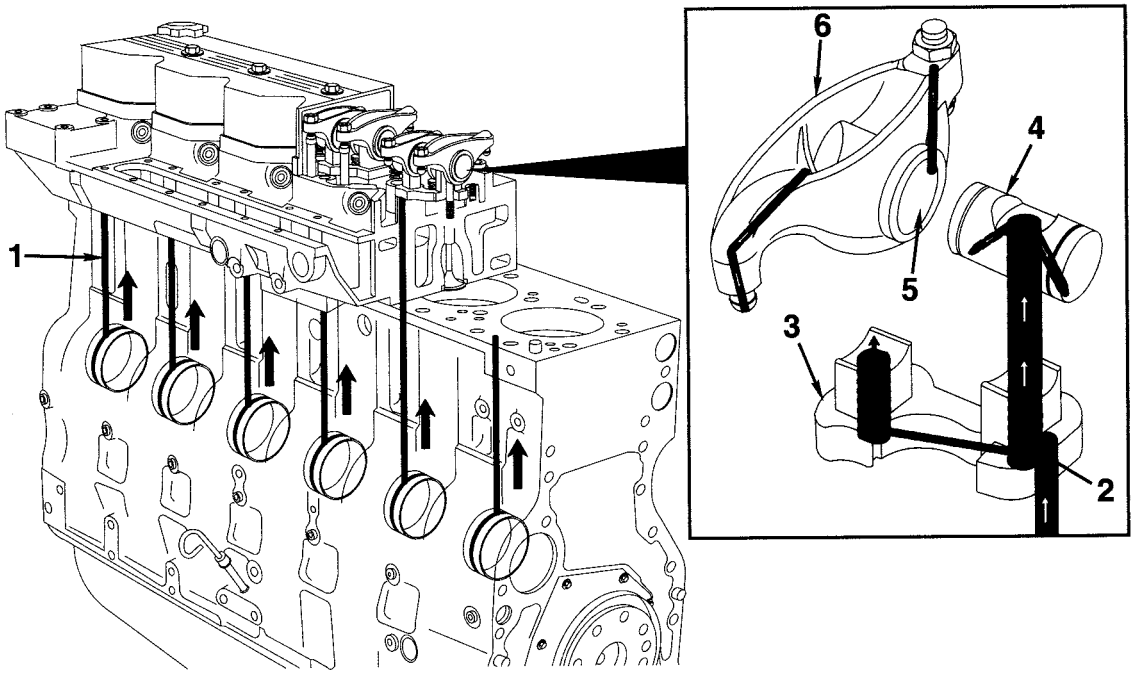


Lubrication for Turbocharger

1. Lubricating oil supply from filter
2. Turbocharger lubricating oil supply
3. Turbocharger lubricating oil drain

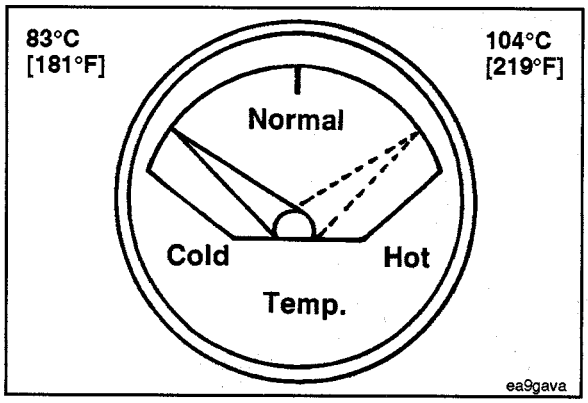
Flow Diagram, Lubricating Oil System

General Information



Lubrication for the Overhead

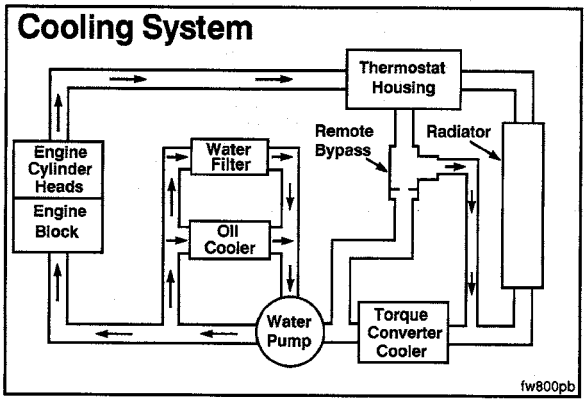
1. From cam bushings
2. Transfer slot
3. Rocker lever support
4. Rocker lever shaft
5. Rocker lever bore
6. Rocker lever.



Cooling System - Overview (008-999)

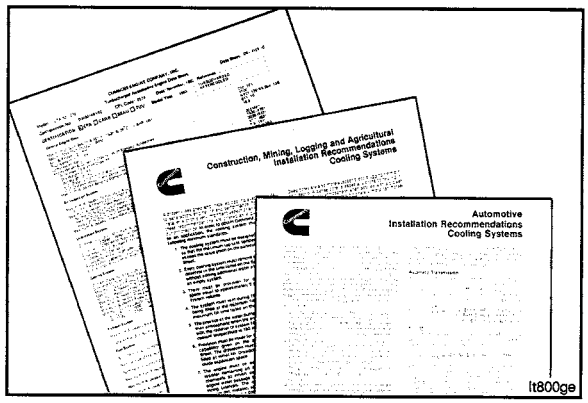
General Information

The function of the cooling system is to maintain a specified operating temperature for the engine. Some of the heat generated by the engine is absorbed by the coolant flowing through the passages in the cylinder block and head. Then, heat is removed from the coolant as it flows through the radiator.



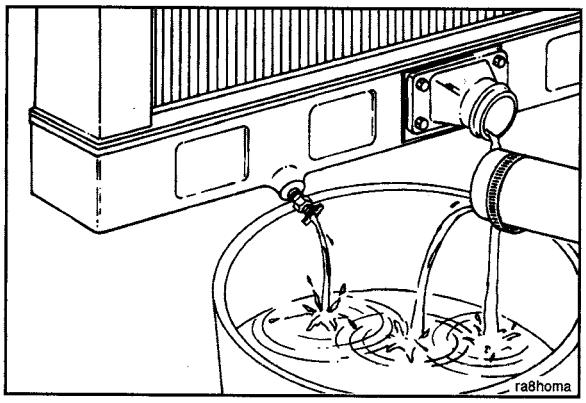
Conventionally cooled engines with automatic transmissions typically use oil-to-water transmission torque converter coolers plumbed between the radiator and the engine water pump.

A torque converter cooling system with a remote bypass allows the torque converter to receive coolant flow when the thermostat is closed (engine cold).



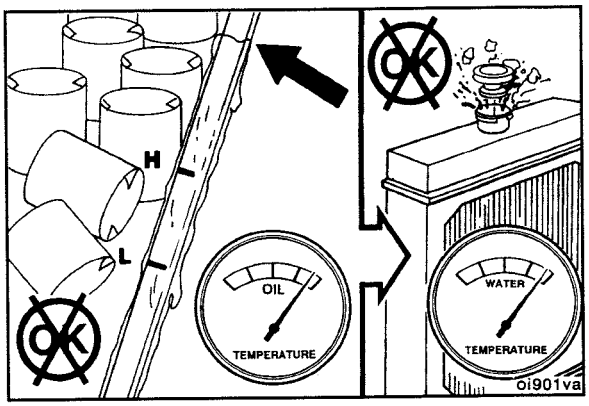
The following publications, available through Cummins Distributors or Cummins Dealers, provide cooling system installation recommendations and specifications approved by Cummins Inc.:

- Automotive Installation Recommendations (Cooling System), Bulletin 3382413
- Construction, Mining, Logging and Agriculture Installation Recommendations (Cooling System), Bulletin 3382171
- Data Sheets for specific engine models
- Operation of Diesel Engines in Cold Climates, Bulletin 3379009
- Heavy-Duty Coolant/SCA Maintenance Requirements, Bulletin 3387910.



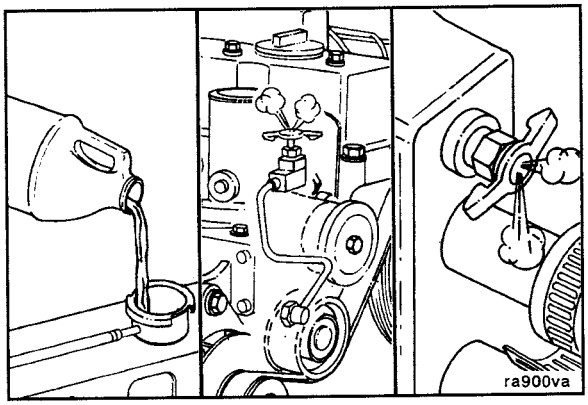
Open the petcocks at the bottom of the radiator and at the bottom of the oil cooler housing. Remove the lower radiator hose. A 20 liter [4 gal] drain pan will contain the coolant in most applications.

When troubleshooting overheating, remember that too much oil in the oil pan can cause additional heat from friction when the rod journals are submerged in oil. Overfilling with oil raises the oil temperature that is transferred to the cooling system at the oil cooler.

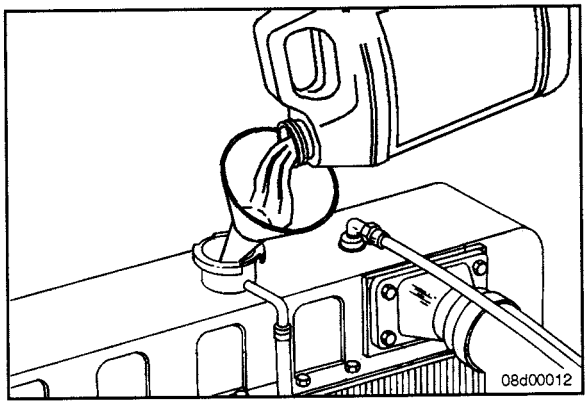


The system is designed to use a specific quantity of coolant. If the coolant level is low, the engine will run hot.

NOTE: The engine or system has a leak if frequent addition of coolant is necessary. find and repair the leak.

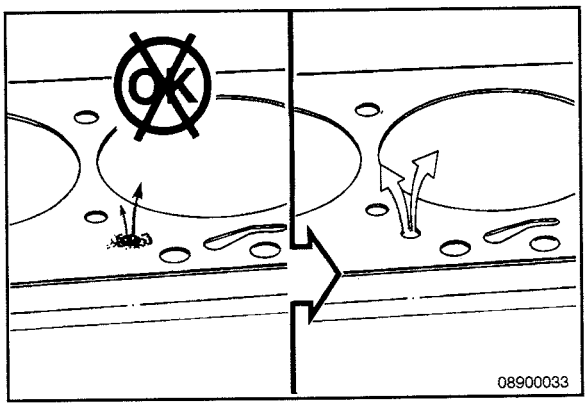


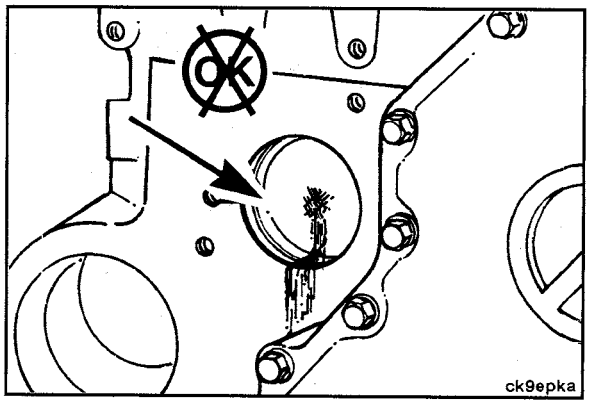
During operation, entrapped air mixes with the coolant which results in cavitation corrosion and poor heat transfer. Highly areated coolant can cause localized overheating of the cylinder head and block which can result in a cracked head, scored cylinder liner, or blown head gasket.



Obstructions in the coolant passages will reduce coolant flow, which can lead to overheating.

NOTE: The small holes in the head gasket are especially susceptible to plugging. Their size is critical. Do **not** enlarge the size of the orifices. Doing so will disturb the coolant flow and will **not** solve an overheating problem.

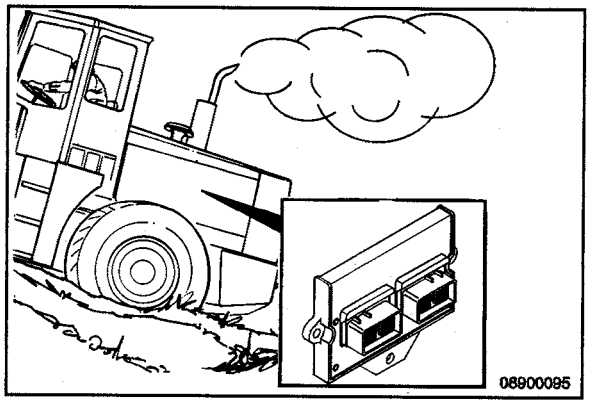




Water will cause rust formation, reducing the flow in the smaller coolant passages.

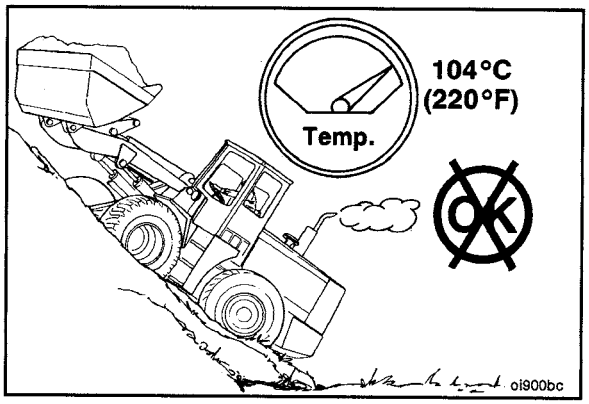
Also, water used as a coolant for even a relatively short period can result in the expansion plugs rusting through, which will allow the coolant to leak.

NOTE: A sudden loss of coolant from a heavily loaded engine can result in severe damage to the pistons and cylinder bore.



Overfueling and Loading

Overfueling can cause the engine to overheat. Make sure that the correct engine electronic control module (ECM) calibration is being used.



Constant overloading (lugging) can cause the engine to run hot.

Flow Diagram, Cooling System

General Information

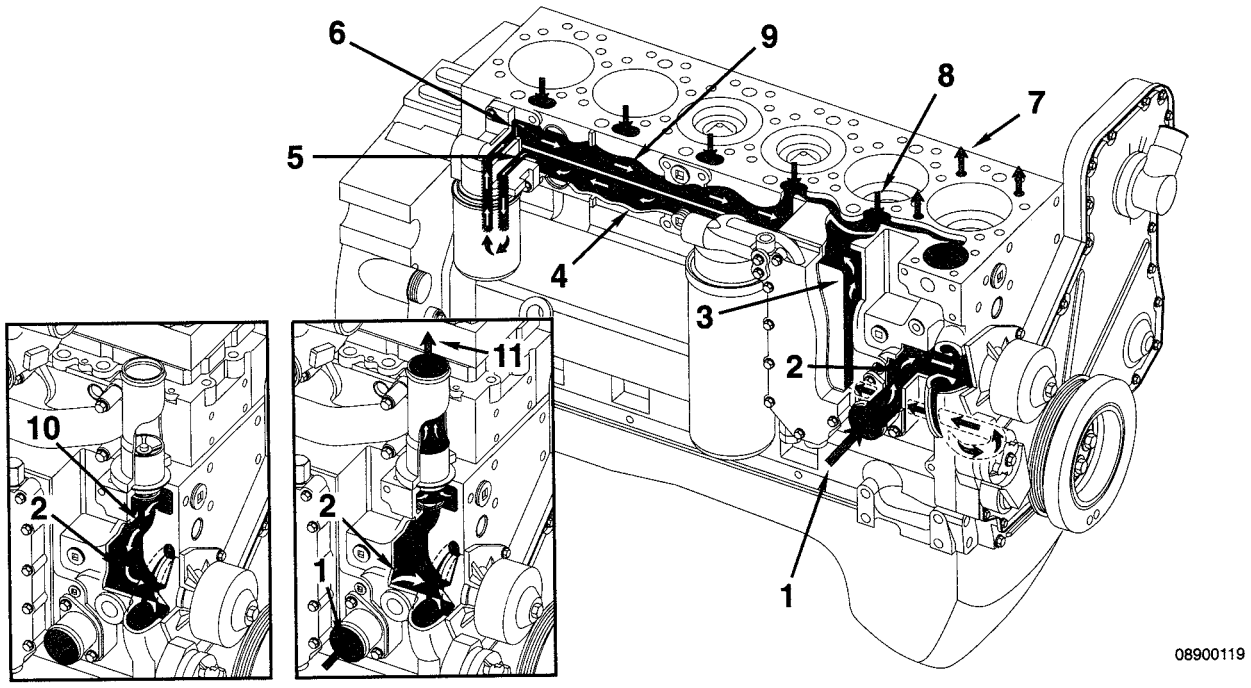
⚠CAUTION⚠

Never operate the engine without a thermostat. Without a thermostat, the coolant will not flow to the radiator, and the engine will overheat.

The following illustration identifies the significant features of the cooling system.

A. Coolant is drawn from the radiator by the integrally mounted water pump. The output from the water pump empties into the oil cooler cavity of the cylinder block.
B. The coolant then circulates around each cylinder and crosses the block to the fuel pump side of the engine.
C. Coolant then flows up into the cylinder head, crosses over the valve bridges, and down the exhaust manifold side of the engine to the integral thermostat housing.
D. As the coolant flows across the head toward the thermostat housing, it provides coolant for the injector. When the engine is below operating temperature, the thermostat is closed, and the coolant flow bypasses the radiator and goes to the water pump inlet through internal drillings in the block.

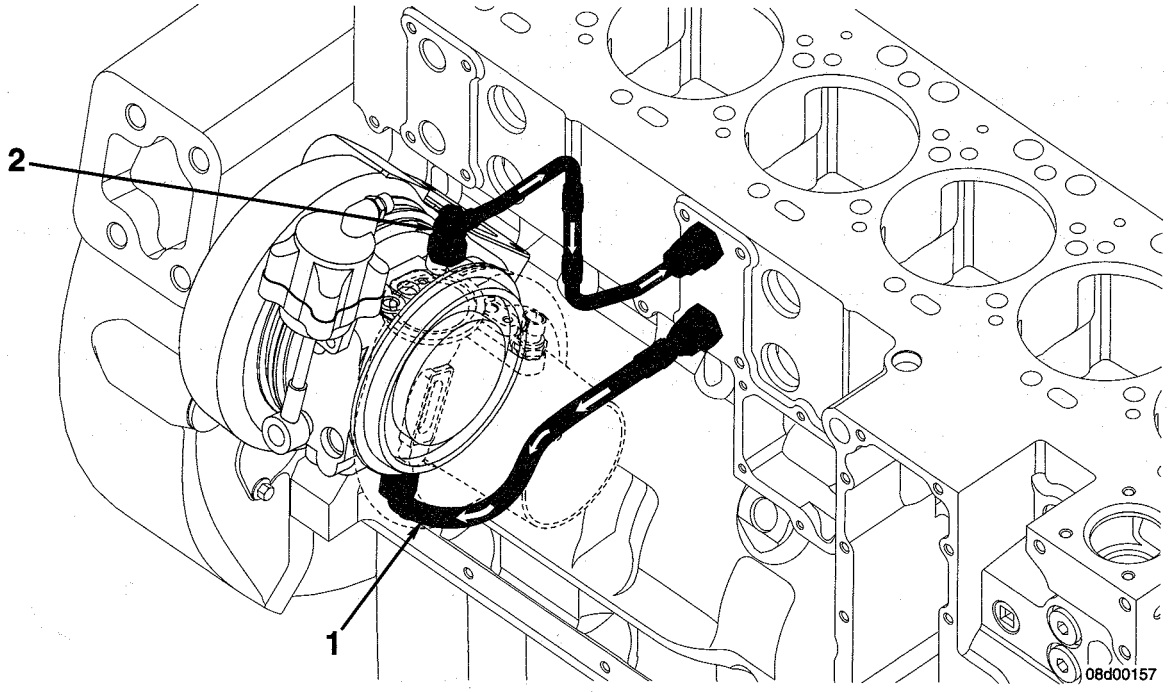
When operating temperature is reached, the thermostat opens, blocking the bypass passage to the water pump and opening the outlet to the radiator.



1. Coolant inlet from radiator
2. Water pump suction
3. Coolant flow through lubricating oil cooler
4. Block lower water manifold (to cylinders)
5. Coolant filter inlet (optional)
6. Coolant filter outlet (optional)
7. Coolant supply to cylinder head
8. Coolant return from cylinder head
9. Block upper water manifold
10. Thermostat bypass
11. Coolant return to radiator

Flow Diagram, Cooling System

General Information



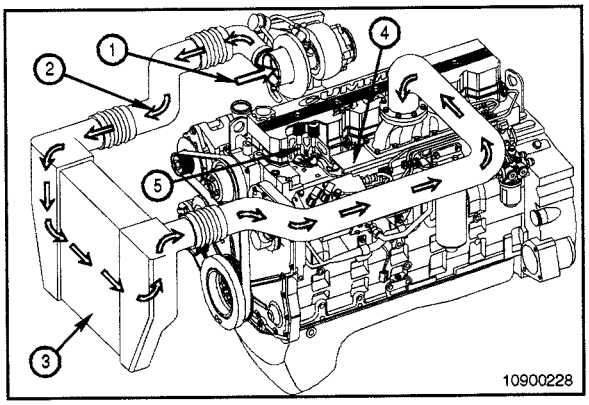
1. Turbocharger coolant supply
2. Turbocharger coolant drain

Air Intake System - Overview (010-999)

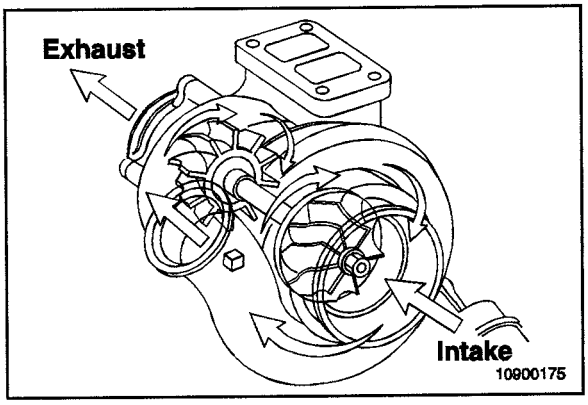
General Information

The combustion air system on the ISC and ISL engine consists of an air cleaner, intake air piping, turbocharger, charge air piping, charge air cooler (CAC), and intake air heater.

Air is drawn through the air cleaner and into the compressor side of the turbocharger (1). It is then forced through the CAC piping (2), to the CAC (3), the intake air heater (if applicable), and into the intake manifold (4). From the intake manifold, air is forced into the cylinders (5) and used for combustion.

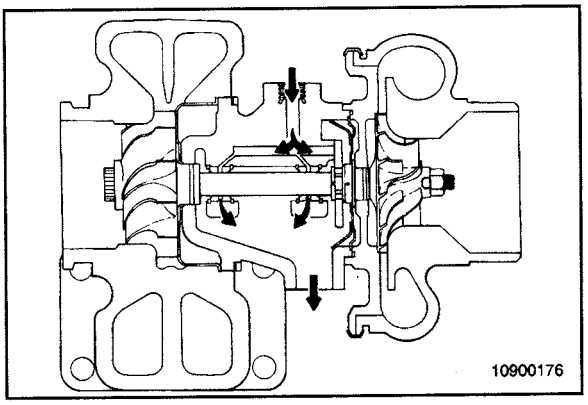


The turbocharger uses exhaust gas energy to turn the turbine wheel. The turbine wheel drives the compressor impeller that provides pressurized air to the engine for combustion. The additional air provided by the turbocharger allows more fuel to be injected to increase the power output from the engine.



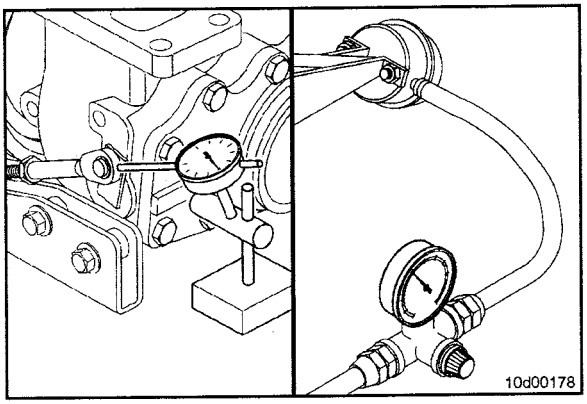
The turbine, compressor wheels, and shaft are supported by two rotating bearings in the bearing housing. Passages in the bearing housing direct filtered, pressurized engine oil to the shaft bearings and thrust bearings. The oil is used to lubricate and cool the rotating components. Oil then drains from the bearing housing to the engine sump, through the oil drain line.

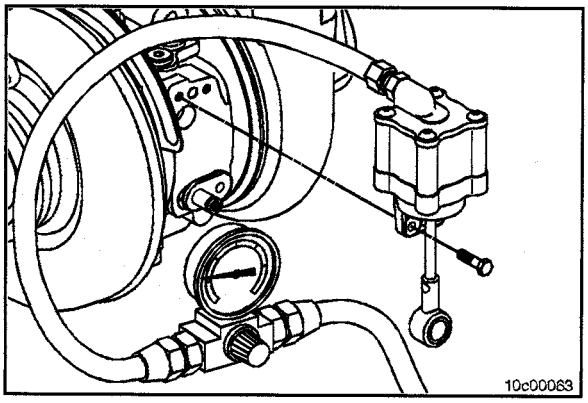
NOTE: An adequate supply of good, filtered oil is very important to the life of the turbocharger. Make sure that a high-quality oil is used and that it and the oil filter are changed according to maintenance recommendations.



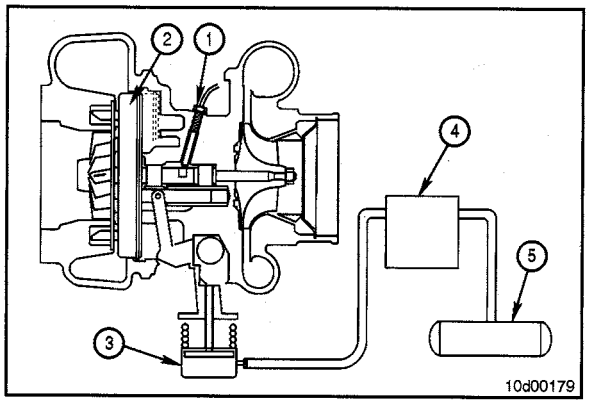
Wastegated turbochargers are used to optimize performance. The wastegated design allows maximum boost to be developed quickly while making sure that the turbocharger does **not** overspeed at higher engine rpm's.

Wastegate operation is controlled by an actuator that senses compressor pressure and balances it against a preset spring load. The wastegate valve is located in the turbine inlet passage. When open, it diverts a portion of the exhaust gas away from the turbine wheel, thereby controlling the shaft speed and boost.



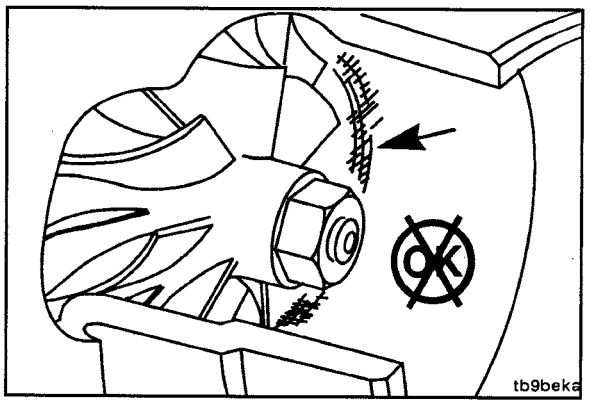


Variable geometry turbochargers are used to improve engine performance by building boost more quickly during acceleration or transient conditions. A variable geometry turbocharger does **not** use a wastegate actuator. A pneumatic or electric actuator is used to vary the turbine exit area. By closing the variable geometry nozzle (reducing the turbine exit area), turbo speeds are increased and boost pressure increases more rapidly. By opening the variable geometry nozzle (increasing the turbine exit area), turbo speeds are lower and less boost pressure is produced.



The variable geometry turbocharger functions as a standard turbocharger with the addition of the following:

- A speed sensor (1) in the bearing housing to monitor turbocharger operation
- Water-cooled bearing housings (in addition to oil lubrication)
- The sliding nozzle (2) is actuated by a pneumatic actuator attached to the vehicle (brake) air supply system
- The pneumatic actuator (3) operated by an air control valve (4) and receives air from the air supply tank (5)
- When the variable geometry turbocharger mechanism opens, a noise can be heard as air is released from the actuator (3) through the control valve (4).



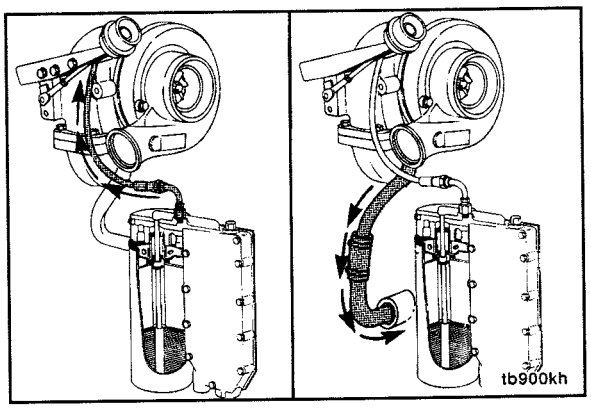
Malfunctioning Turbocharger

Failure of the internal components of the turbocharger can reduce its effectiveness and also cause excessive smoke and low power. A bearing failure can produce friction that will slow the speed of the rotor assembly. Failed bearings can also allow the blades of the rotor assembly to rub the housings, thus reducing the rotor assembly speed.

A malfunctioning turbocharger wastegate failure, variable geometry turbocharger actuator, variable geometry turbocharger actuator controller, or miscalibration of the turbocharger wastegate can result in excessively high or low boost pressures. Low boost pressures can cause excessive smoke and low power. High boost pressures can cause major engine damage.

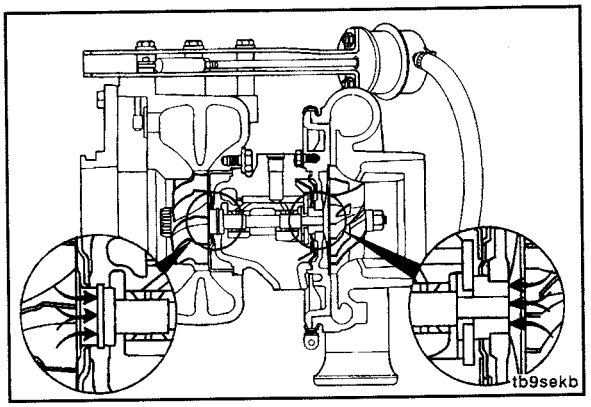
Lubricating Oil Consumption and Leaks

Engine lubricating oil is used to lubricate the bearings and provide some cooling for the turbocharger. The lubricating oil supplied to the turbocharger through the supply line is at engine operating pressure. A return line connected to the bottom of the turbocharger routes the lubricating oil back to the engine lubricating oil pan.

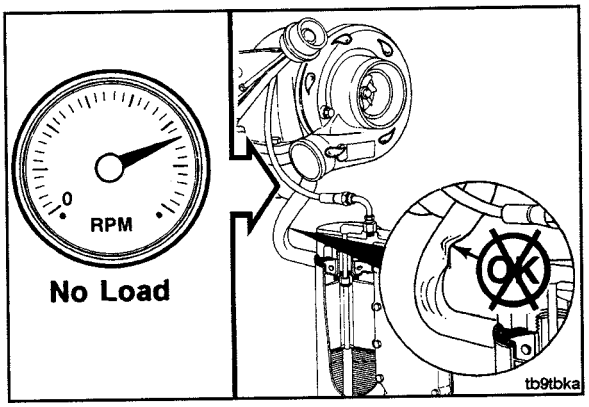


Seal rings are used on each end of the rotor assembly. The primary function of the seals is to prevent exhaust gases and compressed air from entering the turbocharger housing. Lubricating oil leakage from the seals is rare, but it can occur.

NOTE: Excessive crankcase pressure can prevent oil from draining to the oil pan. This can load the bearing housing and cause lubricating oil to leak past the compressor seals and into the engine.

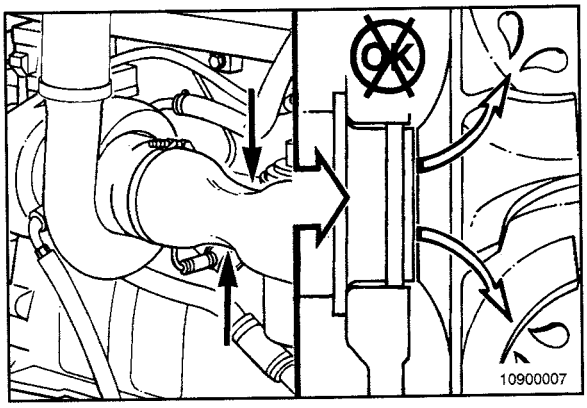


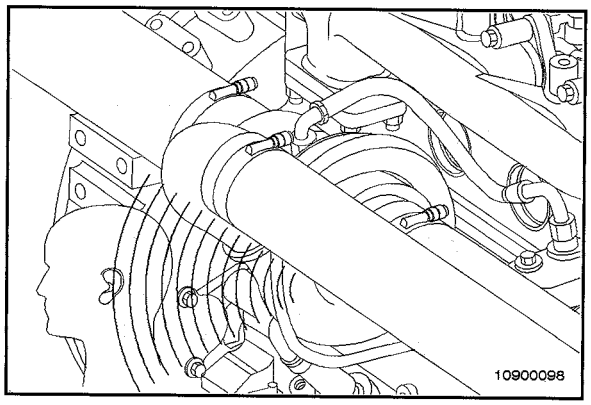
A restricted or damaged lubricating oil return line will cause the turbocharger housing to be pressurized, causing lubricating oil to migrate past the seals.



Additionally, high intake or exhaust restrictions can cause a vacuum between the compressor and the turbocharger housing, resulting in oil leaking past the seals.

NOTE: If oil leaks past the compressor housing seal, it is necessary to flush the charge air cooler to clean oil from the intake system. Refer to Procedures 010-027 and 010-033.

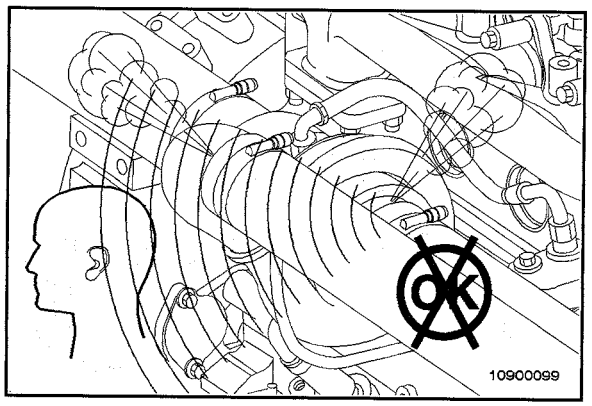




Turbocharger Noise

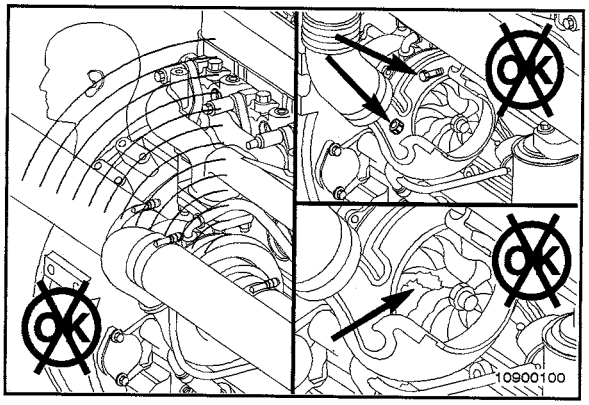
It is normal for the turbocharger to emit a whining sound that varies in intensity depending on engine speed and load. The sound is caused by the very high rotational speed of the rotor assembly and the method used to balance the rotor assembly during manufacturing. Consequently, the sound will be louder at full speed.

NOTE: If possible, operate the engine at full speed to verify the noise level.



Leaks in the air system intake and/or exhaust components can produce excessive engine noise. Leak noise is typically a high pitched whine or sucking sound.

Check for leaks in the intake and exhaust system. Check to make sure all hose clamps are tight. Refer to Procedure 010-024.

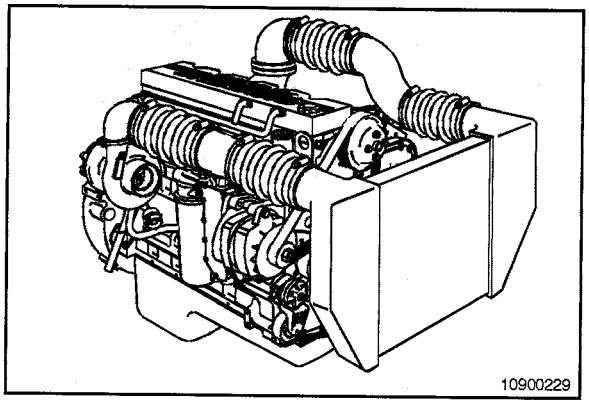


Lower pitched sounds or rattles at lower engine speeds can indicate debris in the system or that the rotor assembly is touching the housings.

Remove the turbocharger inlet and check for foreign objects.

If suspect, check for turbocharger blade damage and bearing clearance. Refer to Procedures 010-033.

If leaks, blade damage, or improper clearances are found, replace the turbocharger. Refer to Procedure 010-033.

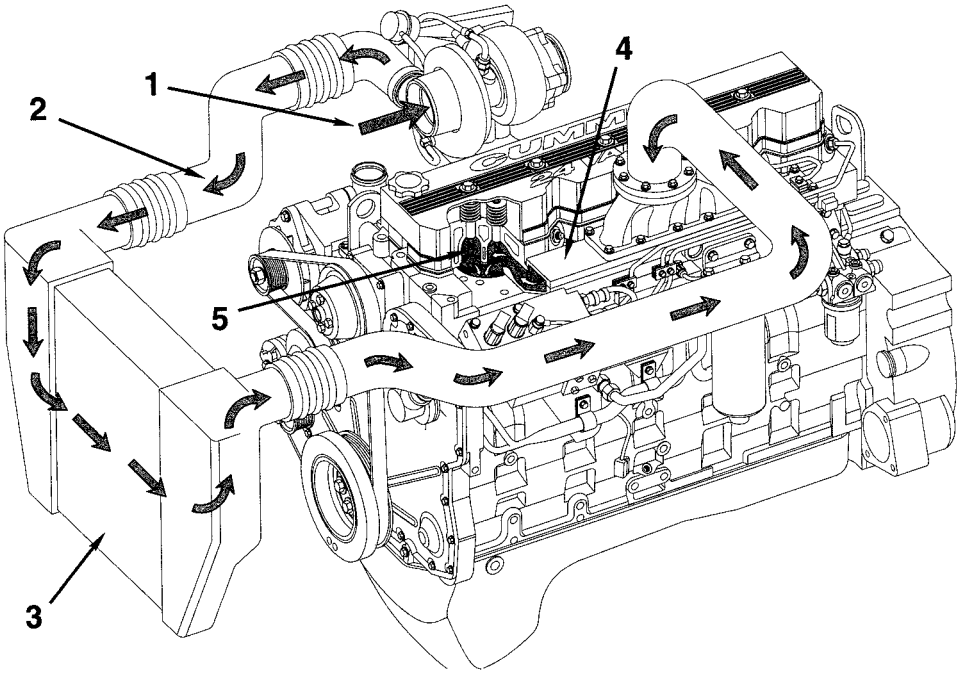


Automotive engines use a chassis-mounted charge air cooler to improve engine performance and reduce emissions. This system also uses large-diameter piping to transfer the air from the engine turbocharger to the CAC, then returns the air from the CAC to the engine intake manifold.

NOTE: The long-term integrity of the charge air cooling system is the responsibility of the vehicle and component manufacturers.

Flow Diagram, Air Intake System

General Information



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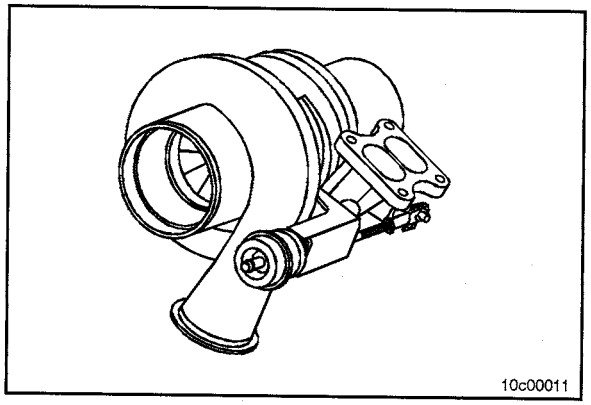
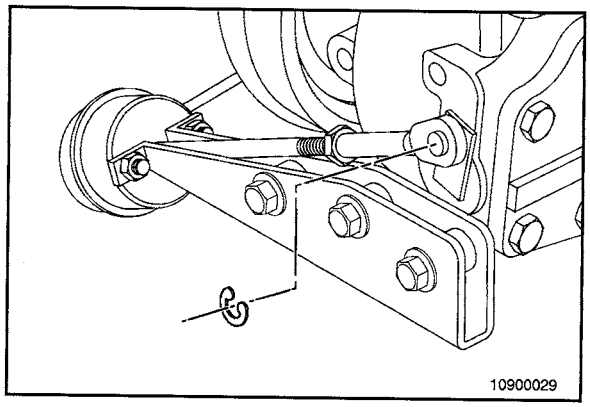
1. Intake Air Inlet to Turbocharger
2. Turbocharger Air to Charge Air Cooler
3. Charge Air Cooler
4. Intake Manifold (integral part of cylinder head)
5. Intake Valve.



Exhaust System - Overview (011-999)

General Information

The wastegated turbocharger is a Holset® Model HX40. 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.

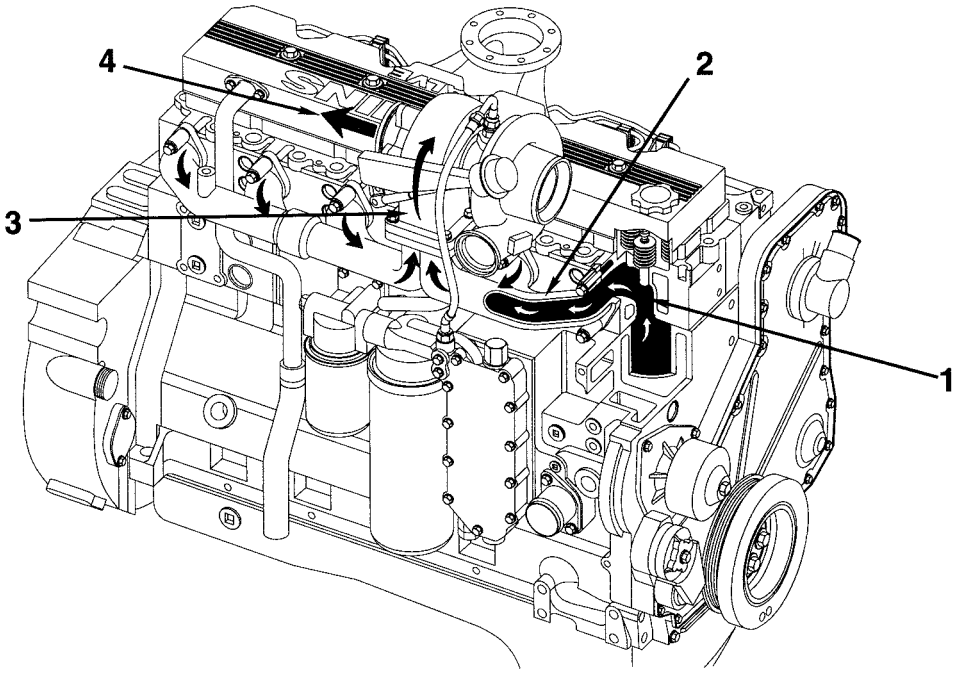


The wastegate actuator is mounted on the turbocharger and consists of a pressure canister, diaphragm, and rod. As pressure changes in the canister, as dictated by the wastegate controller, the actuator rod adjusts the wastegate valve accordingly.

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

General Information



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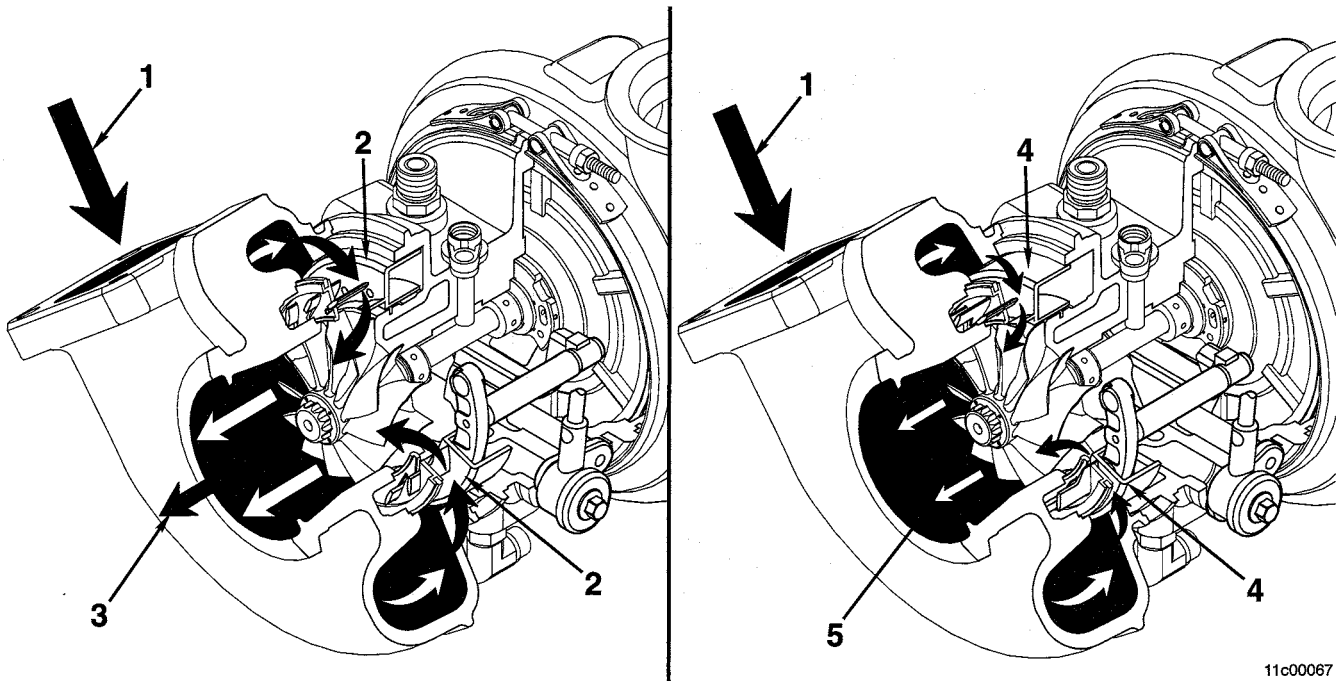
1. Exhaust valve
2. Exhaust manifold (pulse type)
3. Dual-entry turbocharger
4. Turbocharger exhaust outlet.

Flow Diagram, Exhaust System

General Information



Variable Geometry Turbocharger

1. Exhaust in
2. Sliding nozzle open
3. Exhaust gas low velocity flow
4. Sliding nozzle closed
5. Exhaust gas high velocity flow

Compressed Air System - Overview (012-999)

General Information

The compressed air system normally consists of a gear-driven air compressor, an air governor, air tanks, and all necessary plumbing.

The compressor operates continuously but has a "loaded" and "unloaded" operating mode. The operating mode is controlled by a pressure activated governor and the compressor unloader assembly. When the air system reaches a predetermined pressure, the governor applies an air signal to the unloader assembly, causing the unloader to either hold open or shutoff the compressor's intake valve, which causes compressed air to stop flowing into the air system. As the system is used, the pressure drops. At a predetermined pressure, the governor exhausts the air signal to the compressor unloader assembly, allowing the compressor to again pump compressed air into the system.

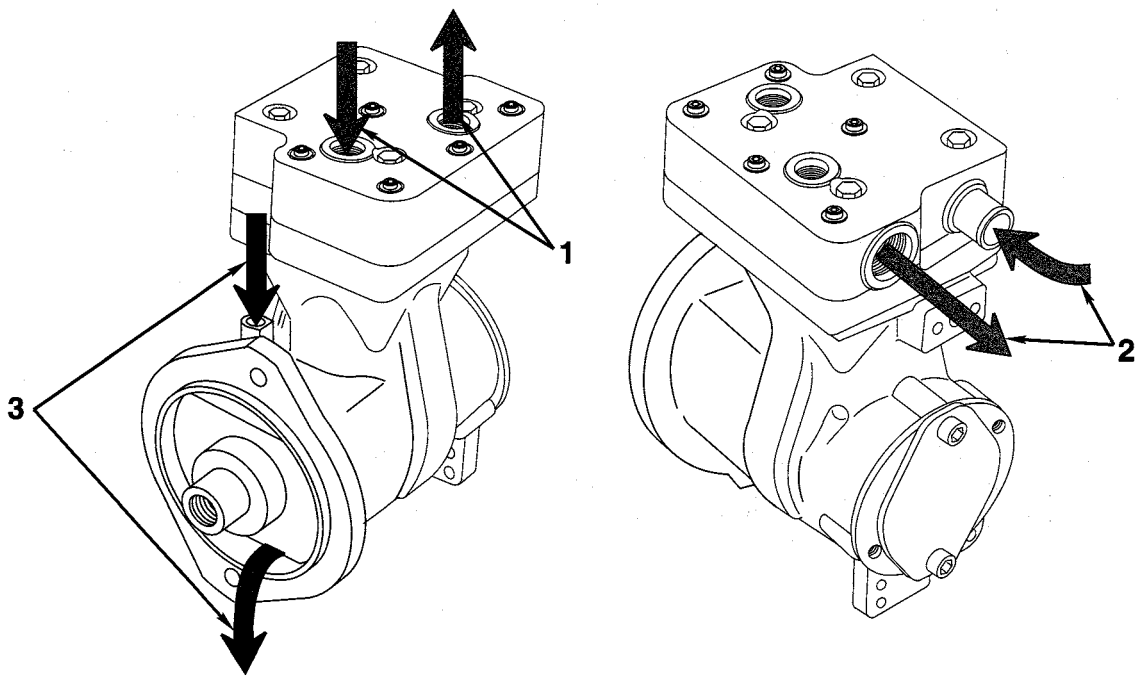
Air compressors are available in an air cooled or water cooled version. The **only** significant difference is that changes have been made to the cylinder head to incorporate a water passage.

Various brands of compressors can be used on the ISC and ISL engines. Troubleshooting procedures are very similar for these air compressors, but refer to the compressor manufacturer's manual for information including detailed repair information and torque values.

Most air compressor cylinder head and unloader valve assemblies can be serviced without removing the compressor from the engine. This manual will cover servicing of the unloader assembly and cylinder head with the compressor installed on the engine. All other servicing and repair of the compressor internal components **must** be done after the compressor has been removed from the engine.

Flow Diagram, Compressed Air System

General Information



12d00033

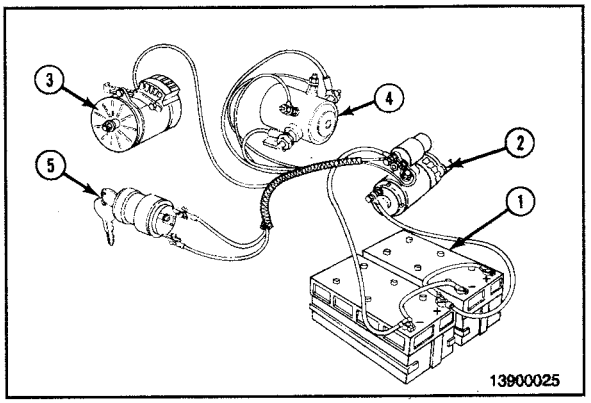
1. Coolant
2. Air
3. Lubricant

Electrical Equipment - Overview (013-999)

General Information

The basic heavy-duty electrical system consists of:

- Batteries (1)
- Starting motor (2)
- Alternator (generator) (3)
- Magnetic switch (4)
- Push-button switch or keyswitch (5)
- Control (or relay) circuit wiring
- Battery cables or cranking circuit.



Engine Testing - Overview (014-999)

General Information

The engine test is a combination of an engine run-in and a performance check. The engine run-in procedure provides an operating period that allows the engine parts to achieve a final finish and fit. The performance check provides an opportunity to perform final adjustments needed to optimize the engine's performance.

An engine test can be performed using **either** an engine dynamometer **or** a chassis dynamometer. If a dynamometer is **not** available, an engine test **must** be performed in a manner that simulates a dynamometer test.

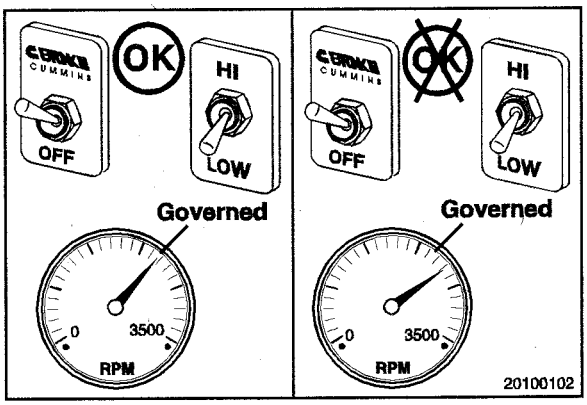
Check the dynamometer before beginning the test. The dynamometer **must** have the capability to test the performance of the engine when the engine is operating at the maximum rpm and horsepower range (full power).

The engine crankcase pressure, often referred to as engine blowby, is an important factor that indicates when the piston rings have achieved the correct finish and fit. Rapid changes of blowby or values that exceed specification by more than 50 percent indicate that something is wrong. The engine test **must** be discontinued until the cause has been determined and corrected.

Vehicle Braking - Overview (020-999)

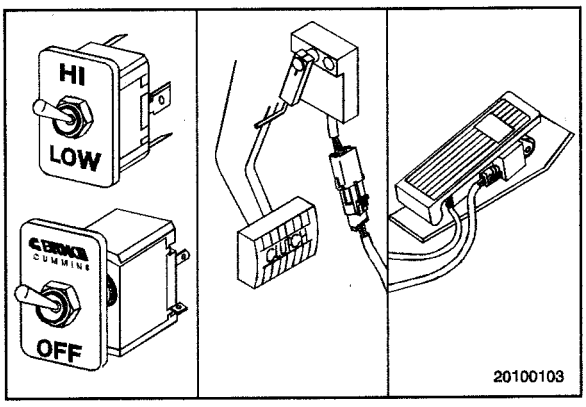
General Information

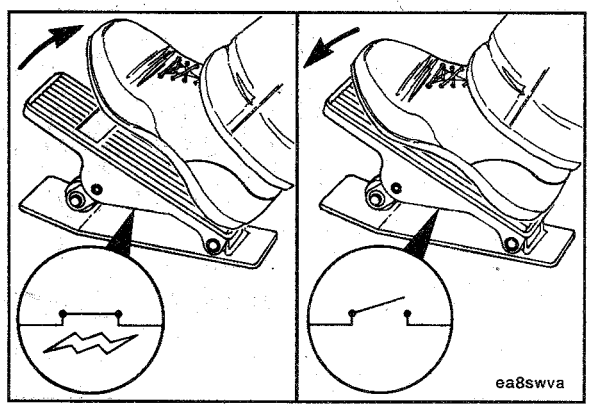
NOTE: The engine brake is a two-piece assembly. The following instructions apply to both of the engine brake assemblies.



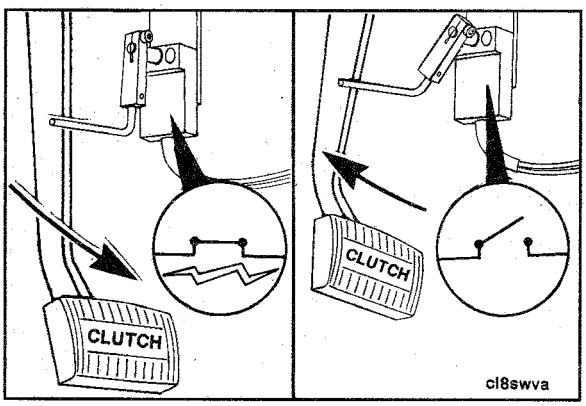
Engine brake controls consist of the following:

- An ON/OFF switch
- Clutch switch
- Throttle sensor
- Two-position selector switch (optional).

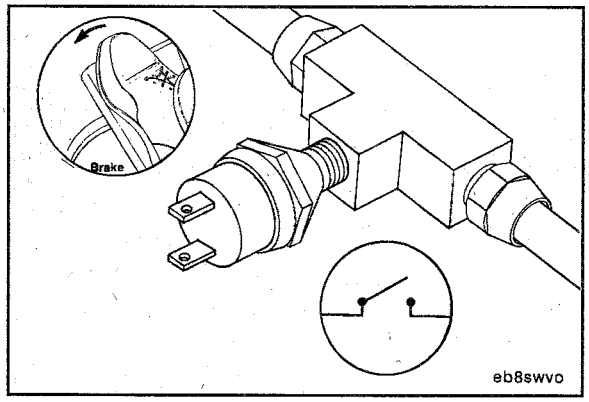




The throttle sensor is part of the accelerator pedal assembly located in the cab, and will deactivate the engine brakes when depressed.

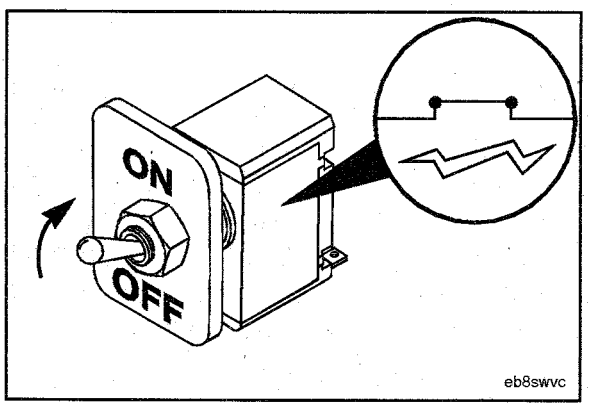


The clutch switch uses the motion of the clutch linkage to deactivate the engine brakes when the clutch pedal is depressed. Depressing the clutch while in cruise control will disengage the cruise control.



The service brake pressure switch is attached to the service brake air supply line.

Applying the service brakes while in cruise control will disengage the cruise control and enable the engine brakes.



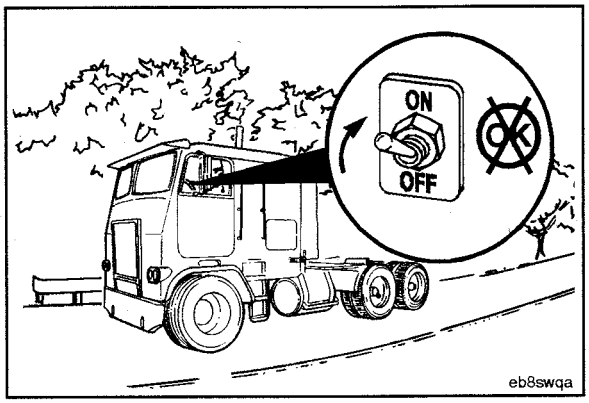
To activate the engine brakes, switch the ON/OFF switch to the ON position. Once activated, the operation of the engine brakes is fully automatic.

NOTE: Refer to the appropriate pages in this section for specific information about engine brake operation under certain road conditions.

⚠WARNING⚠

Do not use the engine brakes while bobtailing or pulling an empty trailer. With the engine brakes in operation, wheel lockup can occur more quickly when the service brakes are applied, especially on vehicles with single-drive axles.

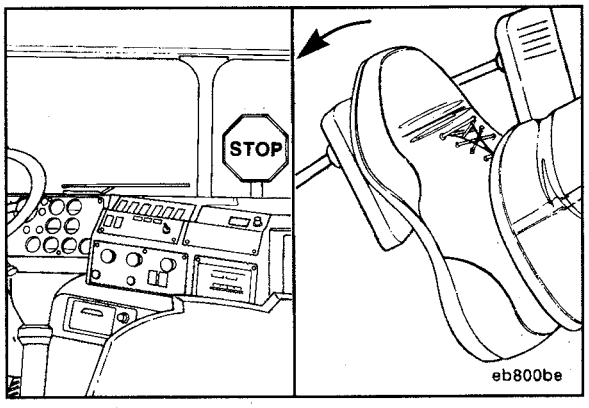
Make sure the engine brakes are switched to the OFF position when bobtailing or pulling an empty trailer.



△CAUTION△

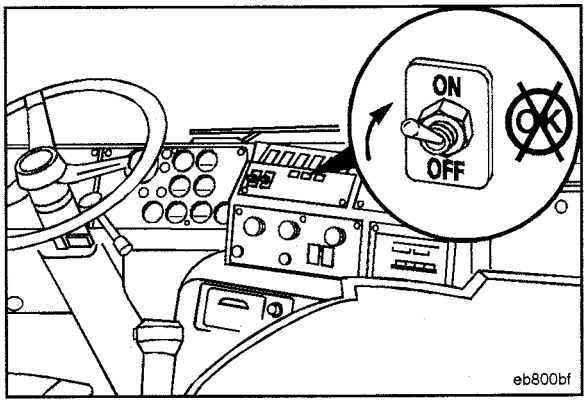
The engine harness are designed to assist the vehicle's service brakes in slowing the vehicle to a stop.

Remember, service brakes will be required to bring the vehicle to a stop.



△CAUTION△

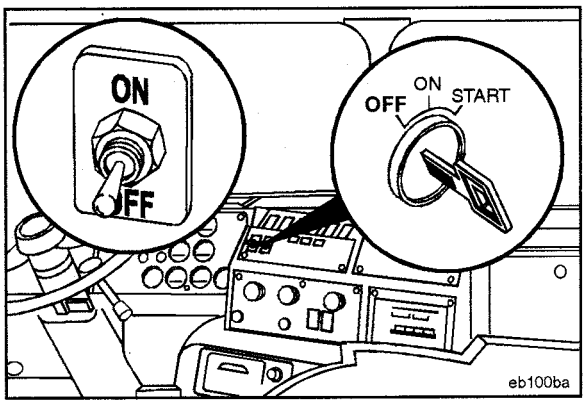
Do not use the engine brakes to aid clutchless gearshifting. This can cause the engine to stall or lead to engine damage.



△CAUTION△

Do not operate the engine if the engine brakes will not deactivate.

If the engine brakes will **not** shut off, shut off the engine immediately.



Notes

Section TS - Troubleshooting Symptoms

Section Contents

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Troubleshooting Procedures and Techniques

General Information

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

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

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

Follow these basic troubleshooting steps:

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

Troubleshooting Symptoms Charts

General Information

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.

Air Compressor Air Pressure Rises Slowly

This is symtom tree t004

Cause	Correction
STEP 1 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
Go To Next Step

STEP 2 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, tanks, and valves. Refer to the OEM service manual.

OK
Go To Next Step

STEP 3 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to the OEM service manual.

OK
Go To Next Step

STEP 4 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. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedures 010-033.

OK
Go To Next Step

STEP 5 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
Go To Next Step

STEP 6 Unloader valve is malfunctioning	Check the unloader valve and unloader body seal. Refer to the OEM service manual.

OK
Go To Next Step

STEP 7 Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to the OEM service manual.

Air Compressor Cycles Frequently

This is symtom tree t005

Cause	Correction
STEP 1 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, tanks, and valves. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 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 Go To Next Step	
STEP 4 E-type system is **not** plumbed correctly	Install an Econ valve, a check valve, and system hoses. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 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. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedure 010-033.
OK Go To Next Step	
STEP 6 Air compressor pumping time is excessive	Replace the desiccant cartridge on the Turbo/CR 2000 air dryer. Refer to the OEM service manual. Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Air dryer outlet check valve is sticking	Lubricate or replace the air dryer outlet check valve assembly. Refer to the manufacturer's instructions.

Air Compressor Noise is Excessive

This is symtom tree t006

Cause	Correction
STEP 1 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. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedure 010-033.
OK Go To Next Step	
STEP 2 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). Refer to the OEM instructions.
OK Go To Next Step	
STEP 3 Air compressor mounting hardware is loose, worn, or broken	Check air compressor mounting hardware. Refer to Procedure 012-014.
OK Go To Next Step	
STEP 4 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 OEM instructions.
OK Go To Next Step	
STEP 5 Air compressor drive gear or engine gear train is worn or damaged	Inspect the drive gears and gear train and repair as necessary. Refer to Procedure 012-014.
OK Go To Next Step	
STEP 6 Splined drive coupling or gear is excessively worn	Check the coupling for wear. Refer to Procedure 012-014.
OK Go To Next Step	
STEP 7 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 Pumping Excess Lubricating Oil into the Air System

This is symtom tree t007

Cause	Correction
STEP 1 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to Section 2 in the Operation and Maintenance Manual, ISC, ISC^e, ISL Engines, Bulletin 4021428.
OK Go To Next Step	
STEP 2 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 Go To Next Step	
STEP 3 Contaminants are building up in the system reservoirs	Drain the reservoirs daily. Refer to Section 2 in the Operation and Maintenance Manual, ISC, ISC^e, ISL Engines, Bulletin 4021428.
OK Go To Next Step	
STEP 4 E-type system is **not** plumbed correctly	Install an Econ valve, a check valve, and system hoses. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Air compressor pumping time is excessive	Replace the desiccant cartridge on the Turbo/CR 2000 air dryer. Refer to the OEM service manual. Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 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. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedures 010-033.
OK Go To Next Step	
STEP 7 Engine angularity during operation exceeds specification	Refer to the Engine Specification data sheet.
OK Go To Next Step	
STEP 8 Crankcase pressure is excessive	Check for excessive blowby. Refer to the Crankcase Gases (blowby) Excessive symptom tree.
OK Go To Next Step	

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symtom tree t007

Cause	Correction
STEP 9 Lubricating oil pressure is above specification	Check the oil pressure. Refer to the Lubricating Oil Pressure High symptom tree.
OK Go To Next Step	
STEP 10 Air compressor runs hot	If coolant temperature is above normal, refer to the Coolant Temperature Above Normal - Gradual Overheat symptom tree.
OK Go To Next Step	
STEP 11 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 Go To Next Step	
STEP 12 Air compressor drive gear or engine gear train is worn or damaged	Inspect the drive gears and gear train and repair as necessary. Refer to Procedure 012-014.
OK Go To Next Step	
STEP 13 Air compressor pumping too high air pressure	Check the air governor for correct operation. Refer to the OEM service manual.
OK Go To Next Step	
STEP 14 Air compressor is excessively worn or internally damaged	Replace or rebuild the air compressor. Refer to Procedure 012-014 and the OEM service manual.

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

This is symtom tree t008

Cause	Correction
STEP 1 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, tanks, and valves. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to the OEM service manual.

Air Compressor Will Not Pump Air

This is symtom tree t009

Cause	Correction
STEP 1 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Unloader valve is malfunctioning	Check the unloader valve and unloader body seal. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Splined drive coupling or gear is excessively worn	Check the coupling for wear. Refer to Procedure 012-014.
OK Go To Next Step	
STEP 5 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 symtom tree t010

Cause	Correction
STEP 1 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, tanks, and valves. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Unloader valve is malfunctioning	Check the unloader valve and unloader body seal. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Air governor signal line or actuator line is plugged	Inspect the signal line and actuator line. Refer to the manufacturer's instructions.
OK Go To Next Step	
STEP 5 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 Go To Next Step	
STEP 6 Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to the OEM service manual.

Alternator Not Charging or Insufficient Charging

This is symtom tree t013

Cause	Correction
STEP 1 Vehicle gauge is malfunctioning	Check the vehicle gauge. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Alternator belt is loose	Check the alternator belt tension. Refer to Procedures 013-001.
OK Go To Next Step	
STEP 3 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 Go To Next Step	
STEP 4 Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009.
OK Go To Next Step	
STEP 5 Batteries have malfunctioned	Check the condition of the batteries. Replace the batteries, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Alternator or voltage regulator is malfunctioning	Test the alternator output. Replace the alternator or voltage regulator if necessary. Refer to Procedure 013-001 and the OEM service manual.
OK Go To Next Step	
STEP 7 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.

Alternator Overcharging

This is symtom tree t014

Cause	Correction
STEP 1 Battery cell is damaged (open circuit)	Check the condition of the batteries. Replace the batteries, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Voltage regulator is malfunctioning	Check the voltage regulator. Replace the voltage regulator, if necessary. Refer to the OEM service manual.

Coolant Loss - Internal

This is symtom tree t021

Cause	Correction
STEP 1 Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks. Refer to Procedure 007-003.
OK Go To Next Step	
STEP 2 Air compressor cylinder head is cracked or porous, or has a leaking gasket	Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-007.
OK Go To Next Step	
STEP 3 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-021.
OK Go To Next Step	
STEP 4 Cylinder head is cracked or porous	Pressure-test the cylinder head. Refer to Procedure 002-004.
OK Go To Next Step	
STEP 5 Cylinder block is cracked or porous	Remove the oil pan. Pressure-test the cooling system to check for leaks. Refer to Procedure 008-020.

Coolant Temperature Above Normal - Gradual Overheat

This is symtom tree t022

Cause	Correction
STEP 1 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-027.
OK Go To Next Step	
STEP 2 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 x 19.6 cm [7.5 x 7.5 in] of opening at all times.
OK Go To Next Step	
STEP 3 Charge air cooler fins, radiator fins, or air conditioner condenser fins are damaged or obstructed with debris	Inspect the charge air cooler, air conditioner condenser, and radiator fins. Clean, if necessary. Refer to Procedure 010-027 and the OEM service manual.
OK Go To Next Step	
STEP 4 Coolant level is below specification	Inspect the engine and cooling system for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedures 008-018 and 008-020.
OK Go To Next Step	
STEP 5 Coolant mixture of antifreeze and water is **not** correct	Verify the concentration of antifreeze in the coolant. Add antifreeze or water to correct the concentration. Refer to the Cummins Coolant Requirements and Maintenance, Bulletin 3666132.
OK Go To Next Step	
STEP 6 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.
OK Go To Next Step	
STEP 7 Fan drive belt is broken or loose	Check the fan drive belt. Replace the belt if necessary. Refer to Procedure 008-002.
OK Go To Next Step	
STEP 8 Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge, if necessary. Refer to the OEM service manual.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

This is symtom tree t022

Cause	Correction
STEP 9 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047.
OK Go To Next Step	
STEP 10 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 Go To Next Step	
STEP 11 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-045.
OK Go To Next Step	
STEP 12 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 the OEM service manual.
OK Go To Next Step	
STEP 13 Intake manifold air temperature is above specification	Refer to the Intake Manifold Air Temperature Above Specification symptom tree.
OK Go To Next Step	
STEP 14 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-009.
OK Go To Next Step	
STEP 15 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated symptom tree.
OK Go To Next Step	
STEP 16 Water pump is malfunctioning	Check the water pump for correct operation. Replace the water pump if necessary. Refer to Procedure 008-062.
OK Go To Next Step	
STEP 17 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 Procedure 008-042.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

This is symtom tree t022

Cause	Correction
STEP 18 Torque converter is malfunctioning	Check the torque converter. Refer to the OEM service manual.
OK Go To Next Step	
STEP 19 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 Go To Next Step	
STEP 20 Vehicle cooling system is **not** adequate	Verify that the engine and vehicle cooling systems are using the correct components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 21 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-021.
OK Go To Next Step	
STEP 22 Engine is overfueled	Check the engine fuel rate. Refer to the Fuel Consumption Excessive symptom tree.

Coolant Temperature Above Normal - Sudden Overheat

This is symtom tree t023

Cause	Correction
STEP 1 Coolant level is below specification	Inspect the engine and cooling system for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedures 008-018 and 008-020.
OK Go To Next Step	
STEP 2 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-027.
OK Go To Next Step	
STEP 3 Fan drive belt is broken or loose	Check the fan drive belt. Replace the belt if necessary. Refer to Procedure 008-002.
OK Go To Next Step	
STEP 4 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 x 19.6 cm [7.5 x 7.5 in] of opening at all times.
OK Go To Next Step	
STEP 5 Charge air cooler fins, radiator fins, or air conditioner condenser fins are damaged or obstructed with debris	Inspect the charge air cooler, air conditioner condenser, and radiator fins. Clean, if necessary. Refer to Procedure 010-027.
OK Go To Next Step	
STEP 6 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 Go To Next Step	
STEP 7 Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 8 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-045.
OK Go To Next Step	

Coolant Temperature Above Normal - Sudden Overheat

This is symtom tree t023

Cause	Correction
STEP 9 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 the OEM service manual.
OK Go To Next Step	
STEP 10 Water pump is malfunctioning	Check the water pump for correct operation. Replace the water pump if necessary. Refer to Procedure 008-062.
OK Go To Next Step	
STEP 11 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047.
OK Go To Next Step	
STEP 12 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 Go To Next Step	
STEP 13 Cooling system component is malfunctioning	Perform the cooling system diagnostics test. Refer to Procedure 008-020.

Coolant Temperature Below Normal

This is symtom tree t024

Cause	Correction
STEP 1 Coolant temperature gauge or sensor is malfunctioning	Test the gauge and the sensor. Repair or replace, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Excessive coolant flow through OEM plumbing and heater cores	Close valves to heater cores. Run engine. If engine operates at normal temperature, refer to the OEM service manual.
OK Go To Next Step	
STEP 3 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 Go To Next Step	
STEP 4 Engine is operating at low ambient temperature	Check the winterfront, shutters, and under-the-hood air. Use under-the-hood intake air in cold weather. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-027.
OK Go To Next Step	
STEP 6 Cooling system component is malfunctioning	Perform the cooling system diagnostics test. Refer to Procedure 008-020.

Coolant in the Lubricating Oil

This is symtom tree t025

Cause	Correction
STEP 1 Lubricating oil cooler is malfunctioning	Check the oil cooler. Refer to Procedure 007-003.
OK Go To Next Step	
STEP 2 Air compressor cylinder head is cracked or porous, or has a leaking gasket	Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-014.
OK Go To Next Step	
STEP 3 Cylinder head core and expansion plugs leaking or misassembled	Check cylinder head. Refer to Procedure 002-004.
OK Go To Next Step	
STEP 4 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-021.
OK Go To Next Step	
STEP 5 Cylinder head is cracked or porous	Pressure-test the cylinder head. Refer to Procedure 002-004.
OK Go To Next Step	
STEP 6 Cylinder block is cracked or porous	Remove the oil pan. Pressure-test the cooling system to check for leaks. Refer to Procedure 008-020.

Crankcase Gases (Blowby) Excessive

This is symtom tree t027

Cause	Correction
STEP 1 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedures 003-002 and 003-018.
OK Go To Next Step	
STEP 2 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 Go To Next Step	
STEP 3 Exhaust or engine brake is malfunctioning	Check the exhaust or engine brake for correct operation. Refer to Procedure 020-004.
OK Go To Next Step	
STEP 4 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033.
OK Go To Next Step	
STEP 5 Valve stem clearance is excessive or the valve stem seals are damaged	Check the valve stems and seals. Refer to Procedure 002-004.
OK Go To Next Step	
STEP 6 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 Go To Next Step	
STEP 7 Cylinder liner, pistons, or piston rings are worn or damaged	Check the pistons, piston rings, and cylinder liner. Refer to Procedures 001-043 and 001-047. Check the pistons for correct part numbers. Refer to Control Parts List (CPL), Bulletin 3379133 or 4021327.

Engine Brake Does Not Operate

This is symtom tree t036

Cause	Correction
STEP 1 Engine brake on/off switch is off	Turn on the switch.
OK Go To Next Step	
STEP 2 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 Section 1 of the Operation and Maintenance Manual, ISC, ISC^e, and ISL Engines, Bulletin 4021428.
OK Go To Next Step	
STEP 3 Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3, and QSL Engines, Bulletin 3666271 for fault code troubleshooting.
OK Go To Next Step	
STEP 4 Engine brake on/off switch or circuit is malfunctioning	Check the engine brake on/off switch and circuit. Refer to Procedures 020-012 020-015, or Procedures 019-034 and 019-035 in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedures 019-034 and 019-035 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 5 Engine brake harness connectors are loose or broken	Check the engine brake harness connectors. Check the engine brake harness for continuity.
OK Go To Next Step	
STEP 6 Clutch switch or circuit is malfunctioning	Check the clutch switch adjustment, switch, and circuit. Refer to Procedures 019-009 and 019-010 in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedures 019-009 and 019-010 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	

Engine Brake Does Not Operate

This is symtom tree t036

Cause	Correction
STEP 7 Accelerator pedal or lever position sensor or circuit is malfunctioning	Check for foot pedal restriction. Check the accelerator pedal or lever position sensor and circuit. Refer to Procedures 019-085 and 019-086 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedures 019-085 and 019-086 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 8 Service brake pressure switch or circuit is malfunctioning	Check the service brake pressure switch and circuit. Refer to the OEM service manual.
OK Go To Next Step	
STEP 9 Engine electrical ground is malfunctioning	Check engine ground to chassis and chassis ground to battery negative (-) post. Refer to the OEM service manual and Procedure 013-009.
OK Go To Next Step	
STEP 10 Lubricating oil leak (internal)	Check the engine brake control valve and the engine brake piston. Refer to Procedures 020-004.
OK Go To Next Step	
STEP 11 Engine brake lubricating oil passage is restricted	Check the engine brake assembly for restriction. Refer to Procedure 020-004.
OK Go To Next Step	
STEP 12 Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-004.

Engine Brake - Low Retarding Power or Slow to Activate

This is symtom tree t037

Cause	Correction
STEP 1 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 Go To Next Step	
STEP 2 Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 3 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 Section 1 in the Operation and Maintenance Manual, ISC, ISC^e, ISL Engines, Bulletin 4021428.
OK Go To Next Step	
STEP 4 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 Go To Next Step	
STEP 5 Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-004.
OK Go To Next Step	
STEP 6 Engine brake harness connectors are loose or broken	Check the engine brake harness connectors. Check the engine brake harness for continuity.
OK Go To Next Step	
STEP 7 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 Go To Next Step	

Engine Brake - Low Retarding Power or Slow to Activate

This is symtom tree t037

Cause	Correction
STEP 8 Lubricating oil leak (internal)	Check the engine brake control valve and the engine brake piston. Refer to Procedures 020-017.
OK Go To Next Step	
STEP 9 Engine brake solenoid(s) is malfunctioning	Refer to the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 10 Engine brake control valve(s) is malfunctioning	Check the engine brake control valve(s). Replace the engine brake control valve(s) if necessary. Refer to Procedure 020-004.
OK Go To Next Step	
STEP 11 Engine brake lubricating oil passage is restricted	Check the engine brake assembly for restriction. Refer to Procedure 020-004.
OK Go To Next Step	
STEP 12 Turbocharger is malfunctioning	Monitor the turbocharger boost pressure with an electronic service tool. Refer to the Engine Performance Troubleshooting tree in Section TT.

Engine Noise Excessive

This is symtom tree t047

When troubleshooting engine noise complaints, make sure the engine accessories (air compressor, fan clutch, freon compressor, or hydraulic pump) are not the cause of the noise. Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 1 Fan drive belt is loose	Check the belt tension and tighten if necessary. Refer to Procedure 008-002.
OK Go To Next Step	
STEP 2 Fan is loose, damaged, or **not** balanced	Check the fan. Refer to Procedure 008-040.
OK Go To Next Step	
STEP 3 Fan clutch, hydraulic pump, or refrigerant compressor noise is excessive	Isolate each component and check for noise. Refer to Procedures 008-040, 009-016, or the OEM service manual.
OK Go To Next Step	
STEP 4 Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK Go To Next Step	
STEP 5 Air intake or exhaust piping is contacting the chassis or cab	Inspect the air piping, chassis, and cab for contact points. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-037.
OK Go To Next Step	
STEP 7 Lubricating oil is thin or diluted	Refer to Procedure 007-083. If the oil pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK Go To Next Step	
STEP 8 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, refer to Procedure 007-037.
OK Go To Next Step	
STEP 9 Vibration damper is damaged	Inspect the vibration damper. Refer to Procedure 001-051 or Procedure 001-052.
OK Go To Next Step	

Engine Noise Excessive

This is symtom tree t047

When troubleshooting engine noise complaints, make sure the engine accessories (air compressor, fan clutch, freon compressor, or hydraulic pump) are not the cause of the noise. Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 10 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Gradual Overheat symptom tree.
OK Go To Next Step	
STEP 11 Drivetrain noise is excessive	Disconnect the drivetrain. Check for engine noise. Refer to the OEM service manual.
OK Go To Next Step	
STEP 12 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to Procedure 016-002 or 016-003.
OK Go To Next Step	
STEP 13 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK Go To Next Step	
STEP 14 Overhead components are damaged	Inspect the rocker levers, rocker shafts, and valves for damage or excessive wear. Refer to Procedure 003-008.
OK Go To Next Step	
STEP 15 Injector is malfunctioning	Perform the single-cylinder cutout test. Replace the injectors as necessary. Refer to Procedure 006-026 or 014-008.
OK Go To Next Step	
STEP 16 Air compressor noise is excessive	Refer to the Air Compressor Noise Excessive symptom tree.
OK Go To Next Step	
STEP 17 Torque converter is loose	Check the torque converter. Refer to the OEM service manual.
OK Go To Next Step	
STEP 18 Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to the OEM service manual.
OK Go To Next Step	

Engine Noise Excessive

This is symtom tree t047

When troubleshooting engine noise complaints, make sure the engine accessories (air compressor, fan clutch, freon compressor, or hydraulic pump) are not the cause of the noise. Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 19 Gear train backlash is excessive or the gear teeth are damaged	Check the gear backlash and the gear teeth. Refer to Procedure 001-008.
OK Go To Next Step	
STEP 20 Main bearing or connecting rod bearing noise	Refer to the Engine Noise Excessive - Connecting Rod symptom tree or the Engine Noise Excessive - Main Bearing.
OK Go To Next Step	
STEP 21 Turbocharger noise	Refer to the Engine Noise Excessive - Turbocharger symptom tree.
OK Go To Next Step	
STEP 22 Combustion noise excessive	Refer to the Engine Noise Excessive - Combustion Knocks symptom tree.
OK Go To Next Step	
STEP 23 Piston or piston rings are worn or damaged	Check for air intake system leaks. Check the pistons and piston rings for wear or damage. Refer to Procedure 010-024 or 001-047.

Engine Noise Excessive — Combustion Knocks

This is symtom tree t048

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 1 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of high-quality fuel. Refer to the Fuel for Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 2 Air in the fuel system	Check for air in the fuel system. Vent air from the system. Refer to Procedure 006-003.
OK Go To Next Step	
STEP 3 Coolant temperature is above specification	Refer to Procedures 008-018 and 008-020.
OK Go To Next Step	
STEP 4 Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-026 and 014-008.
OK Go To Next Step	
STEP 5 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK Go To Next Step	
STEP 6 Camshaft timing is **not** correct (after engine rebuild or repair)	Check the gear train timing alignment. Refer to Procedure 001-012.

Engine Noise Excessive — Connecting Rod

This is symtom tree t049

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 1 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 007-037 and 007-009.
OK Go To Next Step	
STEP 2 Lubricating oil pressure is below specification	Check the oil pressure. Refer to Procedure 007-037. If the pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK Go To Next Step	
STEP 3 Lubricating oil is thin or diluted	Refer to Procedure 007-083. If the oil pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK Go To Next Step	
STEP 4 Block stiffener plate is misassembled	Remove and inspect block stiffener plate. Refer to Procedure 001-089.
OK Go To Next Step	
STEP 5 Lubricating oil suction or transfer tube misassembled	Remove and inspect the lubricating oil suction or transfer tube. Refer to Procedure 007-035.
OK Go To Next Step	
STEP 6 Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to Procedure 001-016.
OK Go To Next Step	
STEP 7 Connecting rod capscrews are loose or **not** tightened correctly	Check the torque on the connecting rod capscrews. Refer to Procedure 001-014.
OK Go To Next Step	
STEP 8 Connecting rod is bent or out of alignment	Remove and inspect the connecting rods. Refer to Procedure 001-014.
OK Go To Next Step	

Engine Noise Excessive — Connecting Rod

This is symtom tree t049

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 9 Connecting rod and bearings are damaged or worn, are **not** assembled correctly, or are the wrong bearings	Inspect the connecting rod and bearings. Refer to Procedure 001-014.

Engine Noise Excessive — Main Bearing

This is symtom tree t050

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 1 Lubricating oil pressure is below specification	Check the oil pressure. Refer to Procedure 007-037. If the pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK Go To Next Step	
STEP 2 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 007-037 and 007-009.
OK Go To Next Step	
STEP 3 Lubricating oil is thin or diluted	Refer to Procedure 007-083. If the oil pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK Go To Next Step	
STEP 4 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 Go To Next Step	
STEP 5 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 Go To Next Step	
STEP 6 Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to Procedure 001-016.
OK Go To Next Step	
STEP 7 Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-005.

Engine Noise Excessive — Piston

This is symtom tree t051

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 1 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of high-quality fuel. Refer to the Fuels for Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 2 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK Go To Next Step	
STEP 3 Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-026 and 014-008.
OK Go To Next Step	
STEP 4 Connecting rod is bent or out of alignment	Remove and inspect the connecting rods. Refer to Procedure 001-014.
OK Go To Next Step	
STEP 5 Connecting rod is misassembled	Remove and inspect the connecting rod. Refer to Procedure 001-014.
OK Go To Next Step	
STEP 6 Piston is misassembled	Remove and inspect the piston. Refer to Procedure 001-043 or 001-054.
OK Go To Next Step	
STEP 7 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 or 001-054.

Engine Noise Excessive — Turbocharger

This is symtom tree t052

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 1 Turbocharger is **not** correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin 3379133 or 4021327. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK Go To Next Step	
STEP 2 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 Go To Next Step	
STEP 3 Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK Go To Next Step	
STEP 4 Air intake or exhaust piping is contacting the chassis or cab	Inspect the air piping, chassis, and cab for contact points. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Exhaust system restriction is **not** within specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK Go To Next Step	
STEP 6 Turbocharger is worn or damaged	Check the turbocharger for damage. Measure the turbine and compressor wheel clearances. Refer to Procedure 010-033.

Engine Vibration Excessive

This is symtom tree t075

Cause	Correction
STEP 1 Engine is misfiring	Refer to the Engine Performance symptom tree.
OK Go To Next Step	
STEP 2 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. Refer to Section 1 in the Operation and Maintenance Manual, ISC, ISCe, ISL Engines, Bulletin 4021428.
OK Go To Next Step	
STEP 3 Belt-driven accessories are malfunctioning	Check the fan hub, alternator, refrigerant compressor, and hydraulic pump for interference. Isolate belt-driven accessories and check for vibration. Refer to Procedures 008-027 and 008-039.
OK Go To Next Step	
STEP 4 Fan is loose, damaged, or **not** balanced	Check the fan. Refer to Procedure 008-040.
OK Go To Next Step	
STEP 5 Gear-driven accessories are malfunctioning	Check the hydraulic pump and air compressor. Isolate gear-driven accessories and check for vibration. Refer to Procedures 009-016 and 012-014.
OK Go To Next Step	
STEP 6 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to Procedures 016-002 and 016-003.
OK Go To Next Step	
STEP 7 Vibration damper is damaged	Inspect the vibration damper. Refer to Procedures 001-051 and 001-052.
OK Go To Next Step	
STEP 8 Drivetrain 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 service manual.
OK Go To Next Step	

Engine Vibration Excessive

This is symtom tree t075

Cause	Correction
STEP 9 Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-005.
OK Go To Next Step	
STEP 10 Flywheel housing is **not** aligned correctly	Check the flywheel housing alignment. Refer to Procedure 016-006.
OK Go To Next Step	
STEP 11 Power take-off (PTO) is damaged	Check the PTO for damage and correct installation. Refer to the OEM service manual.
OK Go To Next Step	
STEP 12 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083.

Engine Will Not Crank or Cranks Slowly (Electric Starter)

This is symtom tree t078

Cause	Correction
STEP 1 Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to Procedure 013-007 and Procedure 019-087 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedure 019-087 in Troubleshooting and Repair Manual, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.

OK
Go To Next Step

STEP 2 Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009.

OK
Go To Next Step

STEP 3 Battery capacity is below specification	Refer to Procedure 013-007. Replace the batteries if necessary.

OK
Go To Next Step

STEP 4 Battery cables are **not** the correct gauge or length	Replace the battery cables with larger gauge or shorter length cables. Refer to Procedure 013-009.

OK
Go To Next Step

STEP 5 OEM starter interlock devices engaged	Check the starter interlock devices. Refer to the OEM service manual.

OK
Go To Next Step

STEP 6 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 the OEM service manual.

OK
Go To Next Step

STEP 7 Engine-driven units are engaged	Disengage engine-driven units.

OK
Go To Next Step

STEP 8 Starting circuit component is malfunctioning	Check the starting circuit components. Refer to Section 13.

OK
Go To Next Step

STEP 9 Starting motor pinion or ring gear is damaged	Remove the starting motor, and inspect the gear. Refer to Procedure 013-020.

OK
Go To Next Step

Engine Will Not Crank or Cranks Slowly (Electric Starter)

This is symtom tree t078

Cause	Correction
STEP 10 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.
OK Go To Next Step	
STEP 11 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedures 007-013 and 007-037.
OK Go To Next Step	
STEP 12 Crankshaft rotation is impaired	Check the crankshaft for ease of rotation. Refer to Procedure 001-016.
OK Go To Next Step	
STEP 13 Hydraulic lock in a cylinder	Remove the injectors and rotate the crankshaft. Look for the source of fluid in the cylinder. Refer to Procedure 006-026.
OK Go To Next Step	
STEP 14 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083.

Engine Will Not Shut Off

This is symtom tree t081

Cause	Correction
STEP 1 Keyswitch circuit is malfunctioning	Check the vehicle, equipment, or vessel keyswitch circuit. Refer to Procedure 019-064 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedure 019-064 in Troubleshooting and Repair Manual, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.

OK
Go To Next Step

STEP 2 Starting aid is malfunctioning	Check for correct operation of cold-starting aid. Refer to Procedures 005-008 and 010-029.

OK
Go To Next Step

STEP 3 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedures 010-033.

OK
Go To Next Step

STEP 4 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 manual.

OK
Go To Next Step

STEP 5 Electronic control module (ECM) is malfunctioning	Replace the ECM. Refer to Procedure 019-031 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedure 019-031 in Troubleshooting and Repair Manual, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.

Fuel in Coolant

This is symtom tree t091

Cause	Correction
STEP 1 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 Go To Next Step	
STEP 2 Cylinder head is cracked or porous	Remove intake and exhaust manifolds. Check for evidence of coolant leak. If necessary, operate engine at low idle. Pressure-test the cylinder head. Refer to Procedure 002-004.

Fuel in the Lubricating Oil

This is symtom tree t092

Cause	Correction
STEP 1 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.
OK Go To Next Step	
STEP 2 Injector o-rings are damaged or missing	Remove and check the injectors. Replace the injector o-rings. Refer to Procedure 006-026 in the Troubleshooting and Repair Manual, ISC, QSC8.3, ISL, and QSL9 Series Engines, Engines, Bulletin 4021418.
OK Go To Next Step	
STEP 3 Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-026 or 014-008 in the Troubleshooting and Repair Manual, ISC, QSC8.3, ISL, and QSL9 Series Engines, Engines, Bulletin 4021418.
OK Go To Next Step	
STEP 4 Fuel injection pump is malfunctioning	Inspect the cam housing for cracks and damage. Refer to Procedure 005-088 in the Troubleshooting and Repair Manual, ISC, QSC8.3, ISL, and QSL9 Series Engines, Engines, Bulletin 4021418.
OK Go To Next Step	
STEP 5 Fuel injection pump is malfunctioning	Replace the accumulator module. Refer to Procedure 005-085 in the Troubleshooting and Repair Manual, ISC, QSC8.3, ISL, and QSL9 Series Engines, Engines, Bulletin 4021418.
OK Go To Next Step	
STEP 6 Fuel injection pump is malfunctioning	Inspect the injection pump gear pump module oil seal. Replace gear pump module if there are signs or leakage. Refer to Procedure 005-025 in the Troubleshooting and Repair Manual, ISC, QSC8.3, ISL, and QSL9 Series Engines, Engines, Bulletin 4021418.
OK Go To Next Step	

Fuel in the Lubricating Oil

This is symtom tree t092

Cause	Correction
STEP 7 Cylinder head is cracked or porous	Remove intake and exhaust manifolds. Check for evidence of coolant leak. If necessary, operate engine at low idle. Pressure-test the cylinder head. Refer to Procedure 002-004 in the Troubleshooting and Repair Manual, ISC, QSC8.3, ISL, and QSL9 Series Engines, Engines, Bulletin 4021418.
OK Go To Next Step	
STEP 8 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with noncontaminated oil. Replace the oil filters. Refer to Procedures 007-037 and 007-013 in the Troubleshooting and Repair Manual, ISC, QSC8.3, ISL, and QSL9 Series Engines, Engines, Bulletin 4021418.
OK Go To Next Step	
STEP 9 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to an Authorized Cummins Repair Facility.

Intake Manifold Air Temperature Above Specification

This is symtom tree t096

Cause	Correction
STEP 1 Fan drive belt is broken	Check the fan drive belt. Replace the belt, if necessary. Refer to Procedure 008-002.
OK Go To Next Step	
STEP 2 Fan drive belt is loose	Check the belt tension and tighten if necessary. Refer to Procedure 008-002.
OK Go To Next Step	
STEP 3 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 387 cm^2 [60 in^2] of opening at all times. Refer to Section 1 of the Operation and Maintenance Manual, ISC, ISC^e, ISL Engines, Bulletin 4021428.
OK Go To Next Step	
STEP 4 Charge air cooler fins, radiator fins, or air conditioner condenser fins are damaged or obstructed with debris	Inspect the charge air cooler, air conditioner condenser, and radiator fins. Clean, if necessary. Refer to Procedure 010-027.
OK Go To Next Step	
STEP 5 Intake manifold temperature gauge is malfunctioning, if equipped	Test the temperature gauge. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 7 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 Procedure 019-078 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedure 019-078 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	

Intake Manifold Air Temperature Above Specification

This is symtom tree t096

Cause	Correction
STEP 8 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 019-045 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedure 019-045 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 9 Fan is **not** correct	Check the fan part number and compare it to the OEM-specified part number. Replace fan if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 10 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.
OK Go To Next Step	
STEP 11 Vehicle speed is too low for adequate cooling with high engine load	Reduce the engine load. Increase the engine (fan) rpm by downshifting.
OK Go To Next Step	
STEP 12 Exhaust system leaking hot air into engine compartment	Check the exhaust plumbing for leaks or broken components. Refer to Procedure 010-024.
OK Go To Next Step	
STEP 13 Intake manifold pressure sensor is malfunctioning	Check the intake manifold pressure sensor. Refer to Procedure 019-061 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedure 019-061 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 14 Vehicle cooling system is **not** adequate	Verify that the engine and vehicle cooling systems are using the correct components. Refer to the OEM service manual.
OK Go To Next Step	

Intake Manifold Air Temperature Above Specification

This is symtom tree t096

Cause	Correction
STEP 15 Fan is **not** an adequate size for the application	Verify that the fan is the correct size. Refer to the OEM service manual.

Lubricating Oil Consumption Excessive

This is symtom tree t102

Cause	Correction
STEP 1 Verify the oil consumption rate	Check the amount of oil added versus the mileage.
OK Go To Next Step	
STEP 2 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 7.
OK Go To Next Step	
STEP 3 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-018 and 003-002.
OK Go To Next Step	
STEP 4 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedures 007-037 and 007-013. Use the oil type recommended in Section V of the operation and maintenance manual.
OK Go To Next Step	
STEP 5 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to Section 2 in the Operations and Maintenance Manual, ISC, ISC^e, ISL Engines, Bulletin 4021428.
OK Go To Next Step	
STEP 6 Air compressor is pumping lubricating oil into the air system	Check the air lines for carbon buildup and lubricating oil. Refer to Procedure 012-003.
OK Go To Next Step	
STEP 7 Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks. Refer to Procedure 007-003.
OK Go To Next Step	
STEP 8 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.
OK Go To Next Step	
STEP 9 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033.
OK Go To Next Step	

Lubricating Oil Consumption Excessive

This is symtom tree t102

Cause	Correction
STEP 10 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 Procedure 001-043 and 001-047.
OK Go To Next Step	
STEP 11 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated symptom tree.
OK Go To Next Step	
STEP 12 Piston or piston rings are worn or damaged	Check for air intake system leaks. Check the pistons and piston rings for wear or damage. Refer to Procedure 010-024.
OK Go To Next Step	
STEP 13 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083.

Lubricating Oil Contaminated

This is symtom tree t103

Cause	Correction
STEP 1 Identify lubricating oil contamination	Perform an oil analysis to determine the contaminants.
OK Go To Next Step	
STEP 2 Fuel in the lubricating oil	Refer to the Fuel in the Lubricating Oil symptom tree.
OK Go To Next Step	
STEP 3 Internal coolant leaks	Refer to the Coolant Loss - Internal symptom tree.
OK Go To Next Step	
STEP 4 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with noncontaminated oil. Replace the oil filters. Refer to Procedures 007-013 and 007-037.

Lubricating Oil Pressure High

This is symtom tree t104

Cause	Correction
STEP 1 Coolant temperature is below specification	Refer to the Coolant Temperature is Below Normal symptom tree.
OK Go To Next Step	
STEP 2 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedures 007-037 and 007-013. Use the oil type recommended in Section V of the operation and maintenance manual.
OK Go To Next Step	
STEP 3 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 the OEM service manual.
OK Go To Next Step	
STEP 4 Lubricating oil pressure sensor or circuit is malfunctioning (electronic controlled fuel system)	Check the lubricating oil pressure sensor and circuit. Refer to Procedure 019-066 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedure 019-066 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 5 Main oil pressure regulator is malfunctioning	Check the main oil pressure regulator assembly. Refer to Procedure 007-029.

Lubricating Oil Pressure Low

This is symtom tree t105

Cause	Correction
STEP 1 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 the OEM service manual.
OK Go To Next Step	
STEP 2 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedures 007-037 and 007-009.
OK Go To Next Step	
STEP 3 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 7.
OK Go To Next Step	
STEP 4 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007-013. Use the oil type recommended in Section V of the operation and maintenance manual.
OK Go To Next Step	
STEP 5 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated symptom tree.
OK Go To Next Step	
STEP 6 Engine angularity during operation exceeds specification	Refer to to the engine performance curves and data sheet.
OK Go To Next Step	
STEP 7 Lubricating oil pressure sensor or circuit is malfunctioning (electronic controlled fuel system)	Check the lubricating oil pressure sensor and circuit. Refer to Procedure 019-066 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedure 019-066 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 8 Main oil pressure regulator is malfunctioning	Check the main oil pressure regulator assembly. Refer to Procedure 007-029.
OK Go To Next Step	

Lubricating Oil Pressure Low

This is symtom tree t105

Cause	Correction
STEP 9 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 Go To Next Step	
STEP 10 Lubricating oil pump is malfunctioning	Inspect the lubricating oil pump. Refer to Procedure 007-031.
OK Go To Next Step	
STEP 11 Lubricating oil cooler is plugged	Check the oil cooler. Refer to Procedure 007-003.
OK Go To Next Step	
STEP 12 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 Go To Next Step	
STEP 13 Internal engine damage or internal lubricating oil leak	Analyze the lubricating oil. Inspect the oil filter. Check the main bearings, rod bearings, cam bushings, and rocker lever bushings for excessive wear. Refer to Procedure 007-083 and Section 1.

Lubricating Oil Temperature Above Specification

This is symtom tree t107

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Section TF in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 2 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal symptom tree.
OK Go To Next Step	
STEP 3 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-037.
OK Go To Next Step	
STEP 4 Lubricating oil temperature switch, gauge, or sensor malfunctioning or **not** in the correct location	Check the oil temperature switch, gauge, or sensor for correct operation and location. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 OEM components cooled with engine lubricating oil are malfunctioning	Check OEM components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Lubricating oil cooler is plugged	Check the oil cooler. Refer to Procedure 007-003.
OK Go To Next Step	
STEP 7 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083.

Lubricating or Transmission Oil in the Coolant

This is symtom tree t108

Cause	Correction
STEP 1 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with noncontaminated oil. Replace the oil filters. Refer to Procedures 007-037, 007-013, and 007-083.
OK Go To Next Step	
STEP 2 Lubricating oil cooler is malfunctioning	Check the oil cooler. Refer to Procedure 007-003.
OK Go To Next Step	
STEP 3 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 Go To Next Step	
STEP 4 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-004.
OK Go To Next Step	
STEP 5 Cylinder head is cracked or porous	Remove intake and exhaust manifolds. Check for evidence of coolant leak. If necessary, operate engine at low idle. Pressure-test the cylinder head. Refer to Procedure 002-004.
OK Go To Next Step	
STEP 6 Air compressor cylinder head is cracked or porous, or has a leaking gasket	Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-014.
OK Go To Next Step	
STEP 7 Cylinder block is cracked or porous	Inspect the cylinder block. Refer to Procedure 008-020.

Turbocharger Leaks Engine Oil or Fuel

This is symtom tree t122

Cause	Correction
STEP 1 Engine is operating for extended periods under light- or no-load conditions (slobbering)	Review the engine operating instructions in Section 1 of the Operation and Maintenance Manual, ISC, ISC^e, and ISL Engines, Bulletin 4021428; QSC8.3 Engines, Bulletin 3666398; or QSL9 Engines, Bulletin 3666472.
OK Go To Next Step	
STEP 2 White smoke is present	Refer to the Smoke, White - Excessive symptom tree.
OK Go To Next Step	
STEP 3 Lubricating oil lines leak oil	Check all oil lines and fittings for leaks. Tighten loose fittings and replace leaking oil lines if necessary.
OK Go To Next Step	
STEP 4 Turbocharger oil drain line is restricted	Remove the turbocharger oil drain line and check for restriction. Clean or replace the oil drain line. Refer to Procedure 010-045.
OK Go To Next Step	
STEP 5 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-018.
OK Go To Next Step	
STEP 6 Lubricating oil or fuel is entering the turbocharger	Remove the intake and exhaust piping, and check for oil or fuel.
OK Go To Next Step	
STEP 7 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 Go To Next Step	
STEP 8 Exhaust system restriction is **not** within specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK Go To Next Step	
STEP 9 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedures 010-033.
OK Go To Next Step	

Turbocharger Leaks Engine Oil or Fuel

This is symtom tree t122

Cause	Correction
STEP 10 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 Procedure 010-033.

OK
Go To Next Step

STEP 11 Valve stem clearance is excessive or the valve stem seals are damaged	Check the valve stems and seals. Refer to Procedures 002-004.

Troubleshooting Overview

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 take-off, 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 handheld digital tachometer can help 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.

(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 on 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.

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

Connecting rods with excessive clearance will knock at all engine speeds 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.

(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 that 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 a steady speed.

Driveability - General Information

Driveability is a term that 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 issue 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 issue the vehicle is experiencing. Complete the checklist before troubleshooting the issue. 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, explain 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 issues. 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 that can be caused by any of the following factors:

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

Low power is 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 issue. The chart starts off with basic items that 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 gear shifting
- 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
- Accelerator 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 3387245.

Driveability/Low Power - Customer Complaint Form

Customer Name/Company/Driver_____Date_____

Describe Problem/Complaint_____
Symptoms of the Problem/Complaint
When cranking:
____Cranks too slowly
____Cranks OK but does not start easily
____Cranks OK but does not start
____Slow start; _____ seconds
____Starts then dies
____Idle RPM is rough when engine is cold
____Idle RPM is rough when engine is hot
When driving
____Misses or hesitates during acceleration
____Misses or hesitates during deceleration
____Stalls (dies) during acceleration
____Stalls (dies) during deceleration
____Smokes: ___ black ___ white
____Low power
____Unusal engine _____
When do you notice the Problem/Complaint occuring?
Engine conditions:
When the coolant temperature for the engine is:
___ cold ___ normal ___ hot ___ all temperatures
When the engine is ____ RPM on the tachometer
Weather conditions:
___ cold (below 10°C [50°F]) ___ hot (above 27°C [80°F]) ___ humid or rainy ___ other _____
When driving:
____Accelerating
____Decelerating
____Climbing a grade / hill
____Down hill
____Braking
____Unloaded
____Loaded
How did the problem occur? Suddenly _____ Gradually _____
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 selected programmable parameters? Yes _____ No _____
If so, what was repaired and when?_____
Does the vehicle also experience poor fuel economy? Yes _____ No _____

Answer questions 7 through 10 using selections (A through F) listed below. Circle the letter or letters that best describe the complaint.

A - Compared to fleet, B - compared to competition, C - compared to previous engine

D - Personal expectation, E - will **not** pull on hill, F - will **not** pull on flat terrain

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 _____
Gross vehicle weight _____
A B C D E F
Has the vehicle's load changed? Yes _____ No _____
Is the vehicle able to pull the load? Yes _____ No _____

When?

_____ On hilly terrain
_____ With a loaded trailer
_____ On flat terrain
_____ Other _____

If no was the answer to the previous questions, fill out the Driveability/Low Power/Excessive Fuel Consumption Checklist and go to the Low Power performance tree.

A B C D E F

Is the vehicle slow to accelerate or respond? Yes _____ No _____

When?

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 E F

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

If yes was the answer to the previous two questions, fill out the Driveability/Low Power/ Excessive Fuel Consumption Checklist and go to the Poor Acceleration/Response performance tree.

Additional Comments:

- _____
  _____
  _____

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Driveability/Low Power/Excessive Fuel Consumption - Checklist

Vehicle/Equipment Specifications

Year, Type, and Model:
_____

Transmission (RT 14609, and so forth): _____,

Duty Cycle:_____,

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

Typical Gross Vehicle Weight: _____, Engine Rating: _____

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

Tire Size (11R x 24.5, low profile, and so forth) _____

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 Number:			SC Number:		
Fuel Pump Code:			Fuel Pump Serial Number:		
Mileage:			Engine Serial Number.:		
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:			Conditions (Wind, Rain, Snow):		
Fuel Type:	No. 1D	No. 2D	Other		
Typical Terrain:	Flat	Hilly	% Asphalt		% Concrete

Additional Comments:

_____

_____

NOTE: Use this information for VE/VMS® run.

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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 partial-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. For example, 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 continuous crosswinds and head winds. Less fuel can be used on north/south routes where parts of the trip are **not only** warmer, but also have 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 has a sizable effect on fuel economy and performance. Changing from a bias ply to low-profile radial tire can reduce rolling resistance by about 36 percent.
8. **Additional Devices Using the Same Fuel Source:** Additional devices may use the same fuel tank as the vehicle. For example, excessive use of generators or reefers can falsely indicate high fuel consumption.

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 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 issue (low power orpoor acceleration/response)? Yes _____ No _____

1. Is the problem seasonal? Yes _____ No _____
2. Weather conditions during fuel consumption check? Rain _____, Snow _____, Wind _____, Hot temperatures _____, Cold temperatures _____
3. How is the fuel mileage measured? Tank _____, Trip _____, Month _____, Year _____Hubometer _____, Odometer _____
4. Are accurate records kept of fuel added on the road? Yes _____ No _____
5. Do routes vary between compared vehicles? Yes _____ No _____
6. Have routes changed for the engine being checked? Yes _____ No _____
7. What are the loads hauled, compared to comparison unit? Gross Vehicle Weight _____Heavier _____, Lighter _____
8. What is the altitude during operation?Below 10,000 feet _____, Above 10,000 feet _____
9. How much of the time is the truck spent idling? Hours/day _____
10. Is the driver technique or operating practices affecting fuel economy?

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

- High road speed: mph _____
- Operate at rated speed or above: rpm _____
- Incorrect shift rpm: Shift rpm _____, Torque peak _____
- Operate at a cruise speed: rpm _____
- Compensating for low power: Yes _____ No _____

IF, AFTER FILLING OUT THIS FORM, IT APPEARS THAT THE ISSUE 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 titled Technical Overview of Oil Consumption, Bulletin 3379214.

Cummins 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

Oil Consumption

Cummins Inc., Box 3005 Columbus, IN, U.S.A. 47202-3005 15200020					
Engine Lubricating Oil Consumption Report					
Owner's Name	Date of Delivery Month / Day / Year			Engine Serial Number	
Address	Equipment Manufacturer			Engine Model and hp	
City	State/Province	Equipment Serial Number		Fuel Pump Serial Number	
Engine Application (describe)	Oil and Filter Change Interval Oil / Filters			Complaint Originally Registered Date / Mile/Hours/Kilometers	
Lubricating Oil Added					
Date Added Oil	Engine OperationMiles/ 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 Inc. Form 4755

Oil Consumption

Cummins Inc., Box 3005 Columbus, IN, U.S.A. 47202-3005 15200020	
OIL CONSUMPTION REPORT	
Customer Name:	D/r:
Engine Model:	Mi/Km/Hr:
Engine Serial Number:	CPL Number:
Vehicle Make/Model:	Date:
Signed: _____	

Section TT - Troubleshooting Symptoms (New Format)

Section Contents

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Engine Performance Troubleshooting Tree - CM554 Electronic Control System with CAPS Fuel System

This troubleshooting procedure should be followed for the following symptoms:

- Engine Acceleration or Response Poor
- Cranking Fuel Pressure is Low
- Engine Operating Fuel Pressure is Low
- Engine Decelerates Slowly
- Engine Difficult to Start or Will Not Start (Exhaust Smoke)
- Engine Difficult to Start or Will Not Start (No Exhaust Smoke)
- Engine Power Output Low
- Engine Runs Rough at Idle
- Engine Runs Rough or Misfires
- Engine Speed Surges at Low or High Idle
- Engine Speed Surges Under Load or in Operating Range
- Smoke, Black - Excessive
- Smoke, White - Excessive
- Engine Shuts Off or Dies Unexpectedly or Dies During Deceleration
- Engine Starts But Will Not Keep Running
- Engine Will Not Reach Rated Speed (RPM)
- Intake Manifold Pressure (Boost) is Below Normal

How to Use This Troubleshooting Procedure:

This symptom tree can be used to troubleshoot all performance-based symptoms listed above. Start by performing Step 1 troubleshooting. Step 2 will ask a series of questions and will provide a list of troubleshooting steps to perform depending on the symptom. Perform the list of troubleshooting in the sequence shown in the Specifications/Repair section of the tree.

Shop Talk:

Driveability is a term that 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.

Low power is a term that is used in the field to describe many different performance problems. 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.

Poor acceleration or response is described 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 because it can be caused by several factors.

TROUBLESHOOTING SUMMARY

STEPS	SPECIFICATIONS	SRT CODE

STEP 1: Perform basic troubleshooting procedures.

- STEP 1A: Check for active fault codes or high counts of inactive fault codes.
- STEP 1B: Perform basic troubleshooting checks.

STEP 2: Determination of engine symptom.

- STEP 2A: Low power, poor acceleration, or poor response.
- STEP 2B: Engine misfire, engine speed surge, or engine speed unstable.
- STEP 2C: Excessive white or black smoke.
- STEP 2D: Low intake manifold pressure.
- STEP 2E: Engine will not start or difficult to start, or engine shuts off unexpectedly.

STEP 3: No-start troubleshooting procedures.

- STEP 3A: Check the ECM keyswitch voltage.
- STEP 3B: Check the ECM battery supply voltage.
- STEP 3C: Verify the operation of cold weather starting aids.
- STEP 3D: Check the fuel lift pump pressure.
- STEP 3E: Verify fuel pressure sensor accuracy.
- STEP 3F: Check the accumulator pressure.
- STEP 3G: Check the CPS crank state with INSITE™.
- STEP 3H: Inspect the rate shape snubber valve for debris.
- STEP 3I: Measure the gear pump pressure.
- STEP 3J: Perform the ICV click test.
- STEP 3K: Perform the PCV click test.
- STEP 3L: Check the distributor rotor timing.
- STEP 3M: Inspect the gear pump coupling for wear.

STEP 4: Fuel system troubleshooting procedures.

- STEP 4A: Check for fault codes.
- STEP 4B: Check the CAPS fuel pump wiring.
- STEP 4C: Check for air in the high-pressure pump fuel supply.
- STEP 4D: Measure the fuel inlet restriction.
- STEP 4E: Measure the gear pump pressure.

STEP 4F: Perform the ICV click test.

STEP 4G: Perform the PCV click test.

STEP 4H: Measure fuel drain line restriction.

STEP 4I: Perform the single cylinder cutout test.

STEP 4J: Check for excessive injector drain leakage.

STEP 4K: Pop test the injectors.

STEP 4L: Inspect the gear pump coupling for wear.

STEP 5: Air handling troubleshooting procedures.

STEP 5A: Inspect the turbocharger blades for damage.

STEP 5B: Check the turbocharger axial and radial clearances.

STEP 5C: Inspect the wastegate actuator rod for travel.

STEP 5C-1: Inspect the wastegate actuator rod for travel.

STEP 6: Electronic feature troubleshooting procedures.

STEP 6A: Verify throttle pedal travel.

STEP 6B: Check ambient air pressure sensor accuracy (if equipped).

STEP 6C: Check intake manifold pressure sensor accuracy.

STEP 6D: Verify electronic feature settings are correct.

STEP 7: Base engine troubleshooting procedures.

STEP 7A: Verify overhead adjustments are correct.

STEP 7B: Verify engine brake adjustment (if equipped).

STEP 7C: Inspect the charge air cooler.

STEP 7D: Check air intake restriction.

STEP 7E: Check exhaust restriction.

STEP 7F: Check engine blowby.

STEP 7F-1: Verify turbocharger contribution to engine blowby.

TROUBLESHOOTING STEP

STEP 1: Perform basic troubleshooting procedures.

STEP 1A: Check for active fault codes or high counts of inactive fault codes.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
check for active fault codes. • Use INSITE™ to read the fault codes.	Active fault codes or high counts of inactive fault codes? **YES**	Go to appropriate fault code troubleshooting tree
	Active fault codes or high counts of inactive fault codes? **NO**	1B

STEP 1B: Perform basic troubleshooting checks.

Condition:

Action	Specification/Repair	Next Step
the following items must be checked or verified before continuing: • Verify the fuel level in the tanks, regardless of what the gauge reads. • Verify there have **not** been any changes to CPL components on the engine. • Verify fuel grade is correct for the application. • Verify the engine is operating within the recommended altitude. • Verify engine oil is at the correct level. • Verify engine parasitics have **not** changed. • Verify engine duty cycle has **not** changed. • Verify engine cranking speed is greater than 150 rpm. • Verify battery voltage is adequate.	All steps have been verified to be correct? **YES**	2A
	All steps have been verified to be correct? **NO** **Repair:** Correct the failure and verify complaint is no longer present after repair.	Repair complete

STEP 2: Determination of engine symptom.

STEP 2A: Low power, poor acceleration, or poor response.

Condition:		
Action	**Specification/Repair**	**Next Step**
interview the driver and verify the complaint.	Is the engine symptom low power, poor acceleration, or poor response? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom low power, poor acceleration, or poor response? **NO**	2B

STEP 2B: Engine misfire, engine speed surge, or engine speed unstable.

Condition:		
Action	**Specification/Repair**	**Next Step**
interview the driver and verify the complaint.	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable? **NO**	2C

STEP 2C: Excessive white or black smoke.

Condition:		
Action	**Specification/Repair**	**Next Step**
interview the driver and verify the complaint.	Is the engine symptom Excessive White or Black Smoke? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 5 - Air Handling Checks • Step 4 - Fuel System Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom Excessive White or Black Smoke? **NO**	2D

STEP 2D: Low intake manifold pressure.

Condition:		
Action	**Specification/Repair**	**Next Step**
interview the driver and verify the complaint.	Is the engine symptom Low Boost Pressure? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 5 - Air Handling Checks • Step 4 - Fuel System Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom Low Boost Pressure? **NO**	2E

STEP 2E: Engine will not start or difficult to start, engine shuts off unexpectedly.

Condition:		
Action	**Specification/Repair**	**Next Step**
interview the driver and verify the complaint.	Is the symptom Engine Will Not Start or Difficult to Start, or Engine Shuts Off Unexpectedly? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 3 - No Start Checks • Step 4 - Fuel System Checks • Step 7 - Base Engine Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the symptom Engine Will Not Start or Difficult to Start, or Engine Shuts Off Unexpectedly? **NO**	Return to correct symptom tree

STEP 3: No-start troubleshooting procedures.

STEP 3A: Check the ECM keyswitch voltage.

Condition: • Disconnect the OEM harness from the ECM. • Turn keyswitch ON.		
Action	**Specification/Repair**	**Next Step**
measure the signal voltage from the keyswitch input signal wire of the oem harness to the engine block ground. **NOTE:** Measure the keyswitch voltage with the keyswitch in the ON position and also with the keyswitch in the START position. Refer to the wiring diagram for connector pin identification.	Is the keyswitch voltage equal to battery voltage? **YES**	3B
	Is the keyswitch voltage equal to battery voltage? **NO** **Repair:** Repair or replace the OEM power harness, keyswitch, or check the battery connections.	Repair complete

STEP 3B: Check the ECM battery supply voltage.

Condition:
- Turn keyswitch OFF.
- Disconnect the ECM power harness from the ECM.

Action	Specification/Repair	Next Step
measure the voltage from the ecm battery supply (+) to the ecm battery supply (-) pins in the oem harness connector. Refer to the wiring diagram for connector pin identification.	Is the ECM battery supply voltage equal to the battery voltage? **YES**	3C
	Is the ECM battery supply voltage equal to the battery voltage? **NO** **Repair:** Repair or replace the ECM power harness. Check the battery connections and fuse terminals.	Repair complete

STEP 3C: Verify the operation of cold weather starting aids.

Condition:

Action	Specification/Repair	Next Step
make sure the intake air heater and other cold starting aids are operational, if equipped. Refer to Procedures 008-011 and 010-029.	If equipped, are cold weather starting aids operating correctly? **YES**	3D
	If equipped, are cold weather starting aids operating correctly? **NO** **Repair:** Repair cold weather starting aids. Refer to Procedure 010-029.	Repair complete

STEP 3D: Check the fuel lift pump pressure.

Condition:
- Refer to Procedure 005-045.

Action	Specification/Repair	Next Step
measure the fuel lift pump output pressure. Refer to Procedure 005-045. **NOTE:** At initial key-on, the lift pump will run for 30 seconds, then it will stop. **NOTE:** Lift pump pressure can be low if fuel prime was lost. Multiple keyswitch cycles can be necessary to prime the fuel system using the electric lift pump.	Is the fuel lift pump pressure greater than the specifications outlined in Procedure 005-045? **YES**	3E
	Is the fuel lift pump pressure greater than the specifications outlined in Procedure 005-045? **NO** **Repair:** Find and repair the cause of low lift pump pressure. Refer to Procedure 005-045.	Repair complete

STEP 3E: Verify fuel pressure sensor accuracy.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to monitor accumulator pressure. **NOTE:** The engine speed **must** be zero for at least one minute before performing this test.	Is the Accumulator Pressure value less than 34.5 bar [500 psi]? **YES**	3F
	Is the Accumulator Pressure value less than 34.5 bar [500 psi]? **NO** **Repair:** Replace the fuel pressure sensor. Refer to Service Bulletin 4021293 or 4021294.	Repair complete

STEP 3F: Check the accumulator pressure.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to read accumulator pressure while cranking the engine.	Is Accumulator Pressure greater than 293 bar [4250 psi] while cranking? **YES**	3L
	Is Accumulator Pressure greater than 293 bar [4250 psi] while cranking? **NO**	3G

STEP 3G: Check the CPS crank state with INSITE™.

Condition:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
use insite™ to monitor cps state while cranking the engine.	Does CPS State read Valid Sync while cranking? **YES**	3H
	Does CPS State read Valid Sync while cranking? **NO** **Repair:** Troubleshoot the engine speed sensor circuit. Refer to Fault Codes 115 and 121.	Repair complete

STEP 3H: Inspect the rate shape snubber valve for debris.

Condition:
- Engine serial number is before 46030376. If engine serial number is higher, go to Step 3I.
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
remove the rate shape snubber from the accumulator. Refer to Procedure 005-081.	Is metallic spring debris found? **YES** **Repair:** Replace the fuel injection pump. Refer to Procedure 005-229.	Repair complete
	Is metallic spring debris found? **NO**	3I

STEP 3I: Measure gear pump pressure.

Condition:
- Connect a fuel pressure gauge to the Compuchek® fitting on the cam housing.

Action	Specification/Repair	Next Step
measure the gear pump pressure while cranking the engine. Refer to Procedure 005-089.	Is the fuel gear pump pressure greater than the specifications outlined in Procedure 005-089? **YES**	3J
	Is the fuel gear pump pressure greater than the specifications outlined in Procedure 005-089? **NO**	3L

STEP 3J: Perform the ICV click test.

Condition:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
use insite™ to perform the icv click test. Refer to Procedure 005-078.	Does the ICV pass the click test? **YES**	3K
	Does the ICV pass the click test? **NO** **Repair:** Replace the injection control valve stator. Refer to Procedure 019-430 in the Electronic Control System ISC, QSC8.3, and ISL Engines Troubleshooting and Repair Manual, Bulletin 3666271.	Repair complete

STEP 3K: Perform the PCV click test.

Condition:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
use insite™ to perform the front and rear pcv click test. Refer to Procedure 005-079.	Do the PCV's pass the click test? **YES** **Repair:** Replace the injection control valve module. Refer to Procedure 005-086.	Repair complete
	Do the PCV's pass the click test? **NO** **Repair:** Replace the accumulator module. Refer to Procedure 005-085.	Repair complete

STEP 3L: Check the distributor rotor timing.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
inspect the distributor rotor timing and check for a seized rotor. Refer to Procedure 005-072.	Distributor rotor timing is correct as outlined in Procedure 005-072? **YES**	3M
	Distributor rotor timing is correct as outlined in Procedure 005-072? **NO** **Repair:** Replace the fuel injection pump. Refer to Procedure 005-229.	Repair complete

STEP 3M: Inspect the gear pump coupling for wear.

Condition:
- Turn keyswitch OFF.
- Remove the gear pump module.

Action	Specification/Repair	Next Step
inspect the gear pump drive shaft coupling and shaft for wear. Refer to Procedure 005-089.	Is the gear pump drive shaft or coupling worn? **YES** **Repair:** Replace the gear pump module. Refer to Procedure 005-045.	Repair complete
	Is the gear pump drive shaft or coupling worn? **NO** **Repair:** Replace the injection control valve. Refer to Procedure 005-086.	Repair complete

STEP 4: Fuel system troubleshooting procedures.

STEP 4A: Check for fault codes.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to read the fault code information. Check for active fuel system fault codes related to the complaint.	Are fuel system fault codes active? **YES** **Repair:** Follow the appropriate troubleshooting tree.	Repair complete
	Are fuel system fault codes active? **NO**	4B

STEP 4B: Check the CAPS fuel pump wiring.

Condition:		
Action	**Specification/Repair**	**Next Step**
check the icv, pcv's, fuel pressure sensor, and fuel temperature sensor wiring for damage, cuts, and loose connections.	All fuel pump wiring is undamaged and is properly connected? **YES**	4C
	All fuel pump wiring is undamaged and is properly connected? **NO** **Repair:** Replace the failed fuel system component.	Repair complete

STEP 4C: Check for air in the high-pressure pump fuel supply.

Condition: • Refer to Procedure 006-003.		
Action	**Specification/Repair**	**Next Step**
check for air in the fuel. Refer to Procedure 006-003.	Is air present in the fuel supply? **YES** **Repair:** Locate and correct the cause of air ingestion in the fuel supply system. Sources of air ingestion include loose fuel filters, loose fuel line fittings, loose or cracked fuel tank stand-pipes, and severe restrictions in the fuel supply lines and filters.	Repair complete
	Is air present in the fuel supply? **NO**	4D

STEP 4D: Measure the fuel inlet restriction.

Condition:
- Perform this check during the complaint.

Action	Specification/Repair	Next Step
measure the fuel inlet restriction. Refer to Procedure 006-020.	Is the fuel inlet restriction less than the specifications outlined in Procedure 006-020? **YES**	4E
	Is the fuel inlet restriction less than the specifications outlined in Procedure 006-020? **NO** **Repair:** Locate the cause of the high inlet restriction. Check the OEM fuel inlet plumbing, fuel filters, and lift pump check valve.	Repair complete

STEP 4E: Measure the fuel gear pump pressure.

Condition:
- Connect a fuel pressure gauge to the Compuchek® fitting on the cam housing.

Action	Specification/Repair	Next Step
measure the gear pump pressure while the engine is at the rated condition. Refer to Procedure 005-045.	Is the fuel gear pump pressure greater than the specifications outlined in Procedure 005-045? **YES**	4F
	Is the fuel gear pump pressure greater than the specifications outlined in Procedure 005-045? **NO** **Repair:** Replace the fuel gear pump module. Refer to Procedure 005-045.	Repair complete

STEP 4F: Perform the ICV click test.

Condition:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
use insite™ to perform the icv click test. Refer to Procedure 005-078.	Does the ICV pass the click test? **YES**	4G
	Does the ICV pass the click test? **NO** **Repair:** Replace the injection control valve stator. Refer to Procedure 019-430 in the Electronic Control System ISC, QSC8.3, and ISL Engines Troubleshooting and Repair Manual, Bulletin 3666271.	Repair complete

STEP 4G: Perform the PCV click test.

Condition:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
use insite™ to perform the front and rear pcv click test. Refer to Procedure 005-079.	Do the PCV's pass the click test? **YES**	4H
	Do the PCV's pass the click test? **NO** **Repair:** Replace the accumulator module. Refer to Procedure 005-085.	Repair complete

STEP 4H: Measure fuel drain line restriction.

Condition:
- Refer to Procedure 006-012.
- Perform this check during the complaint.

Action	Specification/Repair	Next Step
check the fuel drain line restriction. Refer to Procedure 006-012.	Is the drain line restriction less than specification? **YES**	4I
	Is the drain line restriction less than specification? **NO** **Repair:** Look for causes of high drain line restriction such as kinked or blocked fuel lines.	Repair complete

STEP 4I: Perform the single cylinder cutout test.

Condition:
- Turn keyswitch ON.
- Engine running at low idle.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
operate the engine at loaded conditions. • Use INSITE™ to perform the Single Cylinder Cutout Test to disable individual injectors.	Can the miss or excessive smoke be attributed to a single cylinder? **YES** **Repair:** Replace the fuel injector in the cylinder that was identified using the single cylinder cutout test. Refer to Procedure 006-026.	Repair complete
	Can the miss or excessive smoke be attributed to a single cylinder? **NO**	4J

STEP 4J: Check for excessive injector drain leakage.

Condition:
- Remove the fuel injector drain banjo fitting from the back of the cylinder head.

Action	Specification/Repair	Next Step
run the engine at low idle while monitoring the amount of fuel draining from the back of the cylinder head.	**Only** a few drops per minute draining from the back of the cylinder head? **YES**	4K
	Only a few drops per minute draining from the back of the cylinder head? **NO** **Repair:** A bad connection between the high-pressure connector and an injector has been detected. Remove all high-pressure connectors and check for burrs or deformation around the tip of the injector. Refer to Procedure 006-052.	Repair complete

STEP 4K: Pop test the injectors.

Condition:
- Remove the injectors. Refer to Procedure 006-026.

Action	Specification/Repair	Next Step
pop test the injectors and check for proper spray pattern. Refer to Procedure 006-026.	The injector spray pattern is correct and the injectors pop between 275 and 300 bar [3989 and 4351 psi]? **YES**	4L
	The injector spray pattern is correct and the injectors pop between 275 and 300 bar [3989 and 4351 psi]? **NO** **Repair:** Replace the failed injector. Refer to Procedure 006-026.	Repair complete

STEP 4L: Inspect the gear pump coupling for wear.

Condition:
- Turn keyswitch OFF.
- Remove the gear pump module.

Action	Specification/Repair	Next Step
inspect the gear pump drive shaft coupling and shaft for wear.	Is the gear pump drive shaft or coupling worn? **YES** **Repair:** Replace the gear pump module. Refer to Procedure 005-045.	Repair complete
	Is the gear pump drive shaft or coupling worn? **NO** **Repair:** Replace the injection control valve. Refer to Procedure 005-086.	Repair complete

STEP 5: Air handling troubleshooting procedures.

STEP 5A: Inspect the turbocharger blades for damage.

Condition:
- Turn keyswitch OFF.
- Remove the intake and exhaust pipes from the turbocharger.

Action	Specification/Repair	Next Step
inspect the compressor and turbine blades for damage or wear. Refer to Procedure 010-033.	Damage found on turbocharger blades? **YES** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033.	Repair complete
	Damage found on turbocharger blades? **NO**	5B

STEP 5B: Check the turbocharger axial and radial clearances.

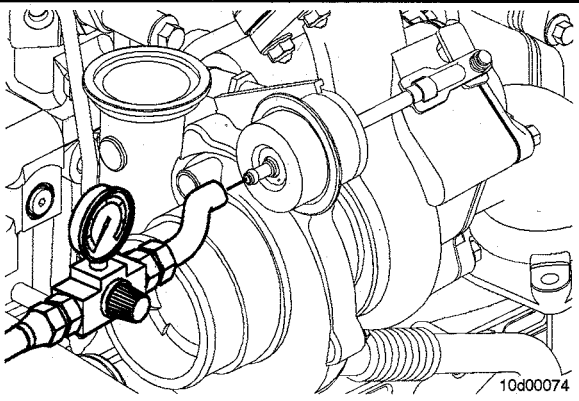
Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
check the turbocharger for correct axial and radial clearance. Refer to Procedures 010-038 and 010-047.	Are the turbocharger axial and radial bearing clearances within specification? **YES**	5C
	Are the turbocharger axial and radial bearing clearance within specification? **NO** **Repair:** Replace the turbocharger. Refer to Procedure 010-033.	Repair complete

STEP 5C: Inspect the wastegate actuator rod for travel.

Condition:
- Turn keyswitch OFF.
- Remove the integral boost line from the wastegate actuator.

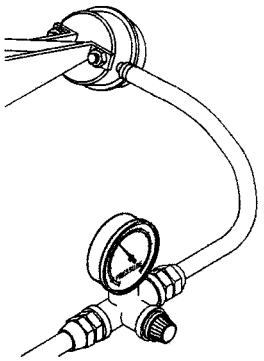
Action	Specification/Repair	Next Step
apply a regulated air supply of 138 kpa [20 psi] to the actuator and check for actuator movement.	Does the wastegate actuator rod move? **YES**	Repair complete
	Does the wastegate actuator rod move? **NO**	5C-1

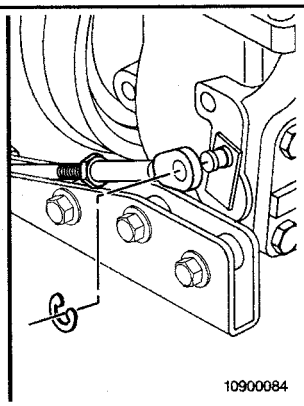


STEP 5C-1: Inspect the wastegate actuator rod for travel.

Condition:
- Turn keyswitch OFF.
- Remove the e-clip from the wastegate pin and disconnect the actuator rod.

Action	Specification/Repair	Next Step
apply a regulated air supply of 138 kpa [20 psi] to the actuator and check for actuator movement.	Does the wastegate actuator rod move? **YES** **Repair:** Move the wastegate lever on the turbocharger back and forth to check for smooth operation. Replace the turbocharger assembly if the wastegate is seized. Refer to Procedure 010-033.	Repair complete
	Does the wastegate actuator rod move? **NO** **Repair:** Replace the wastegate actuator. Refer to Procedure 010-050.	Repair complete





STEP 6: Electronic feature troubleshooting procedures.

STEP 6A: Verify throttle pedal travel.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to monitor throttel position while fully depressing and releasing the throttle pedal.	Does the throttle position read zero when the throttle is released and 100 percent when the throttle is depressed? **YES**	6B
	Does the throttle position read zero when the throttle is released and 100 percent when the throttle is depressed? **NO** **Repair:** Determine and correct the cause of the throttle pedal restriction.	Repair complete

STEP 6B: Check ambient air pressure sensor accuracy (if equipped).

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
start the insite™ data monitor/logger and compare the insite™ reading for barometric air pressure to the local barometric pressure using the table below. Altitude (m) Altitude [ft] Pressure [in Hg] 0 (sea level) 0 29.9 915 3000 26.9 1830 6000 24.0 2744 9000 21.4 3659 12,000 19.0	INSITE™ reading is within 102 mm Hg [4 in Hg] of local barometric pressure? **YES**	6C
	INSITE™ reading is within 102 mm Hg [4 in Hg] of local barometric pressure? **NO** **Repair:** Replace the barometric pressure sensor. Refer to Procedure 019-004 in the CM850 Electronic Control System ISC and ISL Engines Troubleshooting and Repair Manual, Bulletin 4021416.	Repair Complete

STEP 6C: Check intake manifold pressure sensor accuracy.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
start the insite™ data/monitor/logger and read the value of intake manifold pressure.	Intake Manifold Pressure reading is less than 102 mm Hg [4 in Hg]? **YES**	6D
	Intake Manifold Pressure reading is less than 102 mm Hg [4 in Hg]? **NO** **Repair:** Replace the intake manifold pressure sensor. Refer to Procedure 019-061 in the CM850 Electronic Control System ISC and ISL Engines Troubleshooting and Repair Manual, Bulletin 4021416.	Repair complete

STEP 6D: Verify electronic feature settings are correct.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to verify the following adjustable parameters are set correctly: • Maximum Vehicle Speed • Powertrain Protection • Rear Axle Ratio • Tailshaft Teeth • Tire Revolutions per Mile • Gear-Down Protection • Cruise Control Droop Settings • Cruise Control Maximum Vehicle Speed.	Are the electronic features set correctly? **YES**	2A
	Are the electronic features set correctly? **NO** **Repair:** Correct programmable features using the INSITE™ electronic service tool.	Repair complete

STEP 7: Base engine troubleshooting procedures.

STEP 7A: Verify overhead adjustments are correct.

Condition:
- Turn keyswitch OFF.
- Remove the rocker lever cover. Refer to Procedure 003-011.

Action	Specification/Repair	Next Step
measure the overhead settings. Refer to Procedure 003-004.	Are the overhead settings within the reset limits? **YES**	7B
	Are the overhead settings within the reset limits? **NO** **Repair:** Adjust the overhead settings. Refer to Procedure 003-004.	Repair complete

STEP 7B: Verify engine brake adjustment (if equipped).

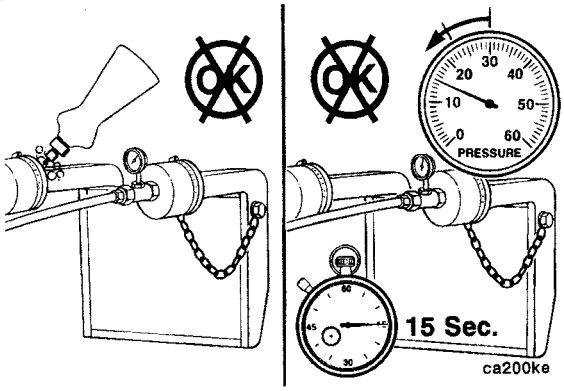
Condition:
- Turn keyswitch OFF.
- Remove the rocker lever cover. Refer to Procedure 003-011.

Action	Specification/Repair	Next Step
verify the engine brakes are operating correctly. • Measure the engine brake settings. Refer to Procedure 020-004.	Are the engine brake settings within the reset limits? **YES**	7C
	Are the engine brake settings within the reset limits? **NO** **Repair:** Adjust the engine brake settings. Refer to Procedure 020-004.	Repair complete

STEP 7C: Inspect the charge air cooler.

Condition:
- Refer to Procedure 010-027.

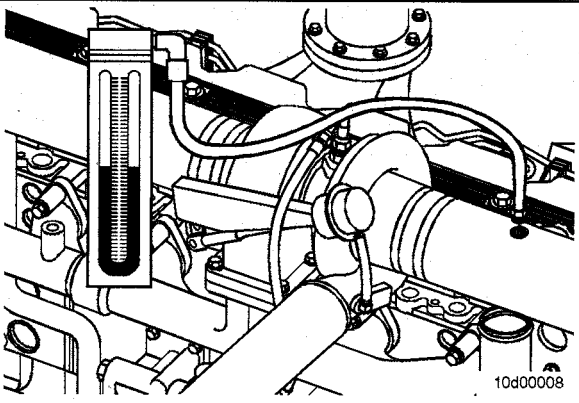
Action	Specification/Repair	Next Step
inspect the charge air cooler for cracks, holes, or damage. Refer to Procedure 010-027.	Is the charge air cooler free of cracks or damage? **YES**	7D
	Is the charge air cooler free of cracks or damage? **NO** **Repair:** Repair the charge air cooler assembly.	Repair complete



STEP 7D: Check air intake restriction.

Condition:
- Refer to Procedure 010-031.

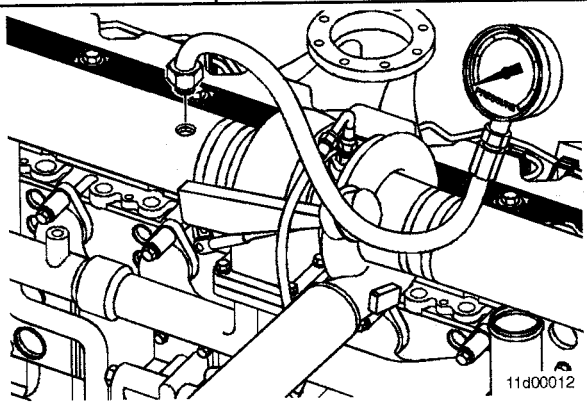
Action	Specification/Repair	Next Step
check the intake system restriction by installing a vacuum gauge into the air intake system. Refer to Procedure 010-031.	Is air intake restriction greater than 635 mm H_2O [25 in H_2O]? **YES** **Repair:** Correct the cause of high intake air restriction. Check for a plugged air filter or restricted air intake piping.	Repair complete
	Is air intake restriction greater than 635 mm H_2O [25 in H_2O]? **NO**	7E



STEP 7E: Check exhaust restriction.

Condition:
- Refer to Procedure 011-009.

Action	Specification/Repair	Next Step
check the exhaust system back pressure by installing a pressure gauge into the exhaust system just past the turbocharger outlet. Refer to Procedure 011-009.	Exhaust back pressure less than 40 in H_2O [3 in Hg]? **YES**	7F
	Exhaust back pressure less than 40 in H_2O [3 in Hg]? **NO** **Repair:** Inspect the exhaust system for the source of high restriction.	Repair complete



STEP 7F: Check engine blowby.

Condition:
- Refer to Procedure 014-005.

Action	Specification/Repair	Next Step
measure the engine blowby. Refer to Procedure 014-005.	Are the engine blowby measurements within specification? **YES**	7F
	Are the engine blowby measurements within specification? **NO**	7F-1

STEP 7F-1: Verify turbocharger contribution to engine blowby.

Condition:
- Turn keyswitch OFF.
- Connect the appropriate orifice to the end of the blowby draft tube.
- Remove the turbocharger oil drain line from the block and drain into a bucket.
- Start the engine.

Action	Specification/Repair	Next Step
load engine to rated rpm on a chassis dynamoter. • Measure the engine blowby as outlined in Procedure 014-005.	Has the total engine blowby dropped more than 30 percent of the total? **YES** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033.	Repair complete
	Has the total engine blowby dropped more than 30 percent of the total? **NO** **Repair:** The engine may need to be rebuilt. Refer to the engine rebuild specifications.	Repair complete

CM850 Electronic Control System

This troubleshooting procedure should be followed for the following symptoms:

- Engine Acceleration or Response Poor
- Cranking Fuel Pressure is Low
- Engine Operating Fuel Pressure is Low
- Engine Decelerates Slowly
- Engine Difficult to Start or Will Not Start (Exhaust Smoke)
- Engine Difficult to Start or Will Not Start (No Exhaust Smoke)
- Engine Power Output Low
- Engine Runs Rough at Idle
- Engine Runs Rough or Misfires
- Engine Speed Surges at Low or High Idle
- Engine Speed Surges Under Load or in Operating Range
- Smoke, Black - Excessive
- Smoke, White - Excessive
- Engine Shuts Off or Dies Unexpectedly or Dies During Deceleration
- Engine Starts but Will Not Keep Running
- Engine Will Not Reach Rated Speed (RPM)
- Intake Manifold Pressure (Boost) is Below Normal

How to Use This Troubleshooting Procedure:

This symptom tree can be used to troubleshoot all performance based symptoms listed above. Start by performing Step 1 troubleshooting. Step 2 will ask a series of questions and will provide a list of troubleshooting steps to perform depending on the symptom. Perform the list of troubleshooting in the sequence shown in the Specifications/Repair section of the tree.

Shop Talk:

Driveability is a term that 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.

Low power is a term that is used in the field to describe many different performance problems. 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.

Poor acceleration or response is described 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 several factors.

TROUBLESHOOTING SUMMARY

STEPS	SPECIFICATIONS	SRT CODE

STEP 1: Perform basic troubleshooting procedures.

- STEP 1A: Check for active fault codes or high counts of inactive fault codes.
- STEP 1B: Perform basic troubleshooting checks.

STEP 2: Determination of engine symptom.

- STEP 2A: Low power, poor acceleration, or poor response.
- STEP 2B: Engine misfire, engine speed surge, or engine speed unstable.
- STEP 2C: Excessive white or black smoke.
- STEP 2D: Low intake manifold pressure.
- STEP 2E: Engine will not start or difficult to start, engine shuts off unexpectedly.

STEP 3: No-start troubleshooting procedures.

- STEP 3A: Verify the operation of cold weather starting aids.
- STEP 3B: Verify the low-pressure fuel lines are routed correctly.
- STEP 3C: Check the ECM keyswitch voltage.
- STEP 3D: Check the ECM battery supply voltage.
- STEP 3E: Check engine speed during cranking.
- STEP 3F: Verify rail fuel pressure sensor accuracy.
- STEP 3G: Check for fuel rail pressure while cranking the engine.
  - STEP 3G-1: Check fuel gear pump pressure.
  - STEP 3G-2: Check fuel lift pump pressure.
- STEP 3H: Check for other fault codes that explain a no-start condition.

STEP 4: Fuel system troubleshooting procedures.

- STEP 4A: Check for fault codes.
- STEP 4B: Check for air in the high-pressure pump fuel supply.
- STEP 4C: Measure fuel gear pump pressure.
  - STEP 4C-1: Measure the fuel inlet restriction.
- STEP 4D: Perform single cylinder cutout test.
- STEP 4E: Perform cylinder balance diagnostic test.

STEP 4F: Measure fuel drain line restriction.

STEP 5: Air handling troubleshooting procedures.

STEP 5A: Inspect the turbocharger blades for damage.

STEP 5B: Check the turbocharger axial and radial clearances.

STEP 5C: Determination of turbocharger type.

STEP 5D: Check variable geometry actuator rod for correct travel.

STEP 5D-1: Check for air leaks and inspect air lines.

STEP 5D-2: Check for air pressure at the turbocharger control valve outlet.

STEP 5D-3: Check for air pressure at turbocharger control valve outlet.

STEP 5D-4: Check for vehicle air tank pressure at turbocharger control valve inlet.

STEP 5D-5: Check for correct turbocharger actuator travel.

STEP 5E: Check for broken shaft inside the turbocharger.

STEP 5F: Inspect wastegate actuator - wastegated turbochargers only.

STEP 5G: Inspect wastegate actuator rod for travel.

STEP 5G-1: Inspect the wastegate actuator rod for travel.

STEP 6: Electronic feature troubleshooting procedures.

STEP 6A: Verify throttle pedal travel.

STEP 6B: Check ambient air pressure sensor accuracy.

STEP 6C: Check intake manifold pressure sensor accuracy.

STEP 6D: Verify electronic feature settings are correct.

STEP 7: Base engine troubleshooting procedures.

STEP 7A: Verify overhead adjustments are correct.

STEP 7B: Verify engine brake adjustment.

STEP 7C: Inspect charge air cooler.

STEP 7D: Check air intake restriction.

STEP 7E: Check exhaust restriction.

STEP 7F: Check engine blowby.

STEP 7F-1: Verify turbocharger contribution to engine blowby.

TROUBLESHOOTING STEP

STEP 1: Perform basic troubleshooting procedures.

STEP 1A: Check for active fault codes or high counts of inactive fault codes.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
check for active fault codes. • Use INSITE™, read the fault codes.	Active fault codes or high counts of inactive fault codes? **YES** **Repair:** Follow the electronic fault code trees for the appropriate troubleshooting procedures.	Repair complete
	Active fault codes or high counts of inactive fault codes? **NO**	1B

STEP 1B: Perform basic troubleshooting checks.

Condition:
None.

Action	Specification/Repair	Next Step
the following items must be checked or verified before continuing: • Verify the fuel level in the tanks • Verify there have **not** been any changes to CPL components on the engine • Verify fuel grade is correct for application • Verify the engine is operating within the recommended altitude • Verify engine oil is at the correct level • Verify engine parasitics have **not** changed • Verify engine duty cycle has **not** changed • Verify engine cranking speed is greater than 150 rpm • Verify battery voltage is adequate.	All steps have been verified to be correct? **YES**	2A
	All steps have been verified to be correct? **NO** **Repair:** Correct the failure and verify complaint is no longer present after repair.	Repair complete

STEP 2: Determination of engine symptoms.

STEP 2A: Low power, poor acceleration, or poor response.

Condition:
None.

Action	Specification/Repair	Next Step
interview the driver and verify the complaint.	Is the engine symptom low power, poor acceleration, or poor response? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom low power, poor acceleration, or poor response? **NO**	2B

STEP 2B: Engine misfire, engine speed surge, or engine speed unstable.

Condition:
None.

Action	Specification/Repair	Next Step
interview the driver and verify the complaint.	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable? **NO**	2C

STEP 2C: Excessive white or black smoke.

Condition: None.		
Action	**Specification/Repair**	**Next Step**
interview the driver and verify the complaint.	Is the engine symptom Excessive White or Black Smoke? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 5 - Air Handling Checks • Step 6 - Fuel System Checks	Perform the troubleshooting steps suggested in the repair procedure.
	Is the engine symptom Excessive White or Black Smoke? **NO**	2D

STEP 2D: Low intake manifold pressure.

Condition: None.		
Action	**Specification/Repair**	**Next Step**
interview the driver and verify the complaint.	Is the engine symptom Low Boost Pressure? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 5 - Air Handling Checks • Step 4 - Fuel System Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom Low Boost Pressure? **NO**	2E

STEP 2E: Engine will not start or difficult to start, engine shuts off unexpectedly.

Condition: None.		
Action	**Specification/Repair**	**Next Step**
interview the driver and verify the complaint.	Is the symptom Engine Will Not Start or Difficult to Start, Engine Shuts Off Unexpectedly? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 3 - No Start Checks • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the symptom Engine Will Not Start or Difficult to Start, Engine Shuts Off Unexpectedly? **NO**	Return to correct symptom tree

STEP 3: No-start troubleshooting procedures.

STEP 3A: Verify the operation of cold weather starting aids.

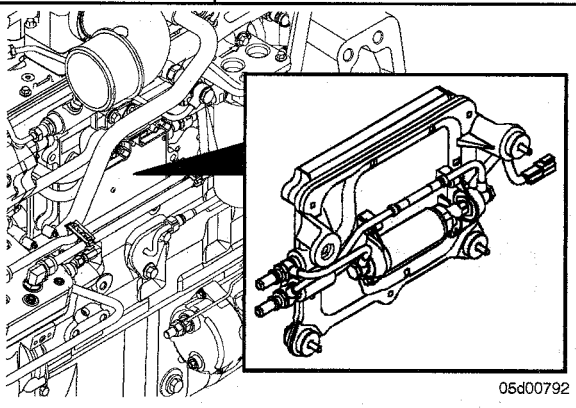
Condition: • Turn keyswitch ON.		
Action	**Specification/Repair**	**Next Step**
make sure the intake air heater and other cold starting aids are operational. Refer to Procedures 008-011 and 010-029.	Are necessary cold weather starting aids operating properly? **YES**	3B
	Are necessary cold weather starting aids operating properly? **NO** **Repair:** Install or repair cold weather starting aids. Refer to Procedure 010-029.	Repair complete

STEP 3B: Verify the low-pressure fuel lines are routed correctly.

Condition:

None.

Action	Specification/Repair	Next Step
it is sometimes possible to get the low-pressure fuel lines connected to the ecm cooling plate installed improperly. the top connection to the ecm cooling plate is the inlet and the bottom connection is the outlet. Verify these connections if the low-pressure fuel lines have been removed and reinstalled on the engine.	Are the low-pressure fuel lines connected properly to the ECM cooling plate? **YES**	3C
	Are the low-pressure fuel lines connected properly to the ECM cooling plate? **NO** **Repair:** Properly connect the low-pressure fuel lines to the ECM cooling plate. The fuel inlet is the top connection.	Repair complete



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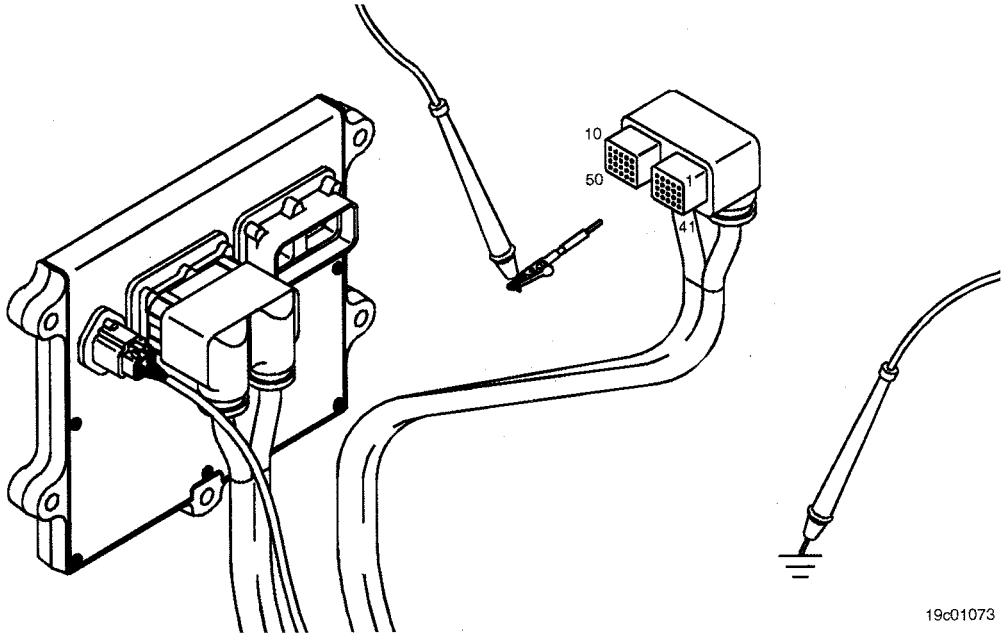
STEP 3C: Check the ECM keyswitch voltage.

Condition:
- Disconnect the OEM harness from the ECM.
- Turn keyswitch ON.

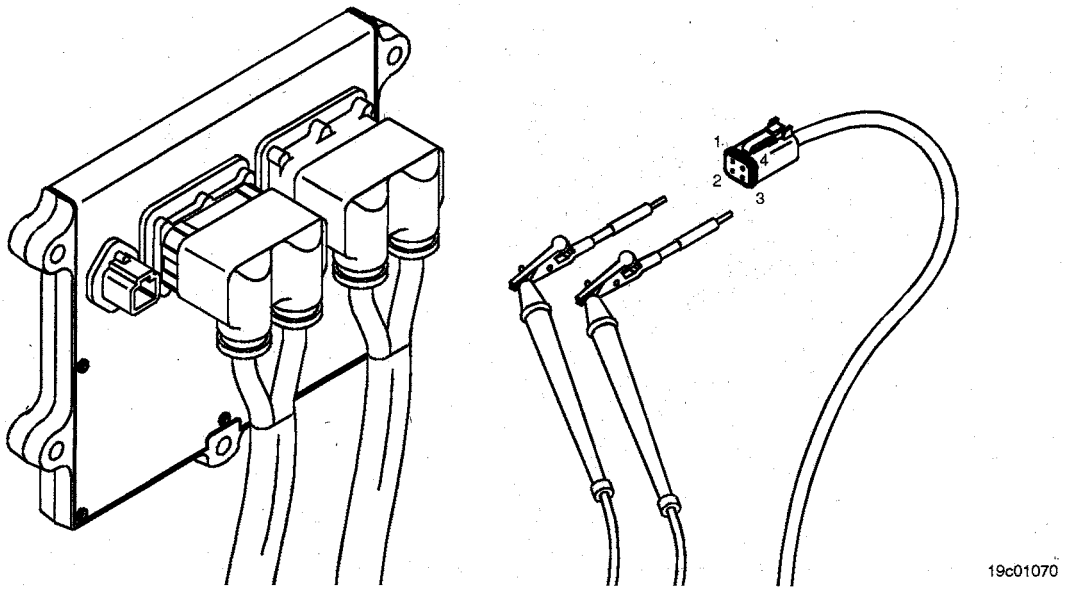
Action	Specification/Repair	Next Step
measure the signal voltage from the keyswitch input signal wire of the oem harness to the engine block ground. Measure the keyswitch voltage with the keyswitch in the ON position and also with the keyswitch in the Cranking position. Refer to the wiring diagram for connector pin identification.	Is the keyswitch voltage equal to battery voltage? **YES**	3D
	Is the keyswitch voltage equal to battery voltage? **NO** **Repair:** Repair or replace the OEM power harness, keyswitch, or check the battery connections.	Repair complete



STEP 3D: Check the ECM battery supply voltage.

Condition:
- Turn keyswitch OFF.
- Disconnect the ECM power harness from the ECM.

Action	Specification/Repair	Next Step
measure the voltage from the ecm battery supply (-) pin to the ecm battery supply (+) pin in the ecm power harness connector. Measure the ECM voltage with the keyswitch in the ON position and also with the keyswitch in the Cranking position. Refer to the wiring diagram for connector pin identification.	Is the ECM battery supply voltage equal to the battery voltage? **YES**	3E
	Is the ECM battery supply voltage equal to the battery voltage? **NO** **Repair:** Repair or replace the ECM power harness. Check the battery connections and fuse terminals.	Repair complete



STEP 3E: Check engine speed during cranking.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to monitor engine speed while cranking the engine.	Is the engine cranking speed greater than 150 rpm? **YES**	3F
	Is the engine cranking speed greater than 150 rpm? **NO** **Repair:** Find and correct the cause for low cranking speed. Check the batteries, engine starting motor, and accessory loads. Refer to Engine Will Not Crank or Cranks Slowly troubleshooting tree.	Repair complete

STEP 3F: Verify rail fuel pressure sensor accuracy.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to monitor the rail fuel pressure sensor (measured) with the keyswitch on and the engine not running.	Is the Rail Fuel Pressure Sensor (Measured) value less than 30 Bar [435 psi]? **YES**	3G
	Is the Rail Fuel Pressure Sensor (Measured) value less than 30 Bar [435 psi]? **NO** **Repair:** Replace the rail fuel pressure sensor. Refer to Procedure 019-115 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.	Repair complete

STEP 3G: Check for fuel rail pressure while cranking the engine.

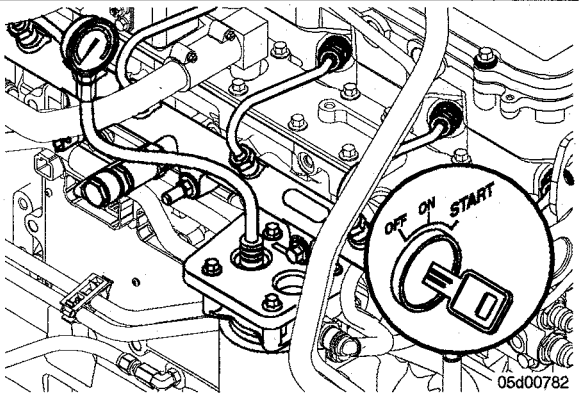
Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
attempt to start the engine by engaging the engine starting motor for at least 30 continous seconds. • Use INSITE™ to monitor Fuel Rail Pressure (Measured) and Fuel Rail Pressure (Commanded). • Use INSITE™ to read the fault codes. Attempting to start the engine for 30 continuous seconds allows the fault code logic time to run. If Fault Code 2215 becomes active, fuel rail pressure is **not** being developed. If the engine starts during this attempt, it is possible that fuel prime to the high pressure pump has been lost. Look for loose fuel lines or filters that allow for loss of fuel prime.	Did Fault Code 2215 become active during the failed the start attempt? **YES**	3G-1
	Did Fault Code 2215 become active during the failed the start attempt? **NO**	3H

STEP 3G-1: Check fuel gear pump pressure.

Condition:
- Install a pressure gauge at the pressure side fuel filter head. Refer to Procedure 005-025.
- Turn keyswitch ON.

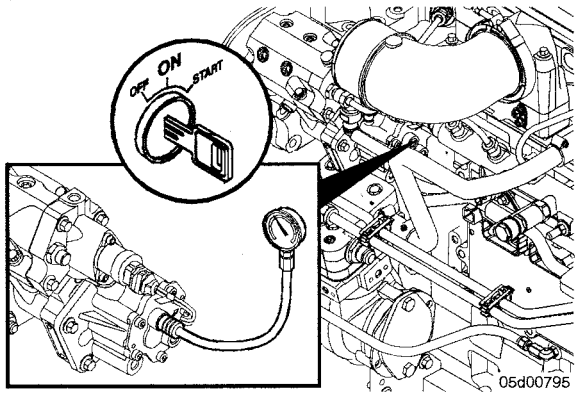
Action	Specification/Repair	Next Step
measure the fuel gear pump output pressure while cranking the engine. Cranking speed **must** be greater than 150 rpm. Refer to Procedure 005-025.	Is the fuel gear pump pressure greater than 138 kPa [20 psi] while cranking? **YES** **Repair:** Follow Fault Code 2215 troubleshooting tree.	Repair complete
	Is the fuel gear pump pressure greater than 138 kPa [20 psi] while cranking? **NO**	3G-2



STEP 3G-2: Check fuel lift pump pressure.

Condition:
- Install a pressure gauge at the inlet port of the high pressure pump gear pump.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
measure the fuel lift pump output pressure. Refer to Procedure 005-045. At initial key-on, the lift pump will run for 60 seconds then stop.	Is the fuel lift pump pressure greater than the specifications outlined in Procedure 005-045? **YES** **Repair:** Replace the fuel gear pump. Refer to Procedure 005-025.	Repair complete
	Is the fuel lift pump pressure greater than the specifications outlined in Procedure 005-045? **NO** **Repair:** Verify fuel prime by making sure the OEM fuel filter is full of fuel and air is purged from the low pressure fuel lines. Perform the INSITE™ Lift Pump Override Test is necessary. If the low pressure fuel system is primed, replace the fuel lift pump. Refer to Procedure 005-045.	Repair complete



STEP 3H: Check for other fault codes that explain a no-start condition.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to read fault code information. Look for fault codes that come active during a failed start attempt that can be the cause for a no-start condition.	Do any fault codes that can cause a no-start condition come active during cranking? **YES** **Repair:** Follow the electronic fault code trees for the appropriate troubleshooting procedures.	Repair complete
	Do any fault codes that can cause a no-start condition come active during cranking? **NO**	4A

STEP 4: Fuel system troubleshooting procedures.

STEP 4A: Check for fault codes.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to read the fault code information. Determine if there are active fuel system fault codes related to the complaint.	Are fuel system fault codes active? **YES** **Repair:** Follow the electronic fault code trees for the appropriate troubleshooting procedures.	Repair complete
	Are fuel system fault codes active? **NO**	4B

STEP 4B: Check for air in the high-pressure pump fuel supply.

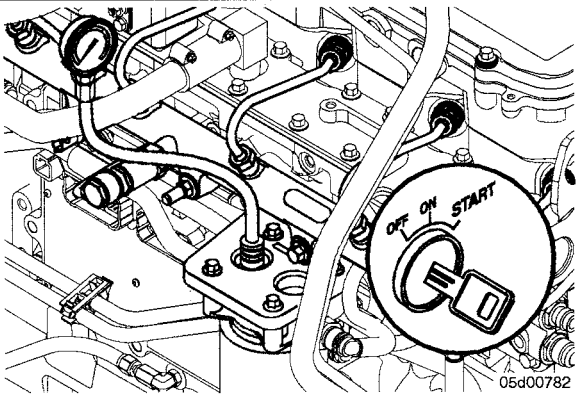
Condition:
- Refer to Procedure 006-003.

Action	Specification/Repair	Next Step
check for air in the fuel. Refer to Procedure 006-003.	Is air present in the fuel supply? **YES** **Repair:** Locate and correct the cause of air ingestion in the fuel supply system. Sources of air ingestion include loose fuel filters, loose fuel line fittings, loose or cracked fuel tank stand-pipes, or severe restrictions in the fuel supply lines and filters.	Repair complete
	Is air present in the fuel supply? **NO**	4C

STEP 4C: Measure fuel gear pump pressure.

Condition:
- Refer to Procedure 005-025.

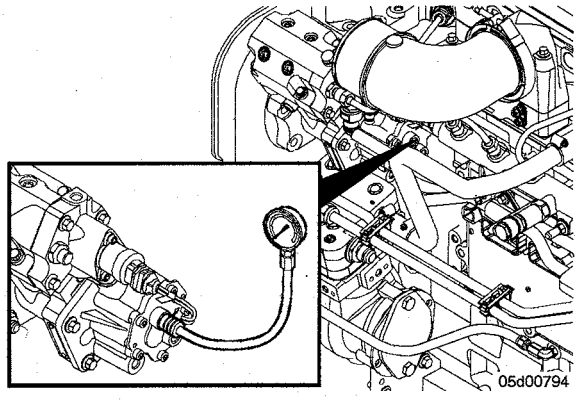
Action	Specification/Repair	Next Step
check the fuel gear pump pressure. Refer to Procedure 005-025.	Is the fuel gear pump pressure within specification? **YES**	4D
	Is the fuel gear pump pressure within specification? **NO**	4C-1



STEP 4C-1: Measure the fuel inlet restriction.

Condition:
- Measure the fuel pump inlet restriction at the diagnostics port on the fuel gear pump. Refer to Procedure 006-020.

Action	Specification/Repair	Next Step
check the fuel inlet restriction. Refer to Procedure 006-020.	Is the fuel inlet restriction above specification? **YES** **Repair:** Find and correct the cause of high inlet restriction. Look for plugged OEM fuel filters or screens, or a restricted ECM cooler, restricted lift pump bypass check valve (in the ECM cooler), pinched OEM fuel lines or restricted stand-pipe in the OEM fuel tank.	Repair complete
	Is the fuel inlet restriction above specification? **NO** **Repair:** Replace the fuel gear pump. Refer to Procedure 005-025.	Repair complete



STEP 4D: Perform single cylinder cutout test.

Condition:
- Turn keyswitch ON.
- Engine running at low idle.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
operate the engine at load. Use INSITE™ to perform the Cylinder Cutout Test to disable individual injectors.	Can the miss or excessive smoke be attributed to a single cylinder? **YES** **Repair:** Look for a cause of the complaint including valve lash and excessive crankcase pressure that can indicate power cylinder damage or camshaft lobe wear. If no other damage is found, replace the fuel injector in the cylinder identified by the single cylinder cutout test. Use the single cylinder cutout test. Refer to Procedure 006-026.	Repair complete
	Can the miss or excessive smoke be attributed to a single cylinder? **NO**	4E

STEP 4E: Perform cylinder balance diagnostic test.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to run the cylinder performance test to determine if a single cylinder is contributing to the engine symptom.	Does the Cylinder Performance Test identify any cylinder that is contributing to a power imbalance? **YES** **Repair:** Look for a cause of the power imbalance including valve lash and excessive crankcase pressure that can indicate power cylinder damage or camshaft lobe wear. If no other damage is found, replace the fuel injector in the cylinder contributing to the power imbalance. Refer to Procedure 006-026.	Repair complete
	Does the Cylinder Performance Test identify any cylinder that is contributing to a power imbalance? **NO**	4F

STEP 4F: Measure fuel drain line restriction.

Condition:
- Refer to Procedure 006-012.

Action	Specification/Repair	Next Step
check the fuel drain line restriction. Refer to Procedure 006-012.	Is the drain line restriction less than specification? **YES**	2A
	Is the drain line restriction less than specification? **NO** **Repair:** Look for causes of high drain line restriction such as kinked or blocked fuel lines.	Repair complete

STEP 5: Air handling troubleshooting procedures.

STEP 5A: Inspect the turbocharger blades for damage.

Condition:
- Turn keyswitch OFF.
- Remove the intake and exhaust pipes from the turbocharger.

Action	Specification/Repair	Next Step
inspect the compressor and turbine blades for damage or wear. Refer to Procedure 010-033.	Damage found on turbocharger blades? **YES** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033.	Repair complete
	Damage found on turbocharger blades? **NO**	5B

STEP 5B: Check the turbocharger axial and radial clearances.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
check the turbocharger for correct axial and radial clearance. Refer to Procedure 010-033.	Are the turbocharger axial and radial bearing clearances within specification? **YES**	5C
	Are the turbocharger axial and radial bearing clearance within specification? **NO** **Repair:** Replace the turbocharger. Refer to Procedure 010-033.	Repair complete

STEP 5C: Determination of turbocharger type.

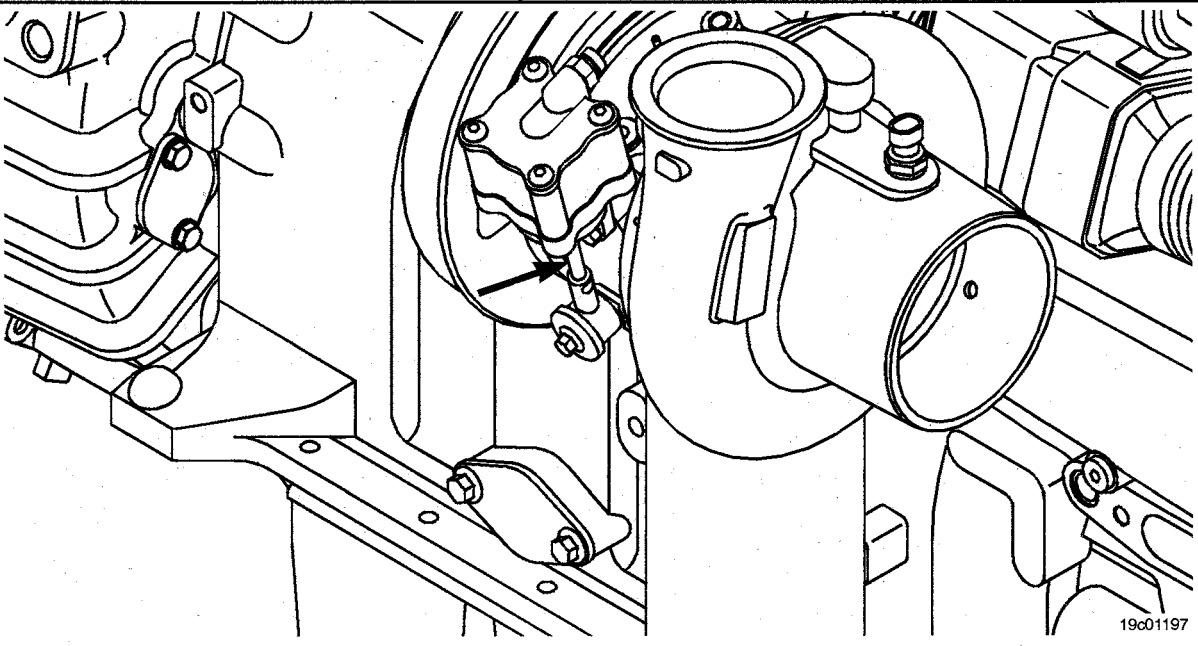
Condition:
None

Action	Specification/Repair	Next Step
determine if the turbocharger is a wastegated or variable geometry turbo.	Is the turbocharger a variable geometry turbocharger? **YES**	5D
	Is the turbocharger a variable geometry turbocharger? **NO**	5F

STEP 5D: Check variable geometry actuator rod for correct travel.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.
- Verify vehicle air tanks are fully charged (greater than 689 kPa [100 psi]).

Action	Specification/Repair	Next Step
use insite™ to start the turbocharger actuator test • Adjust the delay timer in the Turbocharger Actuator Test so that the rod movement can be observed. • Select the Retract Actuator position with INSITE™. • Mark or scribe the variable geometry actuator rod at the base of the actuator. • Select the Extend Actuator position with INSITE™. • Measure the rod travel by measuring the distance from the base of the variable geometry actuator to the scribe mark. The variable geometry actuator **must** move quickly and crisply. If the actuator rod movement is slow, there could be a problem with the air supply or mechanical problems with the variable geometry turbocharger assembly.	Does the turbocharger actuator rod extend between 10.8 and 11.8 mm [0.42 and 0.46 in]? **YES**	5E
	Does the turbocharger actuator rod extend between 10.8 and 11.8 mm [0.42 and 0.46 in]? **NO**	5D-1



STEP 5D-1: Check for air leaks and inspect air lines.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.
- Verify vehicle air tanks are fully charged (greater than 689 kPa [100 psi]).

Action	Specification/Repair	Next Step
use insite™ to perform the turbocharger actuator test. Select the Extended Actuator position and listen for air leaks in the following components: • Turbocharger control valve • Turbocharger control valve inlet connection • Turbocharger control valve outlet connection • Turbocharger actuator inlet connection • Turbocharger actuator • All air lines including OEM supply line to turbocharger control valve and between the turbocharger control valve and the variable geometry turbocharger. A small amount of air will be heard escaping from the turbocharger control valve. This is a normal condition. Do **not** replace the turbocharger control valve for this condition.	Air leaks found in the system or damaged air lines? **YES** **Repair:** Repair air leaks or replace damaged or broken air lines.	Repair complete
	Air leaks found in the system or damaged air lines? **NO**	5D-2

STEP 5D-2: Check for air pressure at the turbocharger control valve outlet.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.
- Verify vehicle air tanks are fully charged (greater than 689 kPa [100 psi]).

Action	Specification/Repair	Next Step
remove the air line connection at the outlet of the turbocharger control valve. Install a Compuchek® fitting in the turbocharger control valve outlet. Install an air pressure gauge that is capable of reading at least 1034 kPa [150 psi]. Use INSITE™ to perform the Turbocharger Actuator Test. Select the Extend position.	Is vehicle tank air pressure present at the turbocharger control valve outlet? **YES**	5D-3
	Is vehicle tank air pressure present at the turbocharger control valve outlet? **NO**	5D-5

STEP 5D-3: Check for air pressure at turbocharger control valve outlet.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.
- Verify vehicle air tanks are fully charged (greater than 689 kPa [100 psi]).

Action	Specification/Repair	Next Step
remove the air line connection at the outlet of the turbocharger control valve. Install an air pressure gauge that is capable of reading at least 1034 kPa [150 psi]. Use INSITE™ to perform the Turbocharger Actuator Test. Select the Retract position.	Can air be heard escaping from the turbocharger control valve outlet? **YES** **Repair:** The turbocharger control valve is stuck open. It **must not** be allowing air to escape when in the Retract position. Replace the turbocharger control valve. Refer to Procedure 019-388 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.	Repair complete
	Can air be heard escaping from the turbocharger control valve outlet? **NO**	5D-4

STEP 5D-4: Check for vehicle air tank pressure at turbocharger control valve inlet.

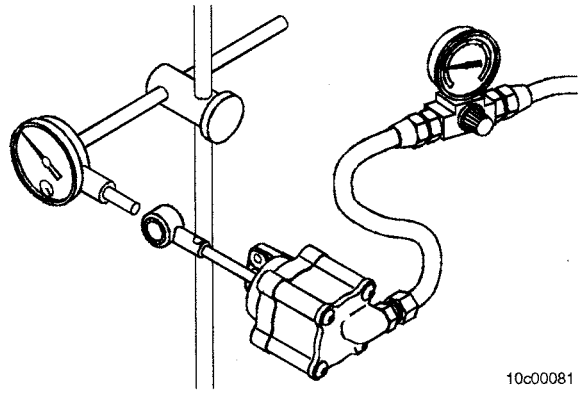
Condition:
- Turn keyswitch ON.
- Verify vehicle air tanks are fully charged (greater than 689 kPa [100 psi]).

Action	Specification/Repair	Next Step
disconnect the air inlet connection to the turbocharger control valve. Verify vehicle air tank pressure is available at the turbocharger control valve inlet.	Vehicle air tank pressure available at the turbocharger control valve inlet? **YES**	5D-5
	Vehicle air tank pressure available at the turbocharger control valve inlet? **NO** **Repair:** No air pressure available at the turbocharger control valve inlet. Troubleshoot OEM air plumbing and determine why air pressure is **not** present.	Repair complete

STEP 5D-5: Check for correct turbocharger actuator travel.

Condition:
- Remove the variable geometry actuator from the turbocharger assembly. Refer to Procedure 010-113.
- Connect INSITE™ electronic service tool.

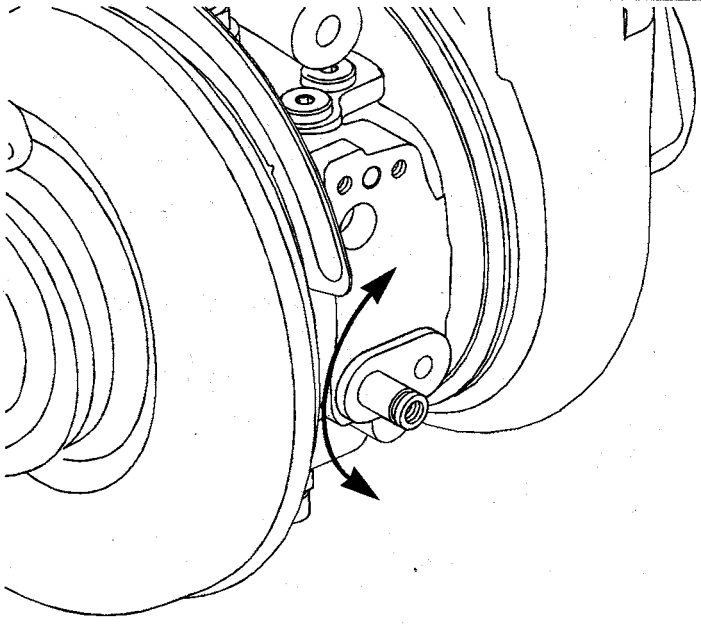
Action	Specification/Repair	Next Step
use insite™ to perform the turbocharger actuator test. Select the Extend Actuator position.	Does the variable geometry actuator rod travel at least 12 mm [0.472 in]? **YES** **Repair:** The variable geometry actuator has correct air pressure and correct travel. The variable geometry mechanism in the turbocharger is seized. Replace the turbocharger assembly. Refer to Procedure 010-033.	Repair complete
	Does the variable geometry actuator rod travel at least 12 mm [0.472 in]? **NO** **Repair:** The variable geometry actuator has correct air pressure but the variable geometry actuator rod is **not** extending. Replace the turbocharger actuator. Refer to Procedure 010-113.	Repair complete



STEP 5E: Check for broken shaft inside the turbocharger.

Condition:
- Turn keyswitch OFF.
- Remove the variable geometry actuator from the turbocharger assembly. Refer to Procedure 010-113.

Action	Specification/Repair	Next Step
check for a broken linkage inside the turbocharger by moving the variable geometry actuator on the turbocharger up and down. The actuator lever **must** move evenly and crisply as it is moved.	Does the sliding nozzle move correctly? **YES**	2A
	Does the sliding nozzle move correctly? **NO** **Repair:** The variable geometry has a mechanical failure inside the turbocharger. The actuator moves properly, but the linkage attaching the actuator to the nozzle is broken. Replace the turbocharger assembly. Refer to Procedure 010-033.	Repair complete



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STEP 5F: Inspect wastegate actuator - wastegated turbochargers only.

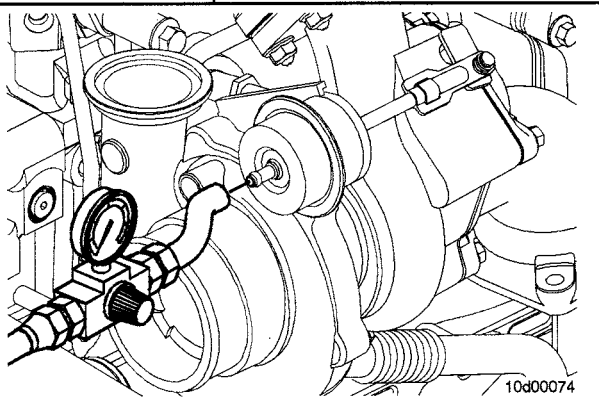
Condition:
- Turn keyswitch OFF.
- Remove the turbocharger if the wastegate actuator is inaccessible.

Action	Specification/Repair	Next Step
inspect the integral wastegate actuator hose for cracks or holes.	Holes or cracks found in the wastegate actuator hose? **YES** **Repair:** Replace the wastegate actuator hose.	Repair complete
	Holes or cracks found in the wastegate actuator hose? **NO**	5G

STEP 5G: Inspect wastegate actuator rod for travel.

Condition:
- Turn keyswitch OFF.
- Remove the integral boost line from the wastegate actuator.

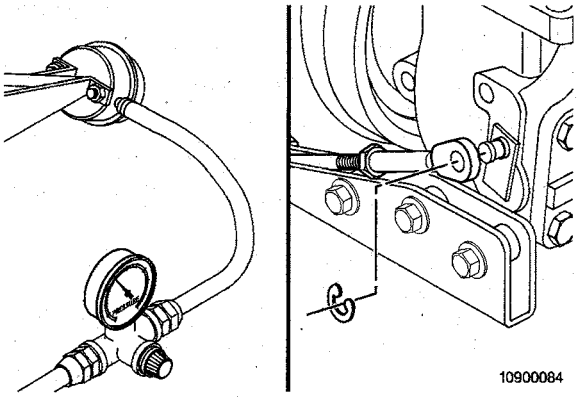
Action	Specification/Repair	Next Step
apply a regulated air supply of 128 kpa [20 psi] to the actuator and check for actuator movement.	Does the wastegate actuator rod move? **YES**	Repair complete
	Does the wastegate actuator rod move? **NO**	5G-1



STEP 5G-1: Inspect the wastegate actuator rod for travel.

Condition:
- Turn keyswitch OFF.
- Remove the e-clip from the wastegate pin and disconnect the actuator rod.

Action	Specification/Repair	Next Step
apply a regulated air supply of 128 kpa [20 psi] to the actuator and check for actuator movement.	Does the wastegate actuator rod move? **YES** **Repair:** Move the wastegate lever on the turbocharger back and forth, and check for smooth operation. Replace the turbocharger assembly if the wastegate is seized. Refer to Procedure 010-033.	Repair complete
	Does the wastegate actuator rod move? **NO** **Repair:** Replace the wastegate actuator. Refer to Procedure 010-050.	Repair complete



STEP 6: Electronic feature troubleshooting procedures.

STEP 6A: Verify throttle pedal travel.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to monitor throttel position while fully depressing and releasing the throttle pedal.	Does the throttle position read 0 when the throttle is released and 100% when the throttle is depressed? **YES**	6B
	Does the throttle position read 0 when the throttle is released and 100% when the throttle is depressed? **NO** **Repair:** Determine and correct the cause of the throttle pedal restriction.	Repair complete

STEP 6B: Check ambient air pressure sensor accuracy.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
start the insite™ data monitor/logger and compare the insite™ reading for barometric air pressure to the local barometric pressure using the table below. Altitude (m) Altitude [ft] Pressure [in-Hg] 0 (sea level) 0 29.9 915 3000 26.9 1830 6000 34.0 2744 9000 21.4 3659 12,000 19.0	INSITE™ reading is within 102 mm-Hg [4 in-Hg] of local barometric pressure? **YES**	6C
	INSITE™ reading is within 102 mm-Hg [4 in-Hg] of local barometric pressure? **NO** **Repair:** Replace the barometric pressure sensor. Refer to Procedure 019-004 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.	Repair Complete

STEP 6C: Check intake manifold pressure sensor accuracy.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to monitor the value of intake manifold pressure without the engine running.	Intake manifold pressure reading is less than 102 mm-Hg [4 in-Hg]? **YES**	6D
	Intake manifold pressure reading is less than 102 mm-Hg [4 in-Hg]? **NO** **Repair:** Replace the intake manifold pressure sensor. Refer to Procedure 019-061 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.	Repair complete

STEP 6D: Verify electronic feature settings are correct.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
use insite™ to verify the following adjustable parameters are correctly set: • Maximum Vehicle Speed • Powertrain Protection • Rear Axle Ratio • Tailshaft Teeth • Tire Revolutions per Mile • Gear-Down Protection • Cruise Control Droop Settings • Cruise Control Maximum Vehicle Speed.	Are the electronic features set correctly? **YES**	2A
	Are the electronic features set correctly? **NO** **Repair:** Correct programmable features Use INSITE™ electronic service tool.	Repair complete

STEP 7: Base engine troubleshooting procedures.

STEP 7A: Verify overhead adjustments are correct.

Condition:
- Turn keyswitch OFF.
- Remove the rocker lever cover. Refer to Procedure 003-011.

Action	Specification/Repair	Next Step
measure the overhead setting. Refer to Procedure 003-004.	Are the overhead settings within the reset limits? **YES**	7B
	Are the overhead settings within the reset limits? **NO** **Repair:** Adjust the overhead settings. Refer to Procedure 003-004.	Repair complete

STEP 7B: Verify engine brake adjustment.

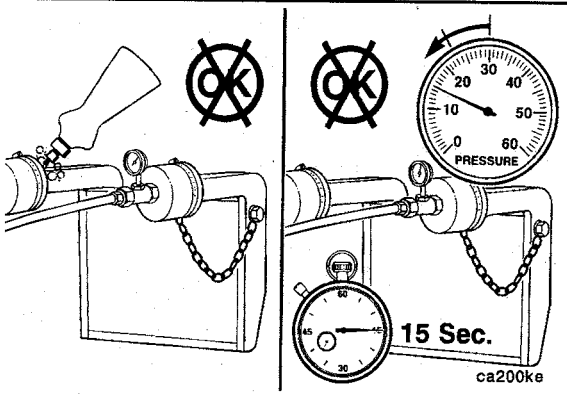
Condition:
- Turn keyswitch OFF.
- Remove the rocker lever cover. Refer to Procedure 003-011.

Action	Specification/Repair	Next Step
verify that the engine brakes are operating correctly. Measure the engine brake settings. Refer to Procedure 020-004.	Are the engine brake settings within the reset limits? **YES**	7C
	Are the engine brake settings within the reset limits? **NO** **Repair:** Adjust the engine brake settings. Refer to Procedure 020-004.	Repair complete

STEP 7C: Inspect charge air cooler.

Condition:
- Refer to Procedure 010-027.

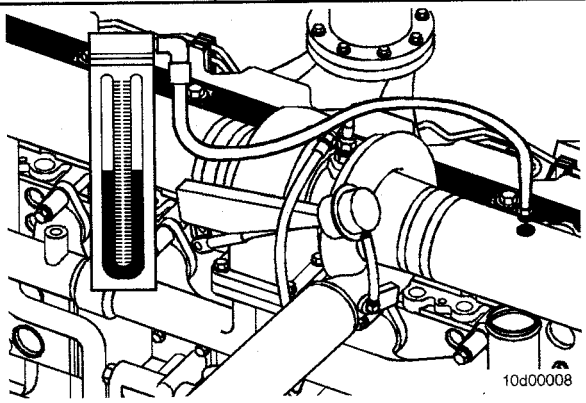
Action	Specification/Repair	Next Step
inspect the charge air cooler for cracks, holes, or damage. Refer to Procedure 010-027.	Is the charge air cooler free of cracks or damage? **YES**	7D
	Is the charge air cooler free of cracks or damage? **NO** **Repair:** Repair the charge air cooler assembly.	Repair complete



STEP 7D: Check air intake restriction.

Condition:
- Refer to Procedure 010-031.

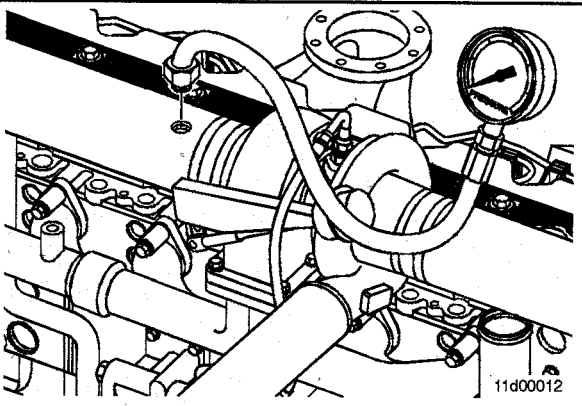
Action	Specification/Repair	Next Step
check the intake system restriction by installing a vacuum gauge into the air intake system. Refer to Procedure 010-031.	Is air intake restriction greater than 635 mm H_2O [25 in H_2O]? **YES** **Repair:** Correct the cause of high intake air restriction. Check for plugged air filter or restricted air intake piping.	Repair complete
	Is air intake restriction greater than 635 mm H_2O [25 in H_2O]? **NO**	7E



STEP 7E: Check exhaust restriction.

Condition:
- Refer to Procedure 011-009.

Action	Specification/Repair	Next Step
check the exhaust system back pressure by installing a pressure gauge into the exhaust system just past the turbocharger outlet. Refer to Procedure 011-009.	Exhaust back pressure less than 76 mm-Hg [3 in-Hg]? **YES**	7F
	Exhaust back pressure less than 76mm-Hg [3 in-Hg]? **NO** **Repair:** Inspect exhaust system for source of high restriction.	Repair complete



STEP 7F: Check engine blowby.

Condition:
- Refer to Procedure 014-005.

Action	Specification/Repair	Next Step
measure the engine blowby as outlined in procedure 014-005.	Are the engine blowby measurements within specification? **YES**	7F
	Are the engine blowby measurements within specification? **NO**	7F-1

STEP 7F-1: Verify turbocharger contribution to engine blowby.

Condition:
- Turn keyswitch OFF.
- Connect the appropriate orifice to the end of the blowby draft tube.
- Remove the turbocharger oil drain line from the block and drain into a bucket.
- Start the engine.

Action	Specification/Repair	Next Step
load engine to rated rpm on a chassis dynamometer. Measure the engine blowby as outlined in Procedure 014-005.	Has the total engine blowby dropped more than 30% of the total? **YES** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033.	Repair complete
	Has the total engine blowby dropped more than 30% of the total? **NO** **Repair:** The engine might need to be rebuilt. Refer to the engine rebuild specifications.	Repair complete

Fuel Economy Troubleshooting Tree

This troubleshooting procedure should be followed for the following symptoms:

- Fuel Consumption Excessive

How to Use This Troubleshooting Procedure:

This symptom tree is to be used to troubleshoot fuel economy complaints. This tree is used along with the Fuel Consumption - Customer Complaint Form and the Driveability Low Power/Excessive Fuel - Consumption Checklist to help isolate engine, chassis, or driver issues associated with excessive fuel consumption.

Shop Talk:

The Fuel Consumption - General Information section of this manual and Troubleshooting Excessive Fuel Consumption, Bulletin 3666094, should be referenced prior to any troubleshooting being performed on a customer's engine.

The cause of excessive fuel consumption is difficult 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 or 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 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.

- Excessive idling time: Idling the engine can use from 0.5 to 1.5 gallons per hour depending on the engine idle speed.
- 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 mile per gallon.
- 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.
- Environmental and Seasonal Weather Changes: There can be as much as 1 to 1.5 mile per gallon difference in fuel consumption, depending on the season and the weather conditions.
- Truck Route and Terrain: East and west routes experience almost continual crosswinds and head winds. Less fuel can be used on north and south routes where parts of the trip are **not** only warmer, but have less wind resistance.
- Driver Technique and Operating Practices: A 1 mile per hour increase in road speed equals a 0.1 mile per gallon 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.
- Result of a Low Power or Driveability Problem: An operator will change driving style to compensate for a low power or driveability problem. Some things the driver is likely to do are (a) shift to a high 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.

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 3387245.

TROUBLESHOOTING SUMMARY

STEPS **SPECIFICATIONS** **SRT CODE**

STEP 1: Verify the complaint.

- **STEP 1A:** Fill out the Fuel Consumption - Customer Complaint Form.
- **STEP 1B:** Run VE/VMS.

STEP 2: Electronic checks using INSITE™.

- **STEP 2A:** Check for fault codes.
- **STEP 2B:** Confirm Features and Parameters.
- **STEP 2C:** Check the ECM calibrations.
- **STEP 2D:** Monitor vehicle speed.
  - **STEP 2D-1:** Inspect the engine and chassis grounds.

STEP 3: Engine performance.

- **STEP 3A:** Engine performance troubleshooting.

TROUBLESHOOTING STEP

STEP 1: Verify the complaint.

STEP 1A: Fill the Fuel Consumption - Customer Complaint Form.

Condition:		
Action	**Specification/Repair**	**Next Step**
fill out the fuel consumption - customer complaint form.	Is the problem caused by vehicle factors, environmental factors, or driver technique? **YES**	Repair complete
	Is the problem caused by vehicle factors, environmental factors, or driver technique? **NO**	1B

STEP 1B: Run VE/VMS.

Condition:		
Action	**Specification/Repair**	**Next Step**
fill out the driveability/low power/excessive fuel consumption - checklist. Use the data gathered to run VE/VMS or provide the data to the appropriate support personnel to run VE/VMS. **NOTE:** VE/VMS does **not** account for adverse ambient conditions.	Taking into consideration the adverse effect of ambient conditions, does the VE/VMS fuel economy conflict with the customer's current fuel economy? **YES**	2A
	Taking into consideration the adverse effect of ambient conditions, does the VE/VMS fuel economy conflict with the customer's current fuel economy? **NO** **Repair:** Explain to the customer the effects of driving habits on fuel consumption.	Repair complete

STEP 2: Electronic checks using INSITE™.

STEP 2A: Check for fault codes.

Condition: • Turn keyswitch ON. • Connect INSITE™ electronic service tool.		
Action	**Specification/Repair**	**Next Step**
using insite™, read the fault codes.	Are there any active or high counts of inactive fault codes? **YES**	Troubleshoot fault codes
	Are there any active or high counts of inactive fault codes? **NO**	2B

STEP 2B: Confirm Features and Parameters.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
confirm the programmable features and parameters are set correctly.	Are the Features and Parameters set correctly? **YES**	2C
	Are the Features and Parameters set correctly? **NO** **Repair:** Reset the Features and Parameters to their appropriate values.	Repair complete

STEP 2C: Check the ECM calibration.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
compare the ecm code with the engine rating and cpl. verify the calibration is correct.	Is the calibration correct? **YES**	2D
	Is the calibration correct? **NO** **Repair:** Recalibrate the ECM with the correct ECM code.	Repair complete

STEP 2D: Monitor vehicle speed.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
with insite™, monitor vehicle speed while the vehicle is not moving.	Does vehicle speed read 0 when the vehicle is not moving? **YES**	3A
	Does vehicle speed read 0 when the vehicle is not moving? **NO**	2D-1

STEP 2D-1: Inspect the engine and chassis grounds.

Condition: • Turn keyswitch OFF.		
Action	**Specification/Repair**	**Next Step**
check for loose or corroded engine, chassis, or battery ground connection. • Check the engine ground connection • Check the chassis ground connections • Check the battery terminal connections.	Are all grounds present, properly grounded, free of corrosion, and tight? **YES** **Repair:** Check the VSS and the VSS circuit. Refer to Procedure 019-091 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.	Repair complete
	Are all grounds present, properly grounded, free of corrosion, and tight? **NO** **Repair:** Replace, clean, or tighten the grounds.	Repair complete

STEP 3: Engine performance.

STEP 3A: Engine performance troubleshooting.

Condition:		
Action	**Specification/Repair**	**Next Step**
perform the fuel system checks, air handling checks, and base engine checks in the engine performance troubleshooting tree.	Poor fuel economy complaint still exists? **YES** **Repair:** Perform the Fuel System Checks, Air Handling Checks, and Base Engine Checks in the Engine Performance Troubleshooting Tree.	Repair complete
	Poor fuel economy complaint still exists? **NO**	Repair complete

Section 0 - Complete Engine - Group 00

Section Contents

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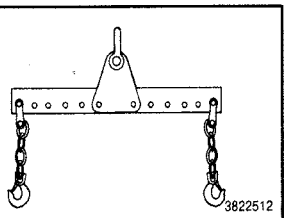
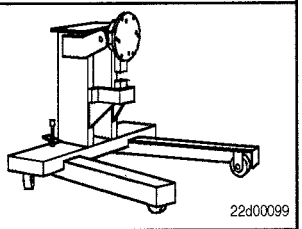
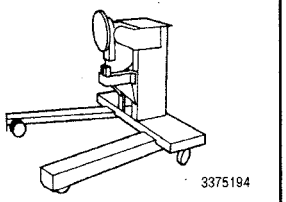
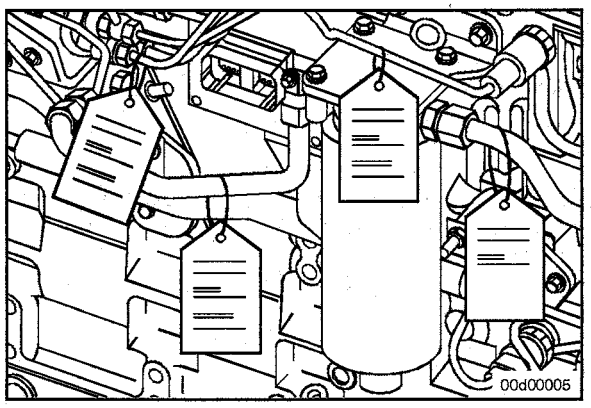
Service Tools

Engine Disassembly/Assembly

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 lift the engine during removal and installation.	
3822607	**Engine Stand Adapter Plate** Used to mount the engine to the rebuild stand.	
3375194 or 3375193	**Engine Rebuild Stand** Portable tilt type engine rebuild stand.	



Engine Removal (000-001)

Remove

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠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.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠

Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

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

Disconnect the battery cables, negative (-) cable first. Refer to Procedure 013-009.

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

Drain the lubricating oil. Refer to Procedure 007-037.

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

Disconnect the drive units from the flywheel. Refer to the manufacturer's instructions.

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

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

NOTE: On applications where the rear engine mounts are attached to the transmission, it will often be necessary to remove the engine and transmission as an assembly. Refer to the equipment manufacturer's manual for instructions.

⚠ WARNING ⚠

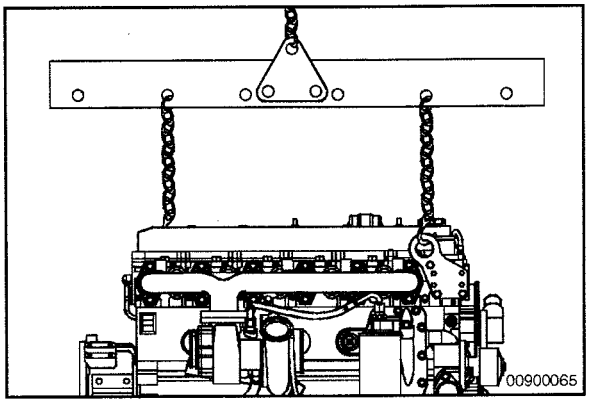
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

Use a properly rated hoist and engine lifting fixture, attached to the engine-mounted lifting brackets, to remove the engine.

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

Place the engine on suitable engine support stands.

Remove all remaining accessories and brackets to use with the replacement engine.



Engine Installation (000-002)

Install

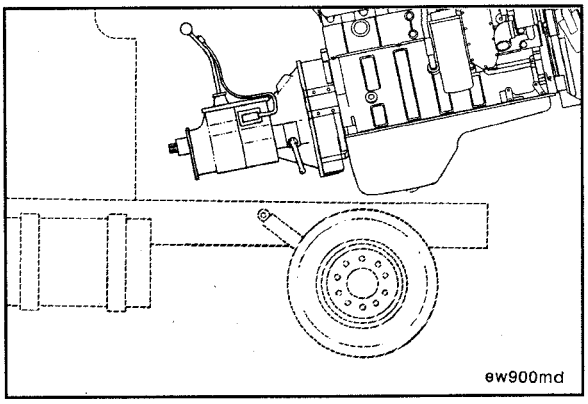
⚠ WARNING ⚠

The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

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

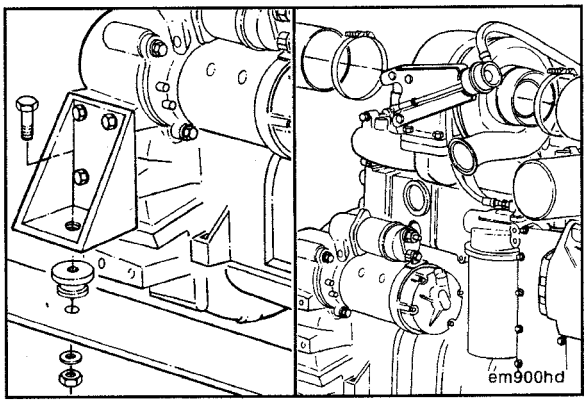
NOTE: On applications where the rear engine mounts are attached to the transmission, it will often be necessary to install the engine and transmission as an assembly.

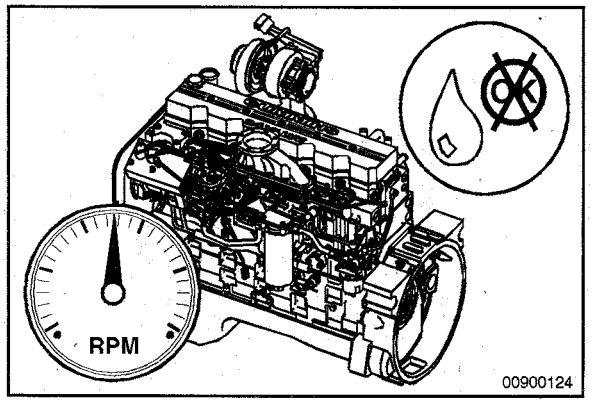
Use a properly rated hoist and engine lifting fixture, attached to the engine-mounted lifting brackets, to install the engine.



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.





Uncover all engine openings.

Connect the drive units to the flywheel. Refer to the manufacturer's instructions.

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

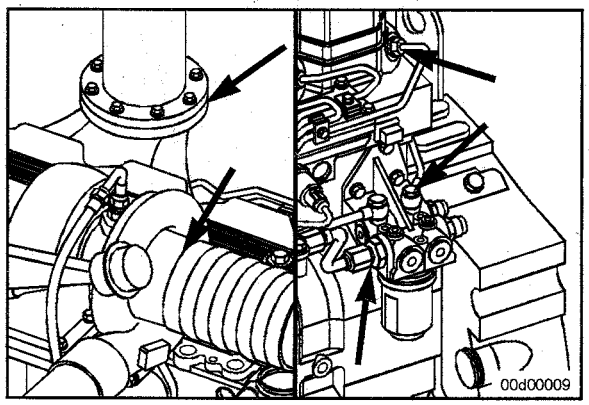
Fill the lubricating oil system. Refer to Procedure 007-037.

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

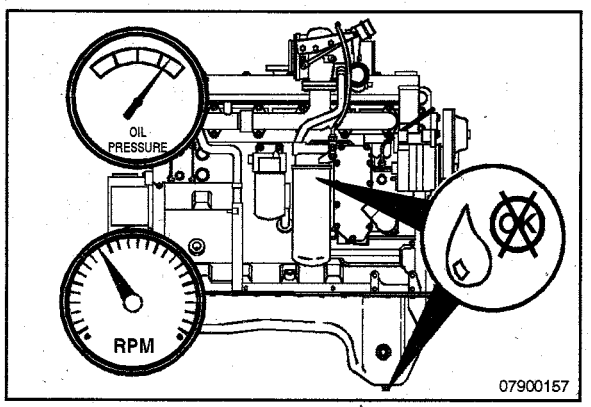
Connect the battery cables, negative (-) cable last. Refer to Procedure 013-009.

Remove all tags on all hoses, lines, linkages and electrical connections.

NOTE: Make sure all lines, hoses and tubes are properly routed and fastened to prevent damage. Make sure the air intake and exhaust pipe connections are tight and free of leaks.



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



Crank the engine until the oil pressure gauge indicates a positive pressure.

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

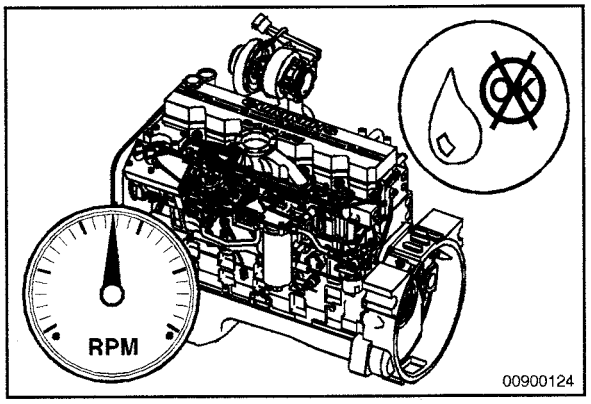
Shut off the engine and wait 5 to 7 minutes for the oil to drain to the oil pan, and check the oil and coolant levels again.

Fill the engine to the correct oil and coolant levels if necessary.

Operate the engine at 1000 to 1200 rpm for 8 to 10 minutes. Check for proper operation, unusual noises, and coolant or oil leaks.

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

Refer to Section 14 for engine run-in procedures.



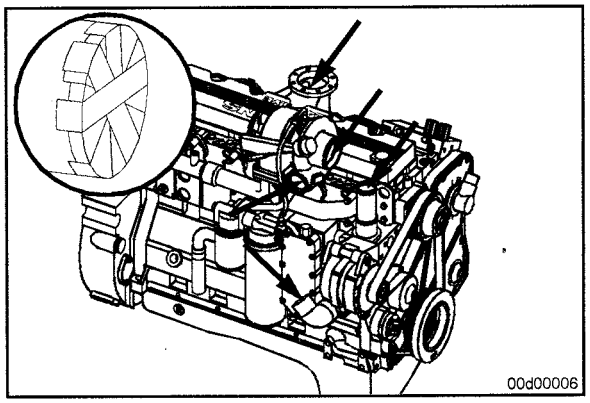
Engine Painting (000-007)

Preparatory Steps

Remove all belts from the engine.

Cover the following parts of the engine:

- Exhaust and intake openings
- Electrical components
- Fuel inlet and drain connections.



⚠ WARNING ⚠

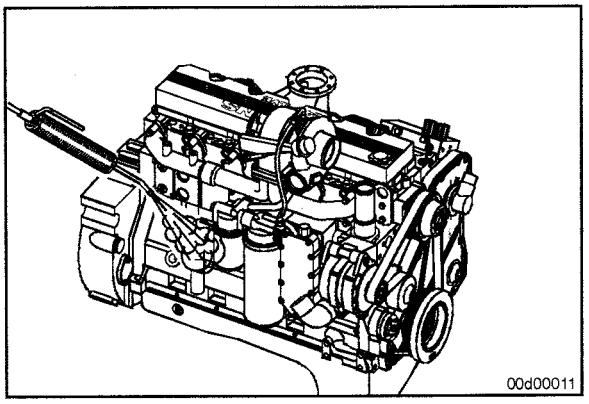
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

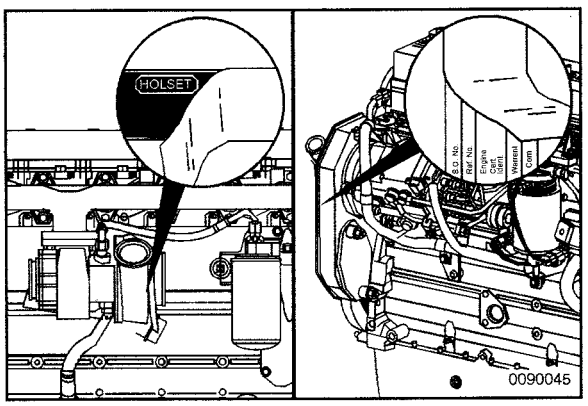
Use steam to clean the engine, and dry with compressed air. Avoid prolonged, direct steam or water spray on electrical components.

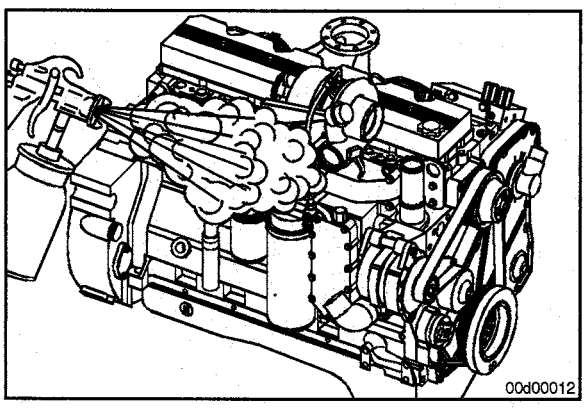
NOTE: Make sure all engine surfaces are clean and dry before painting the engine.



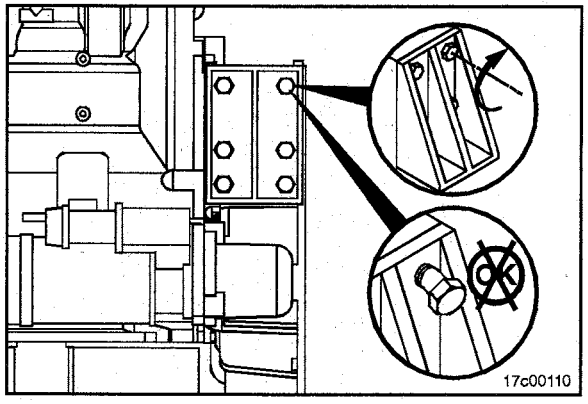
Protect the following components from the paint:

- All dataplates (engine, ECM, fuel pump, turbocharger, air compressor, etc.)
- Exhaust manifold
- Turbocharger turbine housing
- Flywheel
- Flywheel housing transmission mounting surface
- Electrical connections
- All decals
- All pulley belt surfaces
- Any exposed fittings, threads, and electrical wire terminals.





Paint the engine.



Engine Mounting Bolts (000-008)

Maintenance Check

⚠CAUTION⚠

Damaged engine mounts and brackets can cause engine misalignment. Driveline component damage can result in vibration complaints.

Inspect all rubber-cushioned mounts for cracks or damage.

Inspect all mounting brackets for cracks or damaged bolt holes.

Check the torque on the engine-mounting nuts and bolts. Tighten any that are loose. Refer to the equipment manufacturer for torque specifications.

Section 1 - Cylinder Block - Group 01

Section Contents

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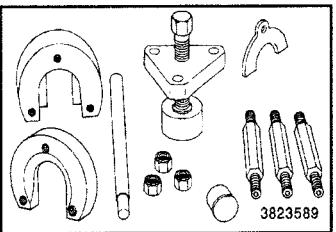
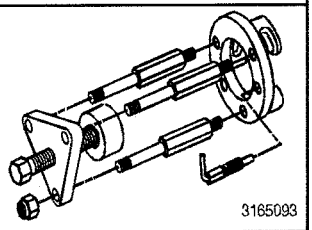
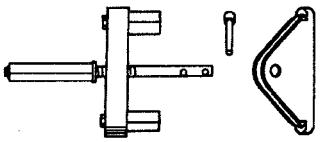
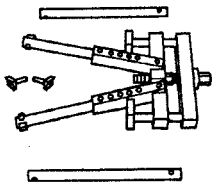
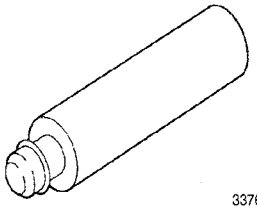
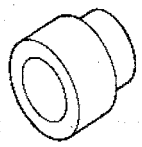
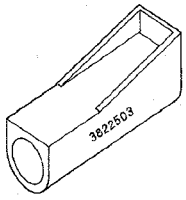
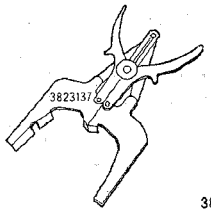
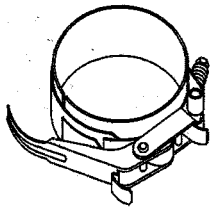
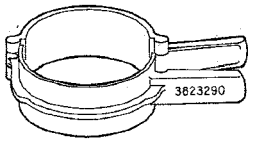
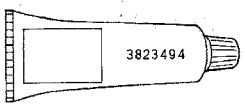
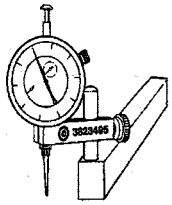
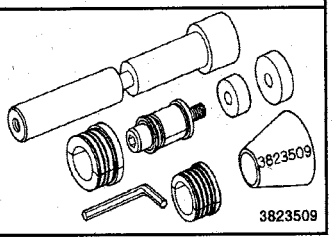
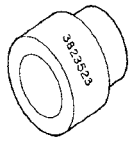
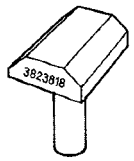
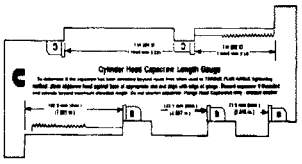
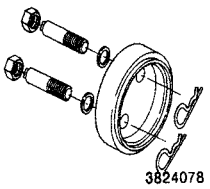
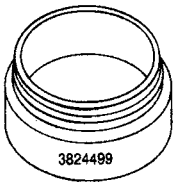
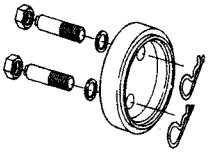
Service Tools

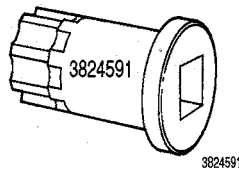
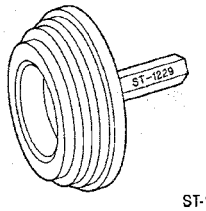
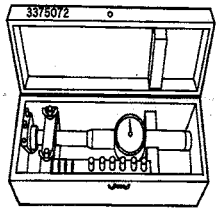
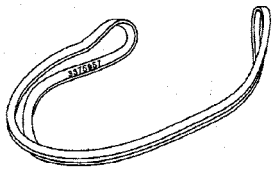
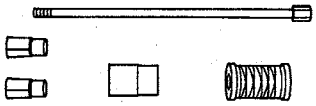
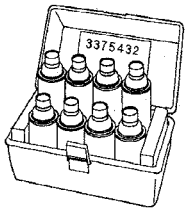
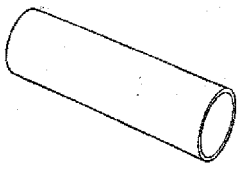
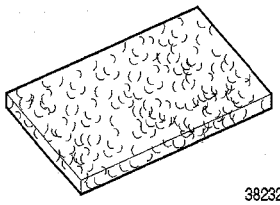
Cylinder Block

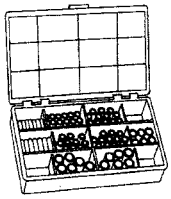
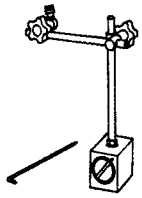
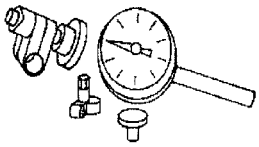
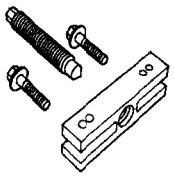
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3163054	**Camshaft Gear Installation/Removal Tool** Used to remove and install the camshaft gear. Used **only** on engines **not** equipped with a tapped hole in the camshaft.	
3165093	**Camshaft Gear Installation/Removal Tool** Used to remove and install the camshaft gear without removing the camshaft. Can **only** be used on engines with a tapped hole in the camshaft. Use with camshaft gear installation/removal tool, Part Number 3163054.	
3375068	**Cup Plug Sealant** Used when installing pipe plugs, cup plugs, etc. on the engine to prevent leaks.	 bp8togk
3163745	**Cylinder Liner Puller** Used to remove cylinder liners from the cylinder block. Requires Cummins Part Number 3822786 Cylinder Liner Puller Plate.	
3376015	**Cylinder Liner Puller (Universal)** Used to remove cylinder liners from the cylinder block. Requires two Cummins Part Number 3376649 Puller Arm Extension Feet.	
3164085	**Expansion Plug Driver Handle** Used with all expansion plug drivers larger than 9.525 mm [0.375 in] diameter.	

Tool No.	Tool Description	Tool Illustration
3376816	**Expansion Plug Driver** Used to install 25.4 mm [1.00 in] expansion plug to specified depth. Used with expansion plug driver handle, Cummins Part Number 3164085.	 3376816
3822503	**Cylinder Liner Clamp Set** Used to clamp the liner into the bore of the cylinder block. Requires two cylinder head capscrews **not** included in clamp set.	 3822503
3823137	**Piston Ring Expander** Used to install piston rings onto pistons without damaging or distorting the rings.	 3823137
3164604	**Piston Ring Compressor** Used to compress the piston rings while installing the pistons into the cylinder bores.	 3164604
3823290	**Piston Ring Compressor** Used to compress the piston rings while installing the pistons into the cylinder bores.	 3823290
3823494	**Sealant, Three Bond (150 Gram Tube)** Used for sealing "T" joints and front gear cover.	 3823494
3164438	**Gauge Block** Used to measure cylinder liner protrusion, cylinder block counterbore depths, and valve intrusion and/or protrusion.	 3823495
3165045	**Camshaft Bushing Tool** Used to remove and install camshaft bushings.	 3823509

Tool No.	Tool Description	Tool Illustration
3823521	**Expansion Plug Driver** Used to install 20.638 mm [0.8125 in] expansion plug to specified depth. Used with expansion plug driver handle, Cummins Part Number 3164085.	 3823521
3823522	**Expansion Plug Driver** Used to install 30.16 mm [1.1875 in] expansion plug to specified depth. Used with expansion plug driver handle, Cummins Part Number 3376795.	 3823522
3823523	**Expansion Plug Driver** Used to install 34.925 mm [1.375 in] expansion plug to specified depth. Used with expansion plug driver handle, Cummins Part Number 3376795.	 3823523
3823818	**Main Bearing Rollout Tool** Used to remove and install main bearings with the crankshaft installed.	 3823818
3823921	**Capscrew Length Gauge** Used to measure capscrew free length.	 3823921
3824078	**Rear Wear Sleeve Installation Tool** Used to install the rear crankshaft lubricating oil seal wear sleeve.	
3824499	**Lubricating Oil Seal Installation Tool** Used to install the front crankshaft lubricating oil seal in the front cover seal carrier.	 3824499
3165112	**Front Wear Sleeve Installation Tool** Used to install front wear sleeves.	

Tool No.	Tool Description	Tool Illustration
3824591	**Engine Barring Gear** Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591
ST-1229	**Cylinder Liner Driver** Used to install cylinder liners into the cylinder block.	 ST-1229
3376619	**Dial Bore Gauge Kit** Used to measure internal diameter bores from 78.5 mm [3.09 in] to 203.2 mm [8.00 in].	 oi8togu
3375957	**Nylon Lifting Sling** Aid in removal and installation of crankshaft flywheel and other heavy components up to 907 kg [2000 lb].	 3375957
3163720	**Dowel Pin Extractor Kit** Used to remove dowel pins.	 ck8toge
3375432	**Crack Detection Kit** Used to inspect components for cracks.	 3375432
3824496	**Connecting Rod Guide Pins** Used to prevent damage to crankshaft during piston installation on engines built with connecting rod studs.	 3824496
3823258	**Abrasive Hand Pad** Used to remove corrosion or carbon buildup.	 3823258

Tool No.	Tool Description	Tool Illustration
3163087	**Lubriplate™ 105** A 10-ounce tube of lubricant.	 3163087
3822709	**Thread Insert Kit** Used to repair several sizes of cylinder block threads.	 3822709
3377399	**Dial Indicator Magnetic Base** Use with indicator base, Part Number 3824564 (metric).	 3377399
3824564	**Dial Indicator, Metric** Use with indicator base, Part Number 3377399.	 3824564
ST-647	**Standard Puller** Used to remove drive pulleys, impellers, air compressor counterweights, etc.	 ad8toga

Bearings, Connecting Rod (001-005)

Preparatory Steps

⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

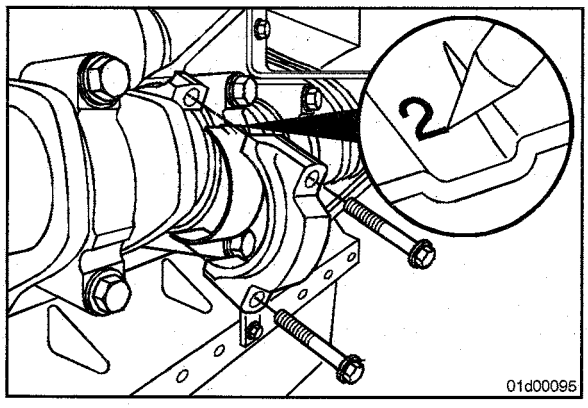
⚠ WARNING ⚠

Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

Drain the lubricating oil. Refer to Procedure 007-037.

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

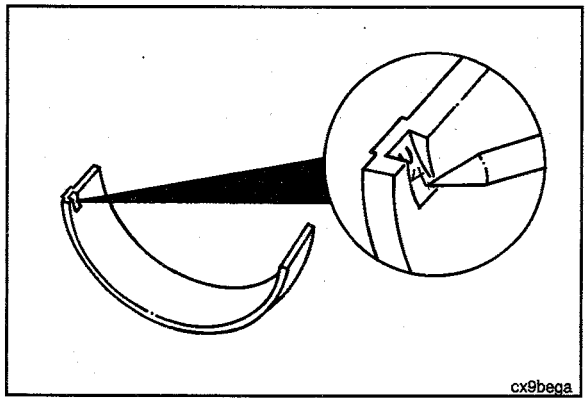
Remove the lubricating oil suction tube. Refer to Procedure 007-035.



Remove

NOTE: The cylinder head does **not** need to be removed if the connecting rod bearings are being inspected or replaced.

Remove the connecting rod caps. Refer to Procedure 001-054.



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

Clean and Inspect for Reuse

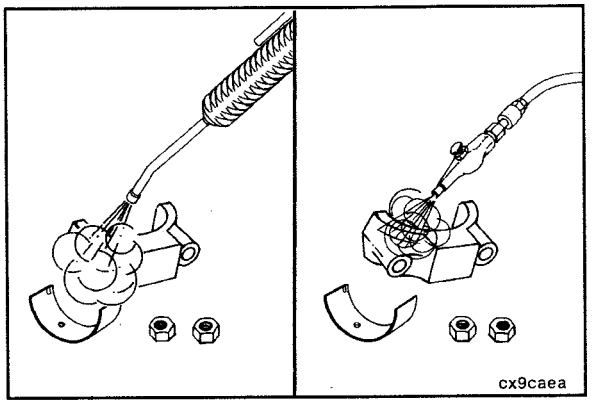
⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Wash the bearing and connecting rod caps.

Dry with compressed air.

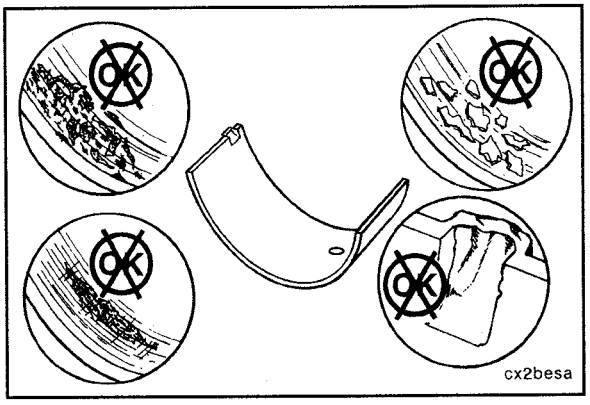
Inspect the connecting rod caps, connecting rod bearing saddles and capscrews for nicks, cracks, burrs, scratches, or fretting.



Inspect the bearings for damage.

Replace any bearings with the following damage:

- Pitting
- Flaking
- Corrosion
- Lock tang damage
- Scratches.

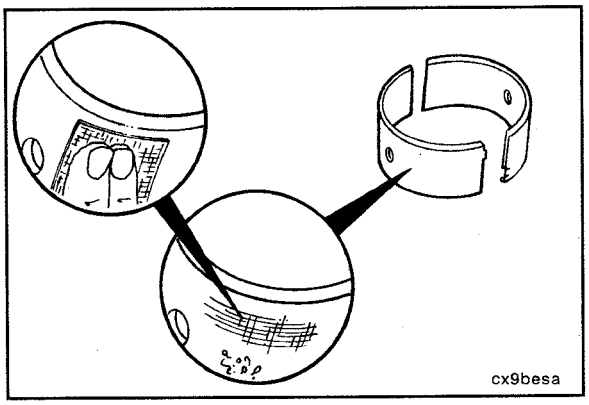


Inspect the bearing shell seating surface for nicks or burrs.

If nicks or burrs can **not** be removed with Scotch-Brite™ 7448, Part Number 3823258 or equivalent, the bearings **must** be replaced.

NOTE: If bearings are damaged they **must** be replaced as a set.

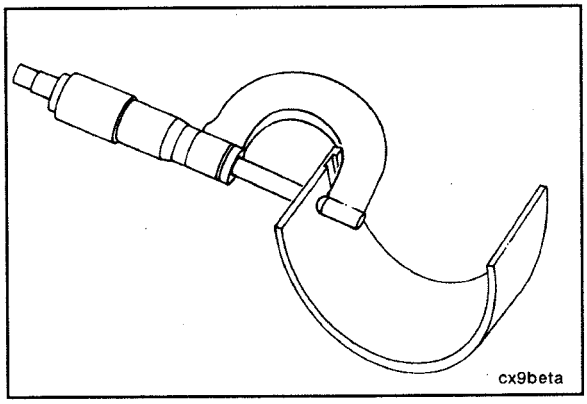
NOTE: For more detailed information of bearing damage, refer to "Analysis and Prevention of Bearing Failures" Bulletin No. 3810387.

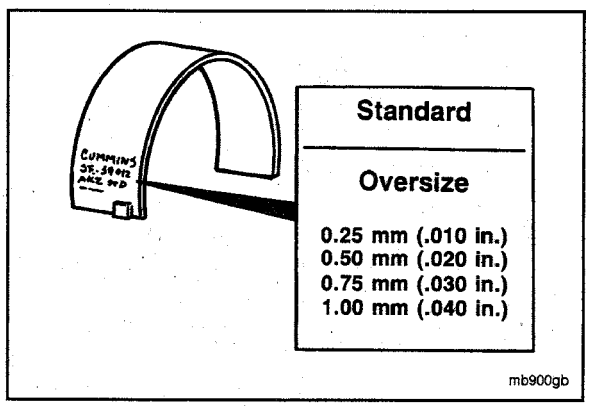


Measure the rod bearing shell thickness with an outside micrometer that has a ball tip.

Connecting Rod Bearing Dimensions			
	mm		in
Standard	2.459	MIN	0.0968
	2.471	MAX	0.0973

Discard a bearing shell if its thickness is below the minimum specification.

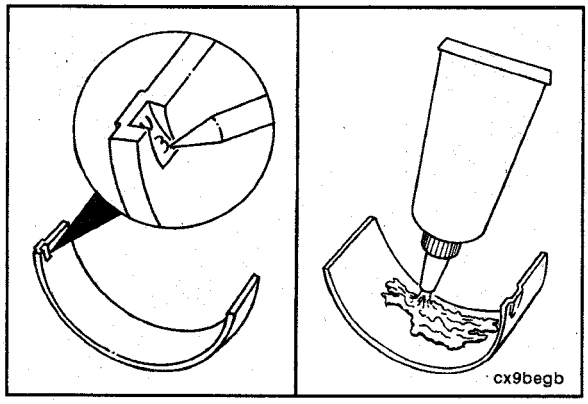




NOTE: Connecting rod bearings are identified with a part number and size stamped on the back side.

Determine the size of the removed rod bearing and obtain a set of the same size.

Oversize service rod bearings are available for use with crankshafts that have been machined undersized. Refer to the appropriate parts catalog.



Install

Refer to Procedure 001-054 for connecting rod bearing installation instructions.

Finishing Steps

Install the lubricating oil suction tube. Refer to Procedure 007-035.

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

Fill the lubricating oil pan. Refer to Procedure 007-037.

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

Bearings, Main (001-006)

Preparatory Steps

⚠WARNING⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

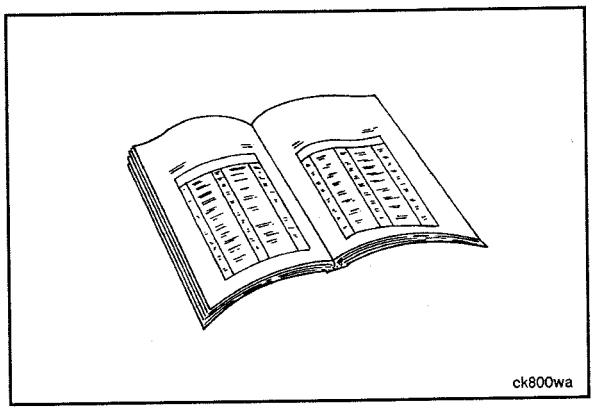
⚠WARNING⚠

Some state and local agencies 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. If not reused, dispose of in accordance with local environmental regulations.

Drain the lubricating oil. Refer to Procedure 007-037.

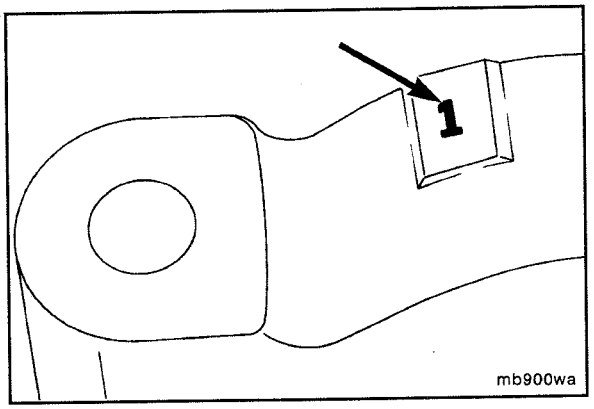
Remove the lubricating oil pan and gasket. Refer to Procedure 007-025.

Remove the lubricating oil suction tube. Refer to Procedure 007-035.


ck800wa

Remove

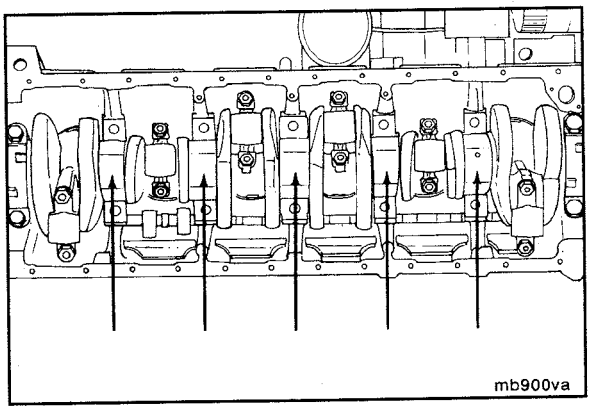
Before removing the main bearing caps, make certain that the caps are clearly marked for their location on the lubricating oil cooler side of the main bearing cap.

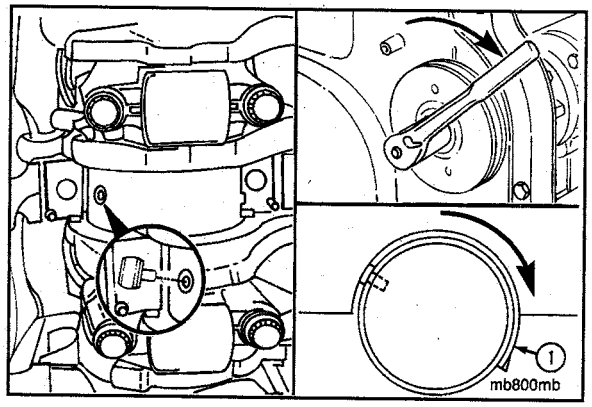


mb900wa

When replacing bearings in chassis, replace number 2 through number 6 while the number 1 and number 7 caps support the crankshaft. After replacing number 2 through number 6, replace number 1 and number 7.

Remove all main bearing caps except the number 1 and number 7 main bearing caps.


mb900va



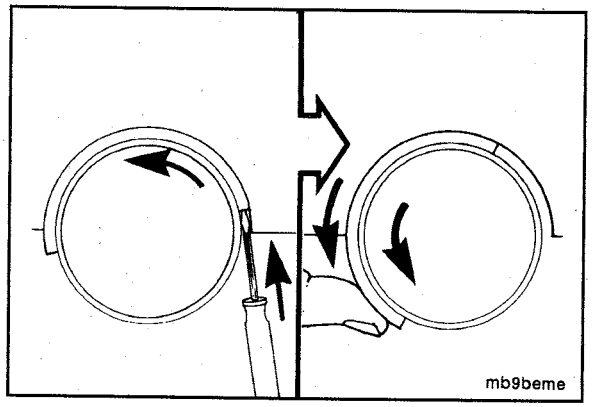
To remove the upper main bearing, install the main bearing replacer, Part Number 3823818, in the oil hole of the crankshaft main bearing journal.

Rotate the crankshaft so that the replacer contacts the upper main bearing on the side opposite the tang.

Continue to rotate the crankshaft in the direction that will remove the tang side (1) of the upper main bearing first.

Remove the bearing.

Follow this procedure to remove the other main bearings except for number 1 front main bearing.

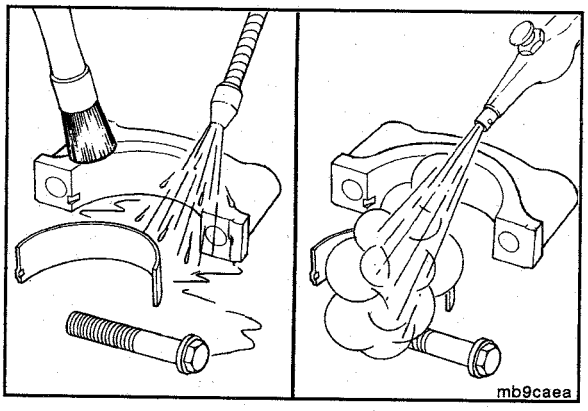


⚠CAUTION⚠

Use care so the screwdriver does not damage the crankshaft or cylinder block.

NOTE: The front main bearing, number 1, does **not** have a hole in the journal, so the tool can **not** be used to replace the bearing.

Using a flat blade screwdriver, gently bump the end of the bearing to loosen it from the cylinder block. Then, use finger pressure against the main bearing shell and rotate the crankshaft to roll the main bearing out.



Clean and Inspect for Reuse

⚠WARNING⚠

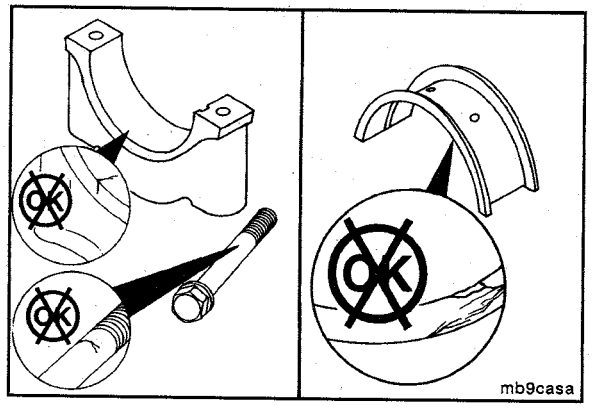
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

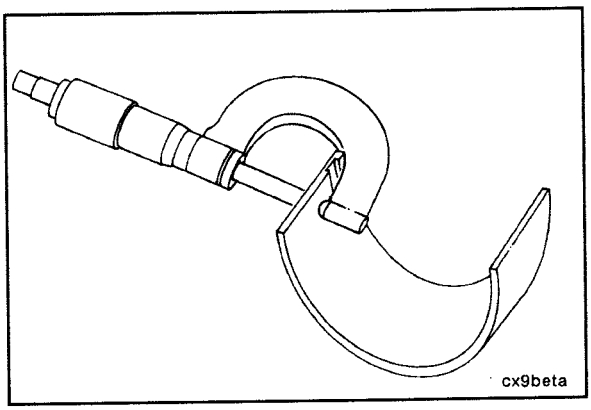
Steam clean main bearing caps.

Dry with compressed air.



Inspect all main bearing caps and main bearing crankshaft journals for deep scoring, overheating, etc.

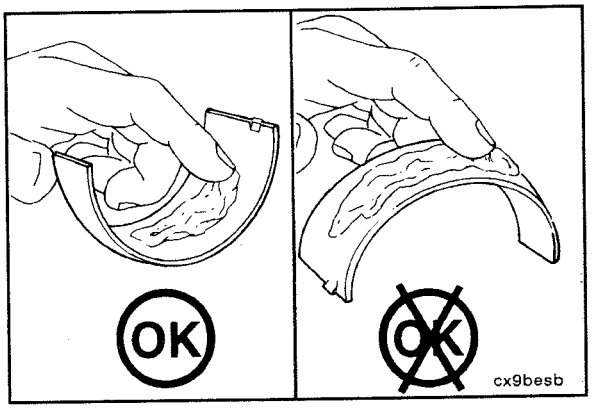
Measure the main bearing shell thickness with an outside micrometer that has a ball tip.



Main Bearing Dimensions			
	mm		in
Standard	3.446	MIN	0.1357
	3.454	MAX	0.1360

Discard a bearing shell if its thickness is below the minimum specification.

Install



Do **not** lubricate the side that is against the cylinder block.

NOTE: Make sure the main bearing being installed is same size as the main bearing removed. The size is engraved on the back of the main bearing.

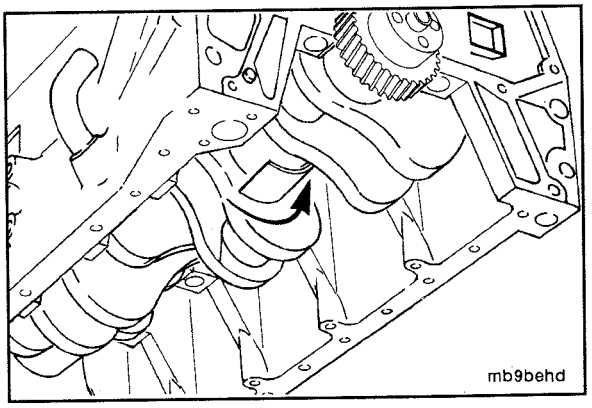
Apply a coat of Lubriplate™ 105 multi-purpose lubricant, Part Number 3163086 or equivalent, to the new upper main bearings.

NOTE: The crankshaft thrust bearing **must** be installed in the number four position.

NOTE: The upper and lower main bearing shells of some engines are **not** interchangeable. The backs of the main bearings are marked with the proper orientation, if required.

Insert the side of the main bearing opposite the tang first. Install as far as possible by hand.

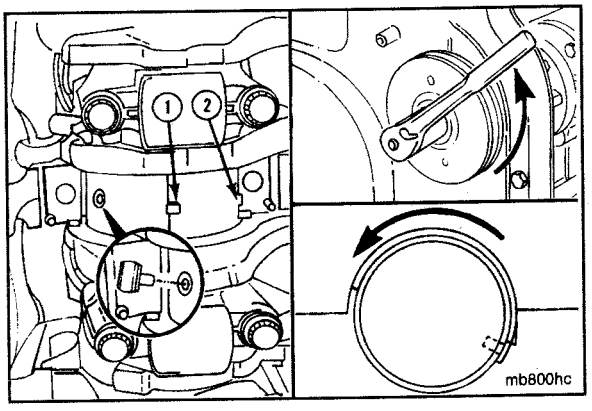
When installing the thrust bearing in the number four journal, it could be necessary to push the crankshaft to the front or rear of the cylinder block.

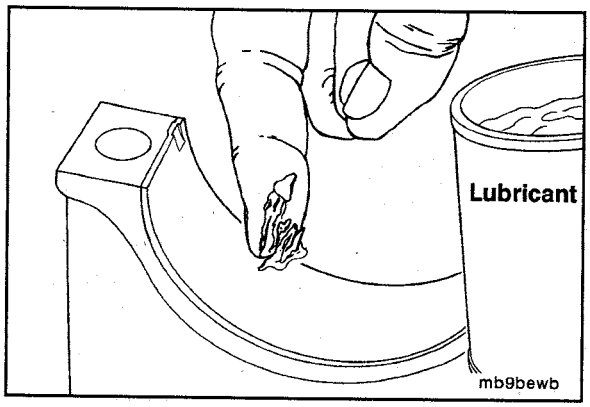


Make sure the pin does not slide under the bearing.

Using the main bearing replacer, Part Number 3823818, finish installing the main bearing by rotating the crankshaft. Make sure the tang (1) on the main bearing is located in the notch (2) of the cylinder block.

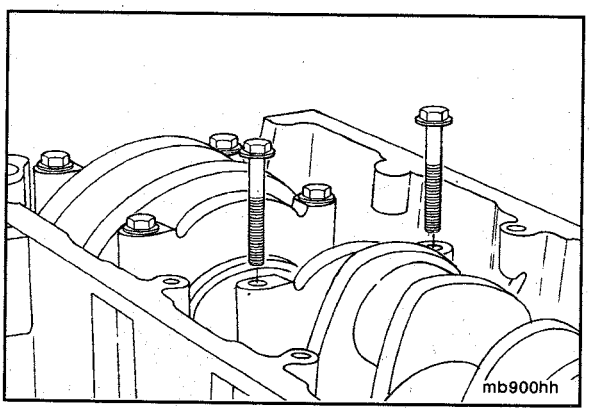
Finish pushing the main bearing into position.





Install the lower main bearings into the main bearing caps.

Apply a coat of Lubriplate™ 105 multi-purpose lubricant, Part Number 3163086 or equivalent, to the crankshaft side of the main bearings.



Make sure the caps are correctly installed with the number towards the oil cooler side of the engine.

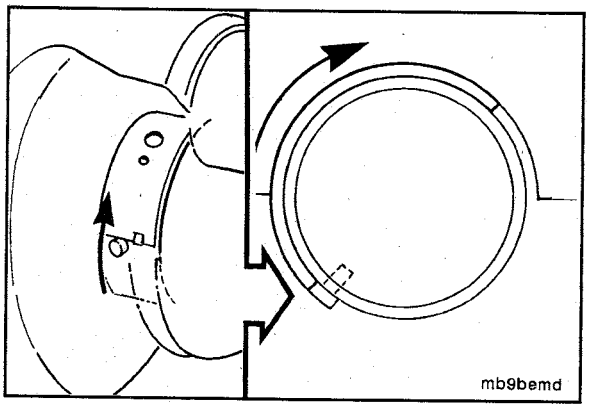
Install a main bearing cap after each upper main bearing is installed to keep the main bearing in place while the other uppers are installed.

Lubricate the main bearing capscrew under the cap and lubricate the main bearing capscrew threads using clean 15W-40 engine oil.

Tighten capscrews.

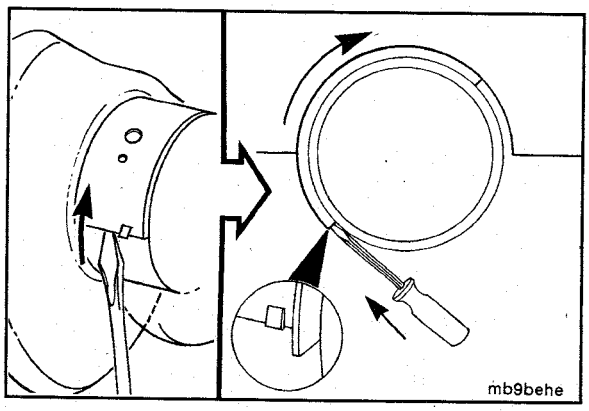
Torque Value: 50 N•m [37 ft-lb]

Do **not** tighten to the final torque value at this time.



Repeat this procedure to install the remaining bearing and caps with the exception of main bearing number 1.

The thrust bearing **must** be installed in the number 4 journal.



NOTE: The front main, number 1, does **not** have a hole in the journal so the pin can **not** be used to replace the bearing.

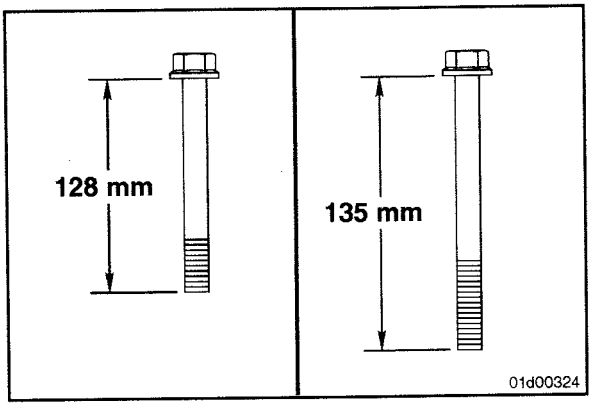
Lubricate and install the number 1 main bearing.

Insert the side of the main bearing opposite the tang first. Install as far as possible by hand.

Use the screwdriver to push the main bearing into position as you rotate the crankshaft.

⚠CAUTION⚠

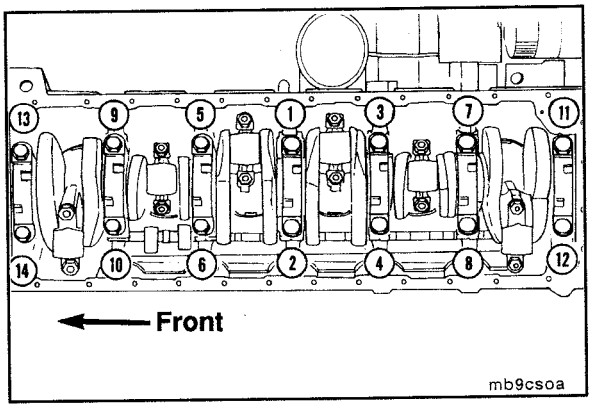
Some engines use 128 mm [5 in] long main bearing cap capscrews. Others use 135 mm [5.3 in] long main bearing cap capscrews. Failure to use the correct torque value for either size capscrew can result in engine damage.



The crankshaft must rotate freely.

Tighten the main bearing capscrews evenly and in sequence.

Torque Value:			
128 mm [5 in] Capscrew	Step1	50 N•m	[37 ft-lb]
	Step2	95 N•m	[70 ft-lb]
	Step3	Rotate 60 degrees	
Torque Value:			
135 mm [5.3 in] Capscrew	Step1	170 N•m	[125 ft-lb]
	Step2	Loosen all capscrews	
	Step3	50 N•m	[37 ft-lb]
	Step4	Rotate 120 degrees	



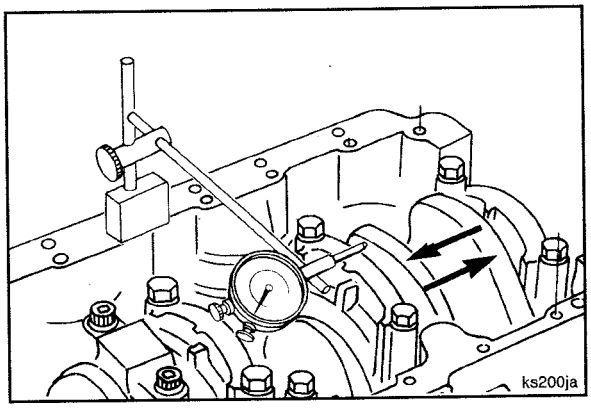
Check the main bearing installation and the size of the main bearings if the crankshaft does **not** rotate freely.

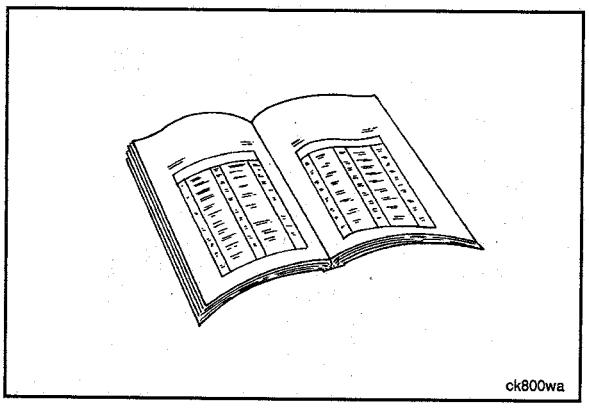
The dimensions of the thrust bearing and crankshaft journal determine end play.

Measure the crankshaft end play using dial indicator, Part Number 3824564 and magnetic base, Part Number 3377399.

Crankshaft End Play Limits

mm		in
0.085	MIN	0.003
0.385	MAX	0.015





Finishing Steps

Install the lubricating oil suction tube. Refer to Procedure 007-035.

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

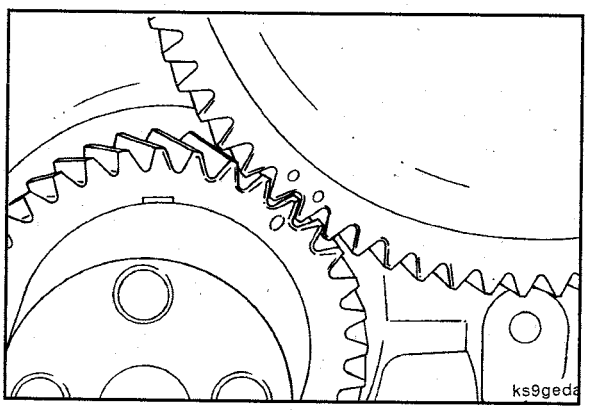
Fill the lubricating oil pan. Refer to Procedure 007-037.

Operate the engine at idle for 5 to 10 minutes. Check for loose parts and leaks.

Camshaft (001-008)

Preparatory Steps

- Remove the rocker lever cover. Refer to Procedure 003-011.
- Remove the engine brakes, if equipped. Refer to Procedure 020-004.
- Remove the rocker lever housing, if equipped. Refer to Procedure 003-013.
- Remove the rocker levers. Refer to Procedure 003-008.
- Remove the push rods. Refer to Procedure 004-014.
- Remove the drive belt. Refer to Procedure 008-039.
- Remove the fan hub, if required. Refer to Procedure 008-039.
- Remove the vibration damper. Refer to Procedure 001-052.
- Remove the gear cover. Refer to Procedure 001-031.
- Raise the tappets. Refer to Procedure 004-015.

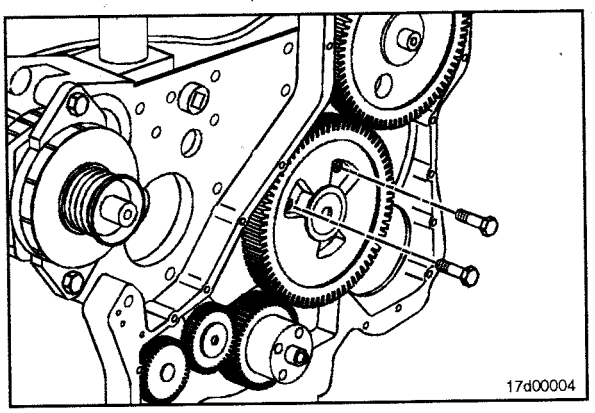


Remove

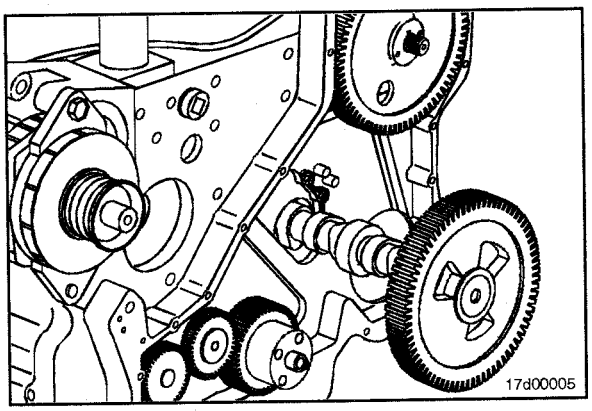
Rotate the crankshaft to align the crankshaft to camshaft timing marks.

NOTE: Because the thrust plate extends more than 180 degrees around the camshaft, the thrust plate can **only** be removed from the camshaft after removing the cam gear from the camshaft.

Remove the capscrews from the thrust plate.

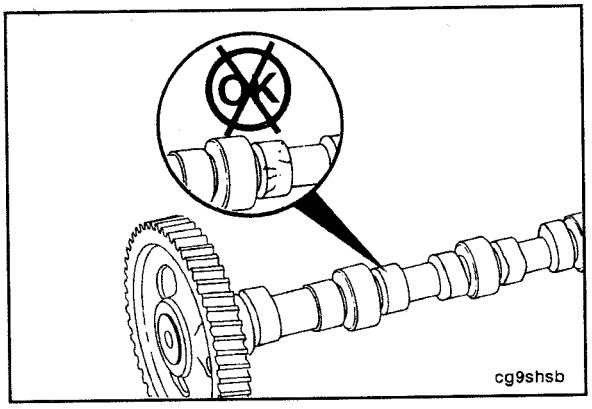


Remove the camshaft and thrust plate together.

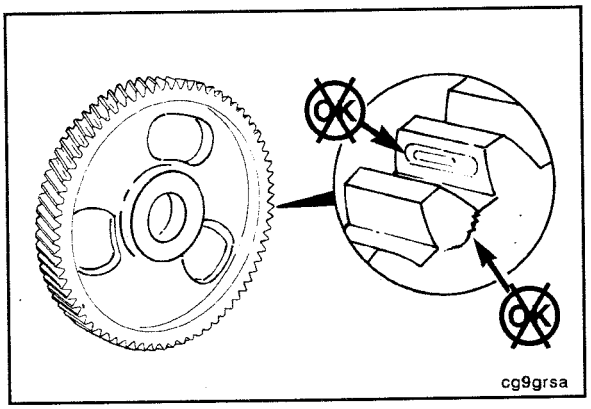


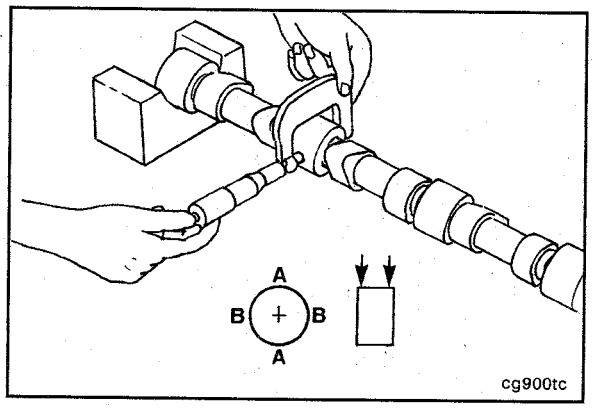
Clean and Inspect for Reuse

Inspect the valve lobes and bearing journals for cracking, pitting and scoring.



Inspect the camshaft gear teeth for pitting. Look for cracks at the root of the teeth.

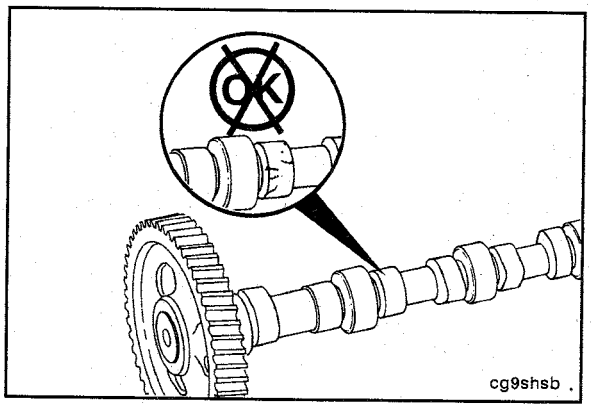




Measure the bearing journals.

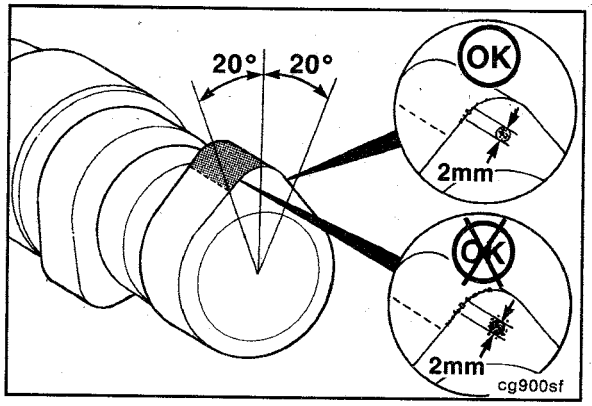
Camshaft Bearing Journal Diameter		
mm		in
59.962	MIN	2.3607
60.013	MAX	2.3627

NOTE: Replace the camshaft if the outside diameter of any bearing surface is less than 59.962 mm [2.3607 in].



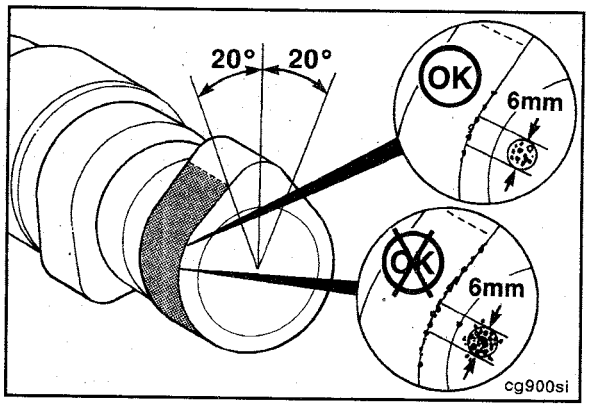
Pitting Reuse Criteria

Refer to Bulletin 3666475 for reuse guidelines for chilled ductile iron (CDI) camshafts and Bulletin 3666052 for reuse guidelines for roller tappet and steel camshafts.



Edge Deterioration (Breakdown) Criteria

The area of edge deterioration **must not** be greater than the equivalent area of a 2 mm [0.079 in] circle within ± 20 degrees of the nose of the cam lobe.

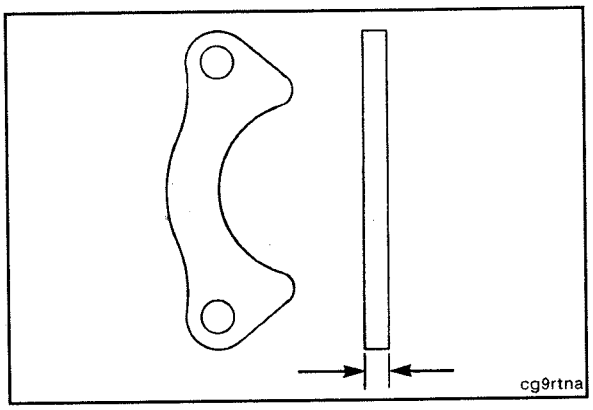


Outside of the ± 20 degrees of the nose of the cam lobe, the areas of edge deterioration **must not** be greater than the equivalent area of a 6 mm [0.236 in] circle.

NOTE: If the camshaft shows any pitting or wear, remove and inspect the tappets before installing the camshaft. Refer to Procedure 004-015. If a new camshaft is installed, new tappets also **must** be installed.

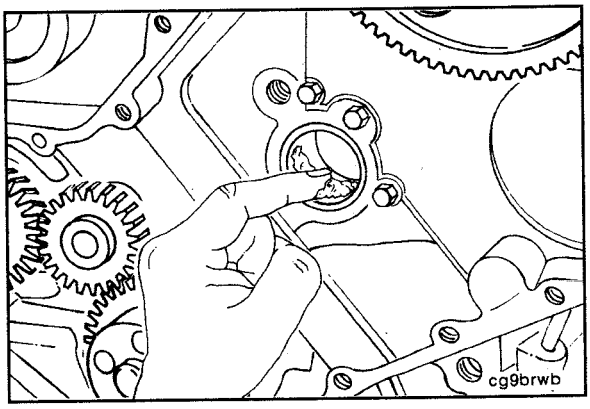
Measure camshaft thrust plate thickness.

Camshaft Thrust Plate		
mm		in
9.40	MIN	0.370
9.60	MAX	0.378

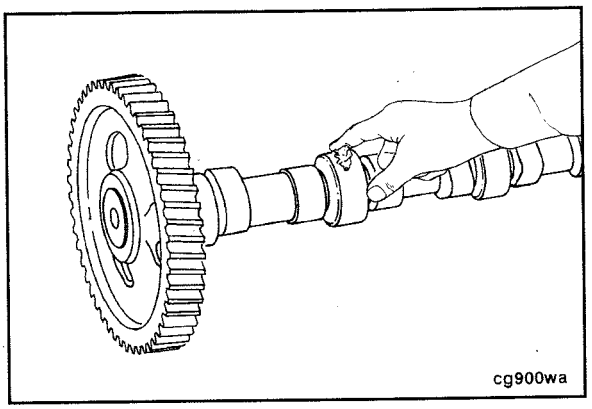


Install

Apply a coat of Lubriplate™ 105, Part Number 3163087 or equivalent, to the front camshaft bore.



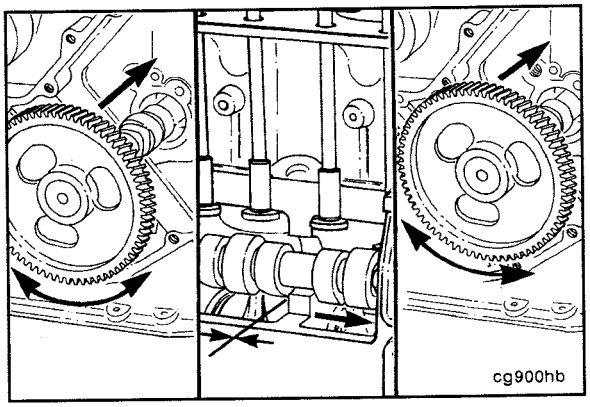
Lubricate the camshaft lobes, journals and thrust plate with Lubriplate™ 105, Part Number 3163087 or equivalent.

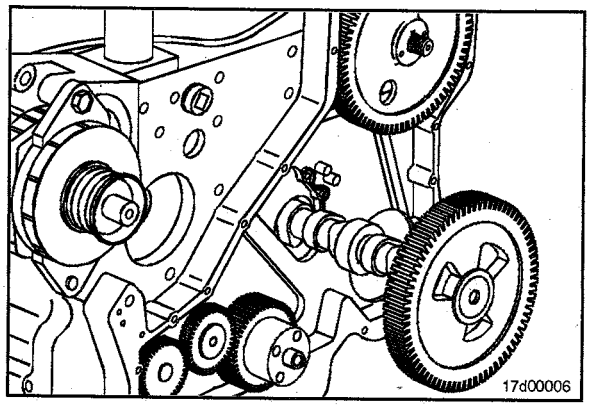


△CAUTION△

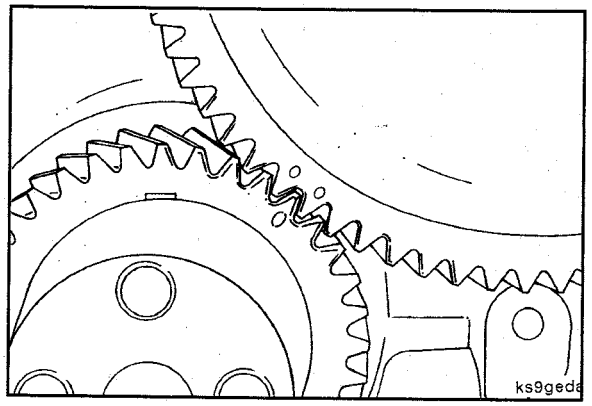
Do not try to force the camshaft into the camshaft bore as damage to the camshaft bushing can result.

Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the lobe from the bushing and allow the camshaft to be installed.

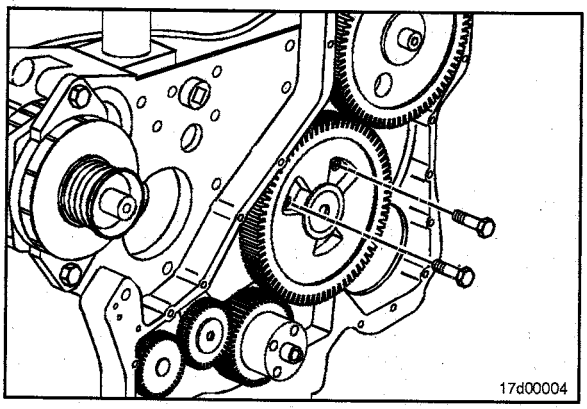




Before the camshaft gear engages the crankshaft gear, check the camshaft for ease of rotation. When installed properly, the camshaft **must** rotate freely.

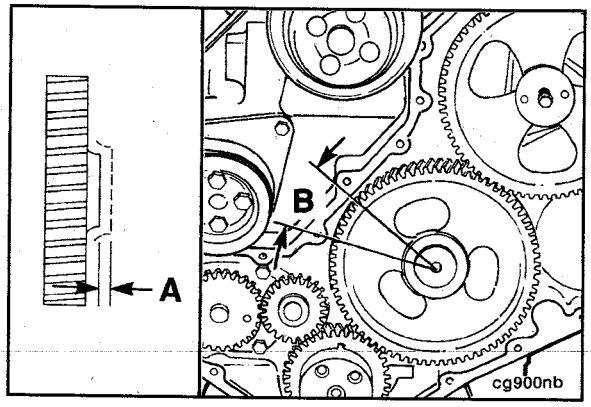


Align the timing marks as illustrated and finish installing the camshaft.



Install the thrust plate capscrews.

Torque Value: 24 N•m [18 ft-lb]



Using gauge, Part Number 3824564, and magnetic base, Part Number 3377399, and verify the camshaft has proper backlash and end play.

Camshaft End Play (A)		
mm		in
0.12	MIN	0.005
0.50	MAX	0.020

Camshaft Gear Backlash Limits (B)		
mm		in
0.08	MIN	0.003
0.33	MAX	0.013

Finishing Steps

- Install the gear cover. Refer to Procedure 001-031.
- Install the vibration damper. Refer to Procedure 001-051.
- Install the fan hub, if required. Refer to Procedure 008-039.
- Install the drive belt. Refer to Procedure 008-003.
- Release the tappets. Refer to Procedure 004-015.
- Install the push rods. Refer to Procedure 004-014.
- Install the rocker levers. Refer to Procedure 003-004.
- Install the rocker lever housing, if equipped. Refer to Procedure 003-013.
- Adjust the valve lash. Refer to Procedure 003-004.
- Install the engine brakes, if equipped. Refer to Procedure 020-004.
- Install the rocker lever cover. Refer to Procedure 003-011.

Operate the engine at idle for 5 to 10 minutes and check for leaks and loose parts.

Camshaft Bushings (001-010)

Preparatory Steps

Remove the camshaft. Refer to Procedure 001-008.

Remove

Remove the camshaft bushings using the camshaft bushing replacer kit, Part Number 3165045. Slide the drive bar through the centering guide and insert the drive bar from the rear of the cylinder block through the camshaft bores.

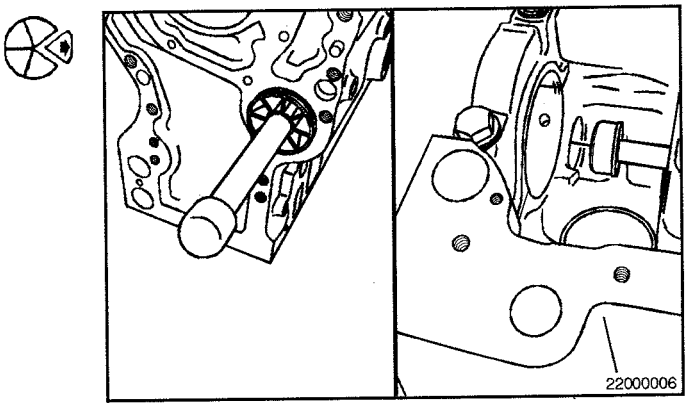
Insert the camshaft bushing replacer and drive the front camshaft bushing from the cylinder block.

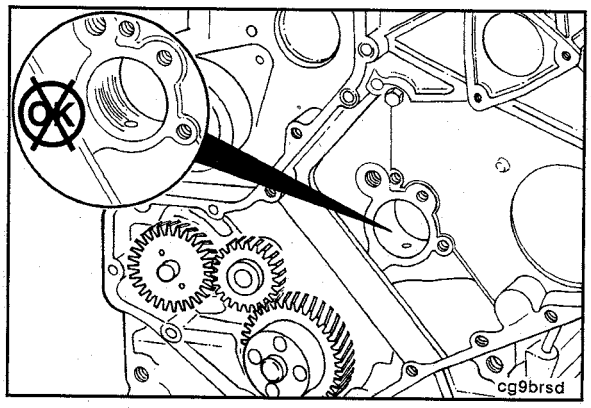
Remove the replacer and drive bar from the cylinder block.

Insert the drive bar, camshaft bushing replacer, and centering guide from the front of the cylinder block.

Drive the remaining camshaft bushings from the cylinder block in succession, starting with the number two camshaft bushing.

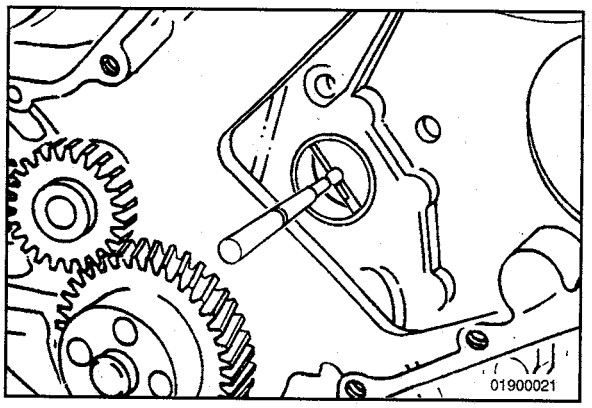
Remove the drive bar, replacer and guide from the front of the cylinder block.





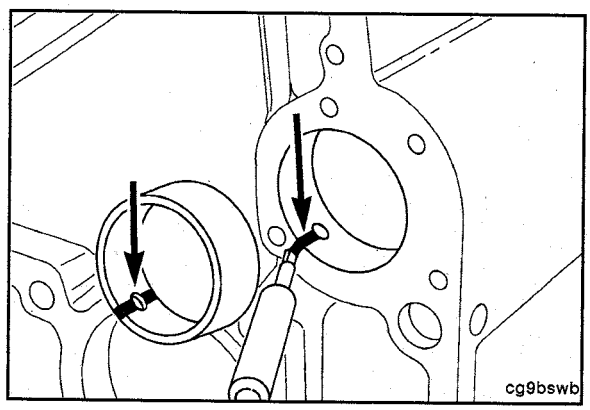
Clean and Inspect for Reuse

Inspect the camshaft bore for damage and excessive wear.



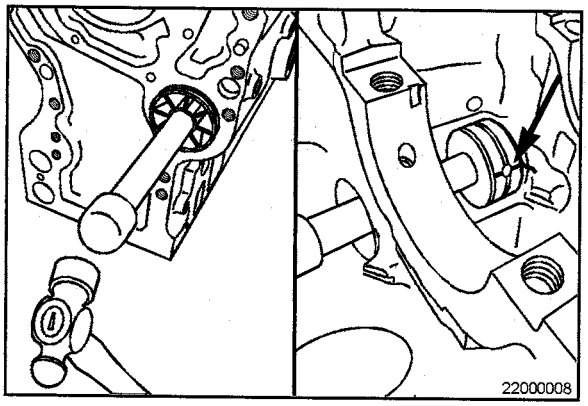
Measure the camshaft bore.

Camshaft Bore Diameter (Maximum)			
	mm		in
Without bushing	64.013	MAX	2.5202
With bushing	60.120	MAX	2.3669



Install

Mark the camshaft bushing and cylinder block so you can align the lubricating oil hole in the cylinder block with the large lubricating oil hole in the bushing.



Slide the camshaft bushing on the replacer. Align the marks on the camshaft bushing and the cylinder block.

Drive the front camshaft bushing to the correct installed depth. The correct installed depth is when the camshaft bushing oil hole aligns with the cylinder block oil hole.

Install the remaining camshaft bushings in succession, starting at the rear of the cylinder block and working toward the front. Remove the drive bar, replacer, and guide from the cylinder block.

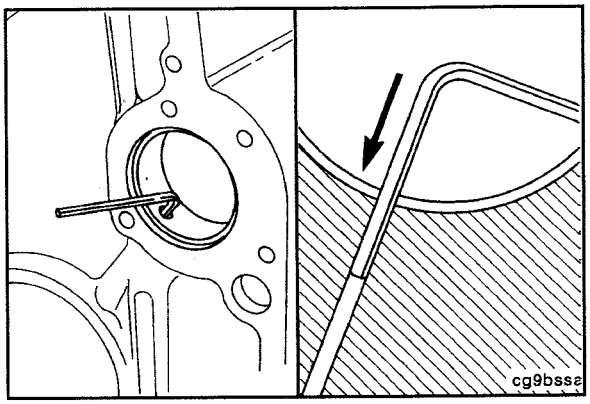
⚠CAUTION⚠

The small hole in the bushing must be installed on the upper side.

Be sure the large lubricating oil hole is aligned.

A 3.2 mm [0.128 in] diameter rod **must** be able to pass through the lubricating oil hole.

Be sure the lubricating oil small hole is aligned with the appropriate hole.



Finishing Steps

Install camshaft. Refer to Procedure 001-008.

Operate the engine and check for leaks.

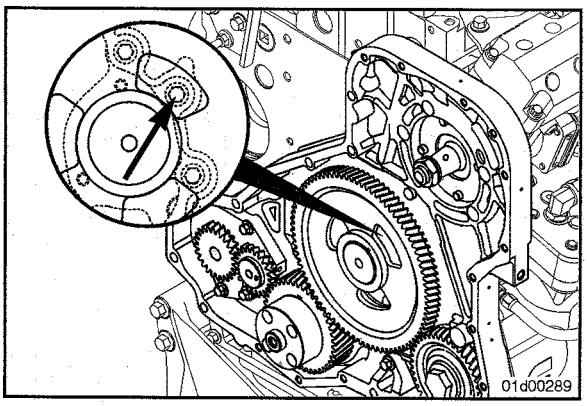
Camshaft Gear (Camshaft Installed) (001-012)

General Information

This procedure applies to engines with high-pressure common rail fuel system **only**.

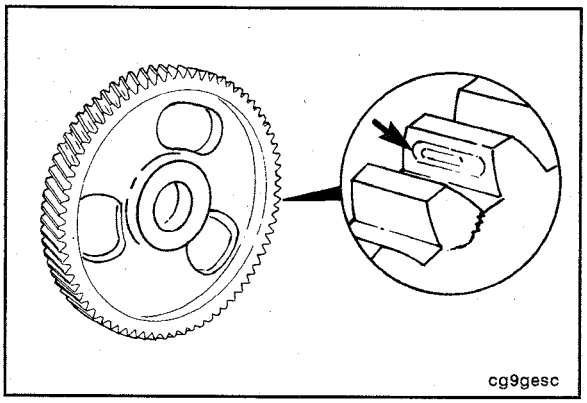
Preparatory Steps

- Remove the drive belt. Refer to Procedure 008-002.
- Remove the fan hub, if required. Refer to Procedure 008-039.
- Remove the vibration damper. Refer to Procedure 001-052.
- Remove the gear cover. Refer to Procedure 001-031.
- Remove the rocker lever cover. Refer to Procedure 003-011.
- Loosen the rocker lever assemblies. Refer to Procedure 003-008.



Remove

Use cam gear removal and installation tool, Part Number 3163054, and puller assembly, Part Number 3165093, to remove the camshaft gear from the camshaft.

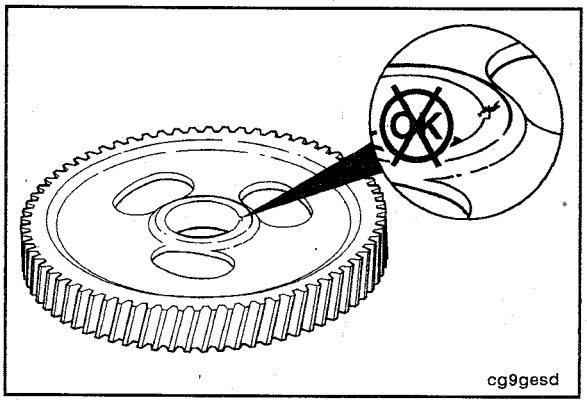


Clean and Inspect for Reuse

Inspect the camshaft gear for cracked, chipped, or broken teeth.

Inspect the camshaft bore for fretting or burrs.

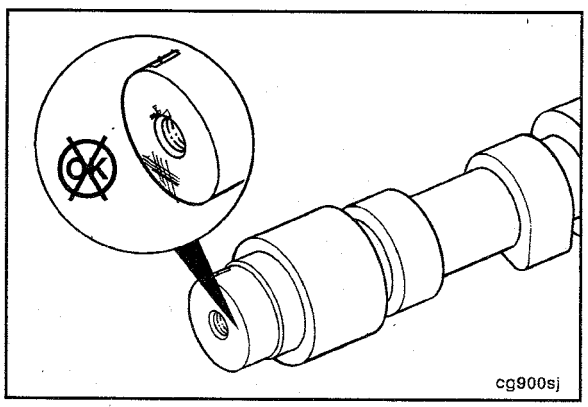
NOTE: If the fretting, burrs, or raised material can **not** be removed with Scotch-Brite™ 7448, or equivalent, replace the camshaft gear.



Inspect the camshaft gear keyway for burrs.

Remove burrs with Scotch-Brite™ 7448, or equivalent.

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

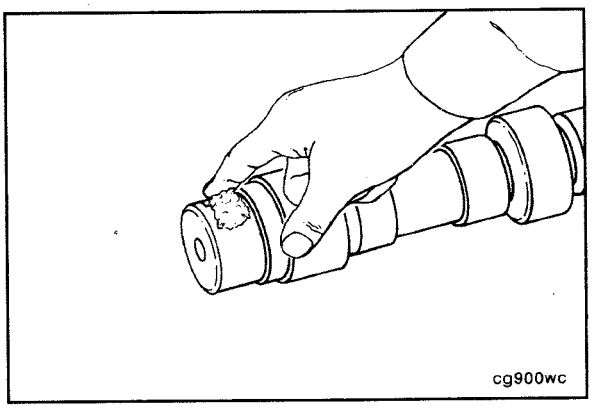


Inspect the camshaft nose for fretting or burrs.

NOTE: If fretting or burrs can **not** be removed with Scotch-Brite™, or equivalent, replace the camshaft.

Install

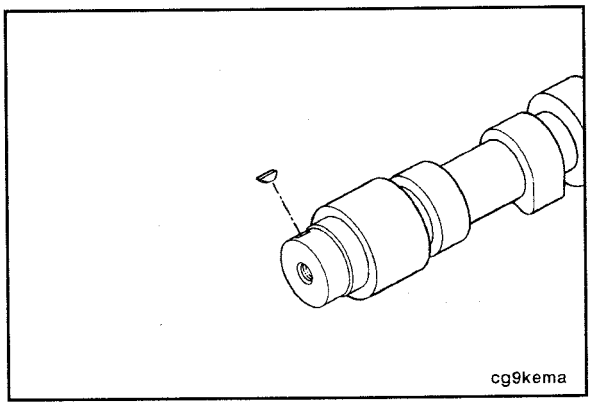
Lubricate the camshaft surface with Lubriplate™ 105, or equivalent.



Install the key into the camshaft nose.

Tighten the thrust plate capscrews.

Torque Value: 24 N•m [18 ft-lb]



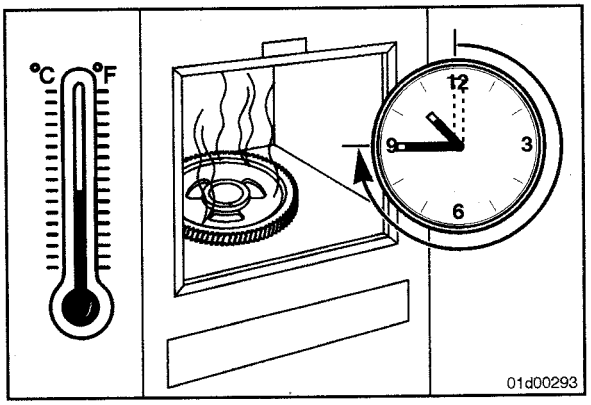
⚠CAUTION⚠

The camshaft gear will be permanently distorted if overheated. The oven temperature should never exceed 204°C [400°F].

Heat the camshaft gear for 45 minutes.

Oven Temperature 204 °C [400 °F]

Use camshaft gear removal and installation tool, Part Number 3163054, and puller assembly, Part Number 3165093, to install the camshaft gear onto the camshaft.

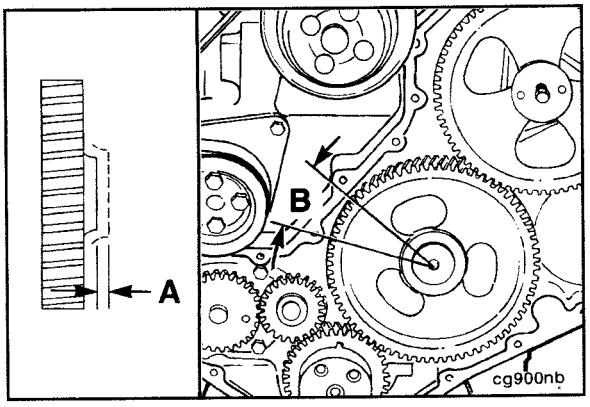


NOTE: Be sure the gear is seated against the camshaft shoulder.

Using gauge, Part Number 3824564, and magnetic base, Part Number 3377399, verify the camshaft has proper backlash and end play.

Camshaft End Play (A)		
mm		in
0.12	MIN	0.005
0.50	MAX	0.020

Camshaft Gear Backlash Limits (B)		
mm		in
0.08	MIN	0.003
0.33	MAX	0.013



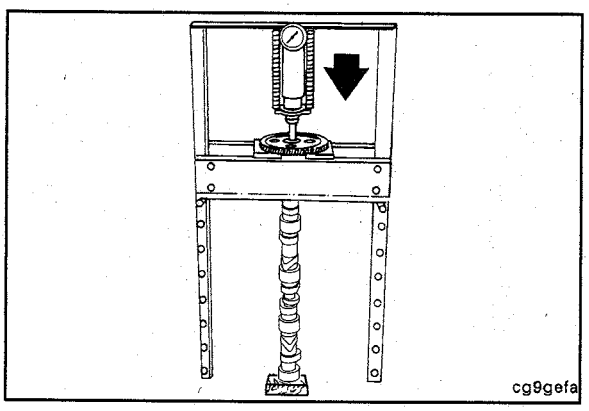
Finishing Steps

- Install the gear cover. Refer to Procedure 001-031.
- Install the vibration damper. Refer to Procedure 001-052.
- Install the fan hub, if required. Refer to Procedure 008-039.
- Install the drive belt. Refer to Procedure 008-002.
- Tighten the rocker lever assemblies. Refer to Procedure 003-008.
- Install the rocker lever cover. Refer to Procedure 003-011.

Camshaft Gear (Camshaft Removed) (001-013)

Preparatory Steps

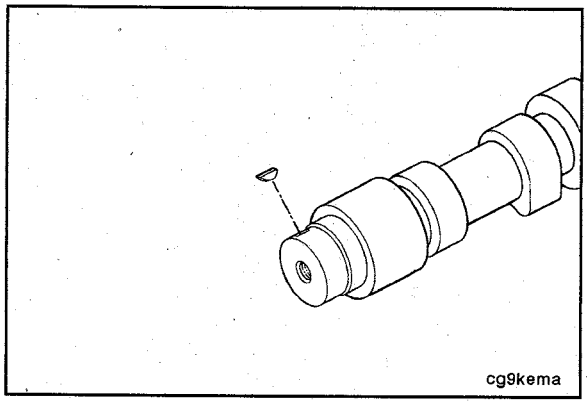
Remove the camshaft. Refer to Procedure 001-008.



Remove

Remove the gear by using a press.

Remove the thrust plate.



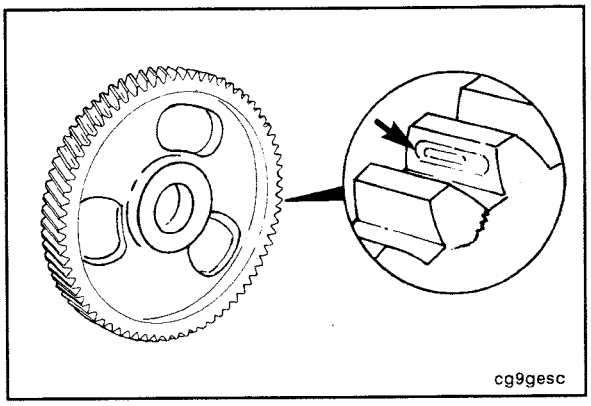
Remove the camshaft key.

Clean and Inspect for Reuse

Inspect the camshaft gear for cracked, chipped, or broken teeth.

Inspect the camshaft bore for fretting or burrs.

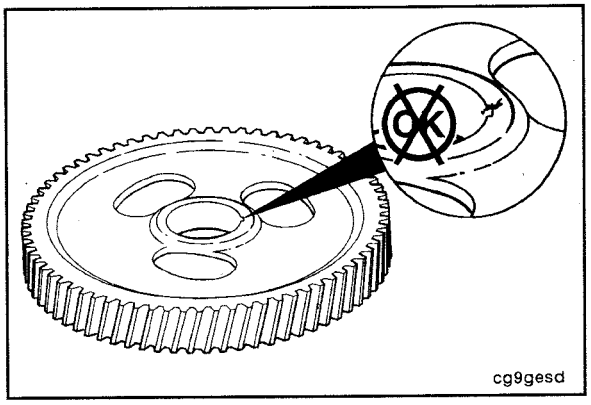
NOTE: If the fretting, burrs, or raised material can **not** be removed with Scotch-Brite™ 7448, or equivalent, replace the camshaft gear.



Inspect the camshaft gear keyway for burrs.

Remove burrs with Scotch-Brite™ 7448, or equivalent.

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



Engines With Bolt On Speed Sensor Targets

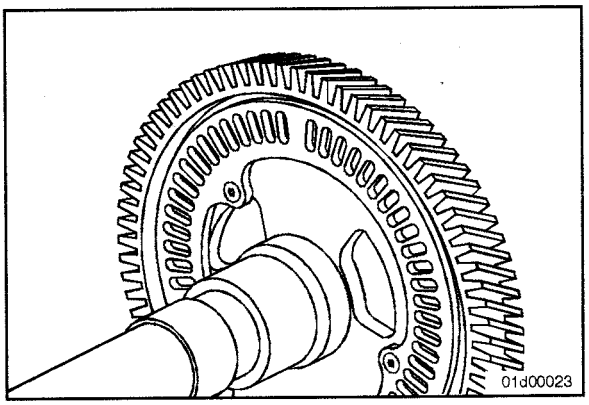
Inspect cam gear and timing plate for damage.

Inspect flathead capscrews to make sure they are tight.

If more than one capscrew is loose, replace cam gear.

If **only** one capscrew is loose, tighten all capscrews.

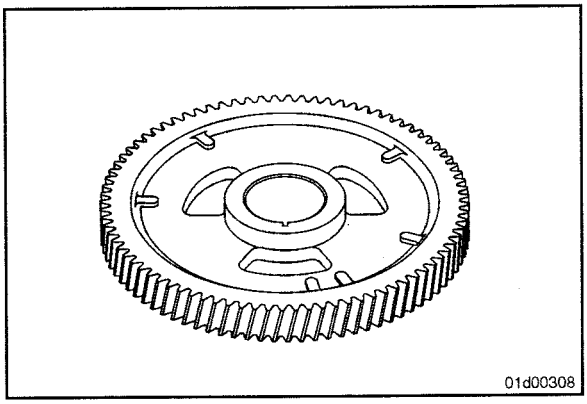
Torque Value: 7 N•m [62 in-lb]

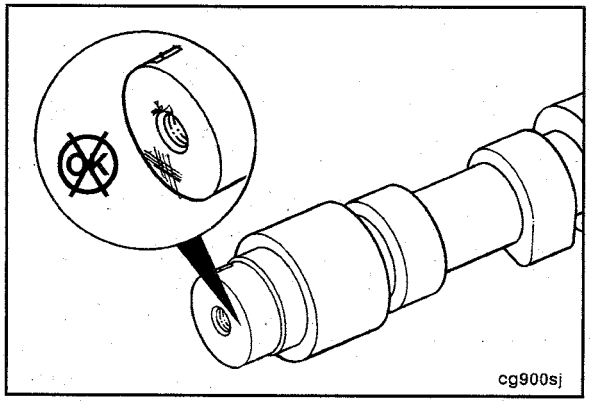


Engines With Machined Speed Sensor Targets

Inspect the cam gear and speed sensor targets.

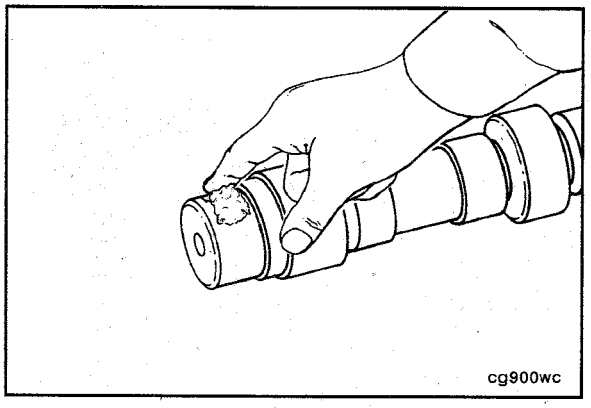
Replace the gear if any damage is found.





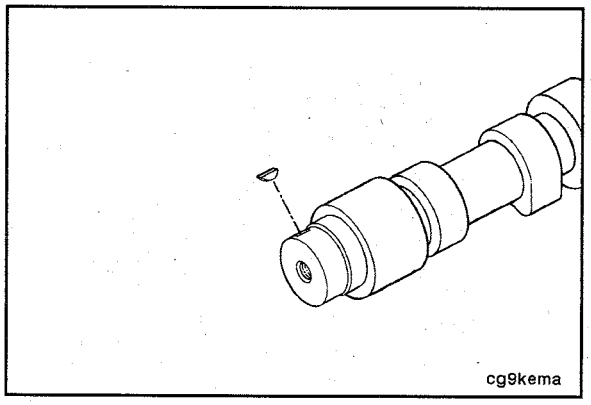
Inspect the camshaft nose for fretting or burrs.

NOTE: If fretting or burrs can **not** be removed with Scotch-Brite™ 7448, or equivalent, replace the camshaft.



Install

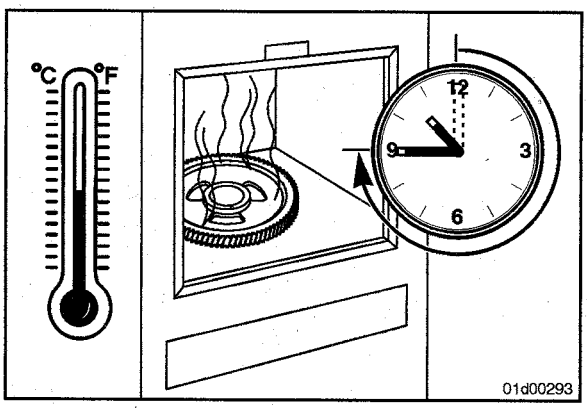
Lubricate the camshaft surface with Lubriplate™ 105, or equivalent.



Install the key.

Install the thrust plate.

NOTE: Because the thrust plate extends more than 180 degrees around the camshaft, the thrust plate **must** be installed before installing the cam gear on the camshaft.



⚠CAUTION⚠

The camshaft gear will be permanently distorted if overheated. The oven temperature should never exceed 204°C [400°F].

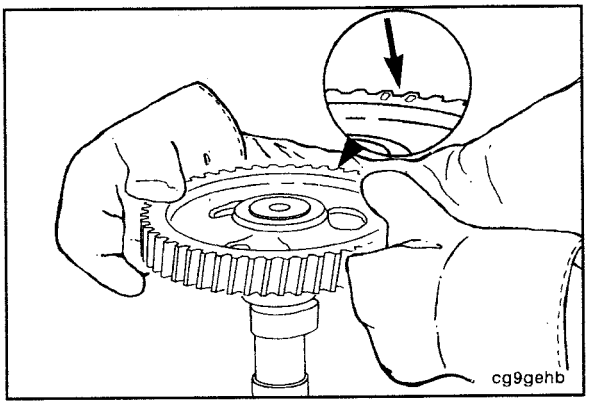
Heat the camshaft gear for 45 minutes.

Oven Temperature 204 °C [400 °F]

⚠WARNING⚠

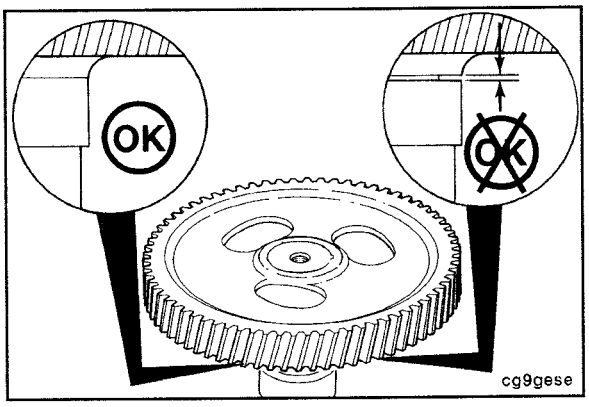
Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.

Install the camshaft gear with the timing marks away from the camshaft.



NOTE: Be sure the gear is seated against camshaft shoulder.

Using a 0.02 mm [0.001 in] feeler gauge, check to see if the feeler gauge can be inserted between the camshaft gear and the shoulder on the camshaft. If the feeler gauge can be inserted, the camshaft gear is **not** properly seated.



Finishing Steps

Install the camshaft. Refer to Procedure 001-008.

Operate the engine and check for leaks.

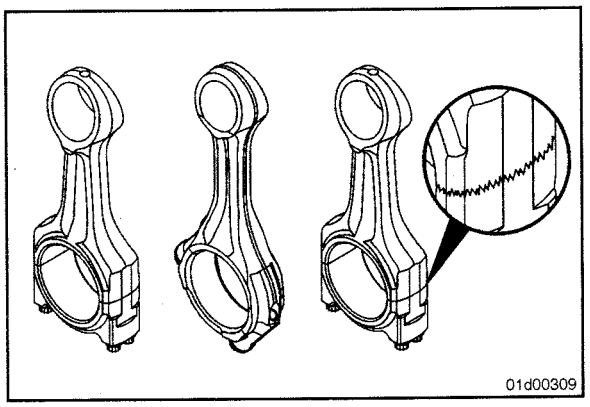
Connecting Rod (001-014)

General Information

The connecting rod configuration may change depending on the engine configuration. Some engines use straight split connecting rods where others use angle split connecting rods. The connecting rod may also have a fracture split surface.

Connecting rods with a fractured split surface **must** be treated with caution. The two pieces of the connecting rod should **not** be rubbed together as this will damage the mating surface. Care should also be taken **not** to drop either piece of the connecting rod.

The art used in this procedure is generic and does **not** represent a specific engine.



Preparatory Steps

⚠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.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠
Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

Drain the coolant. Refer to Procedure 008-018.

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

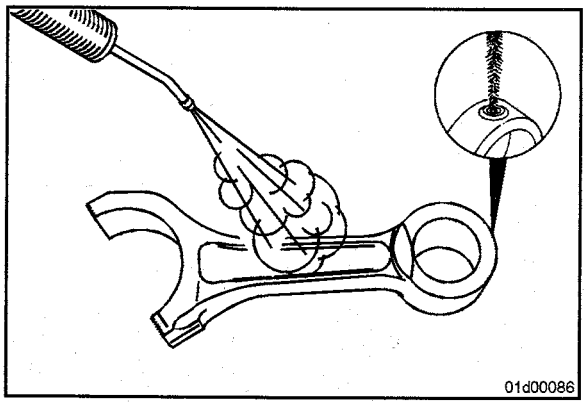
Drain the lubricating oil. Refer to Procedure 007-037.

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

Remove the lubricating oil suction tube. Refer to Procedure 007-035.

Remove the piston and connecting rod assemblies from the engine. Refer to Procedure 001-054.

Disassemble the piston and connecting rod assembly. Refer to Procedure 001-043.



Clean and Inspect for Reuse

⚠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.

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

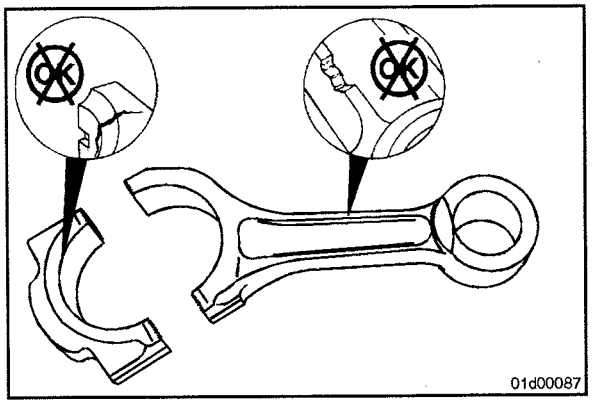
Use a nylon bristle brush to clean the oil drillings.

Use steam or solvent to clean the connecting rods.

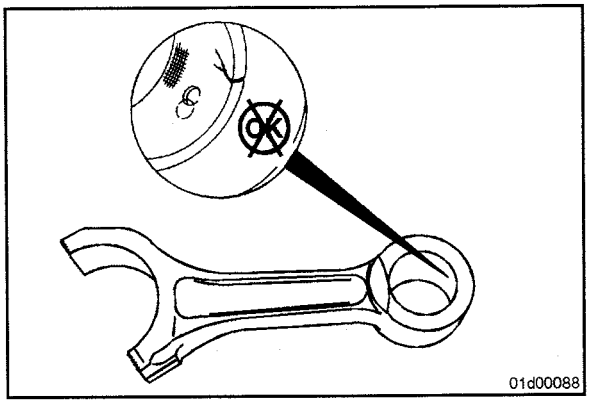
Dry with compressed air.

Inspect the connecting rods and connecting rod caps for damage.

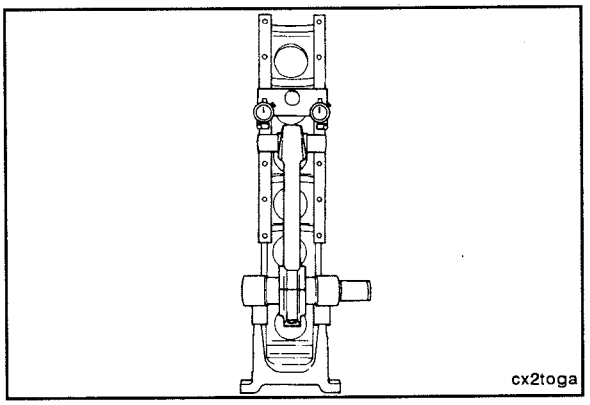
Replace the connecting rod if the "I-beam" is nicked or damaged.



Inspect the piston pin bore for damage or misalignment of the oil passage and bushing.

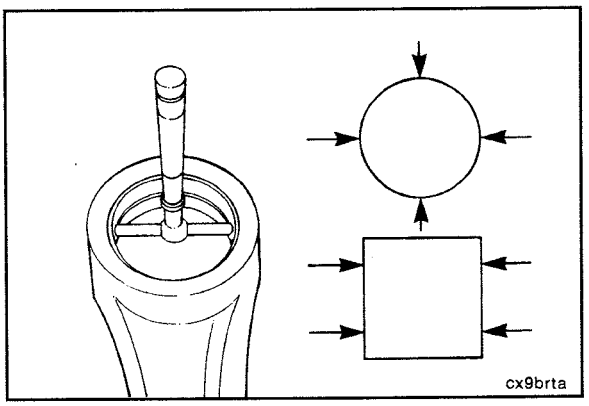


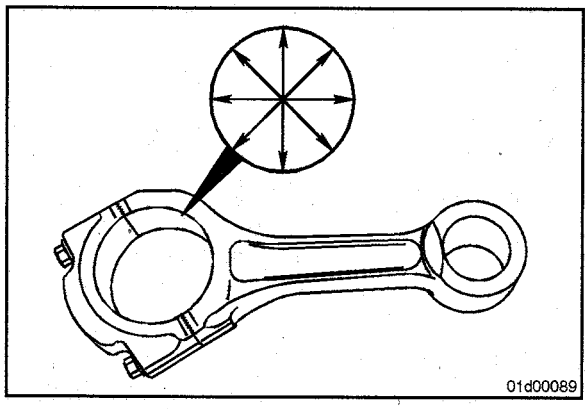
The connecting rod checking fixture, Part Number ST-561, and mandrel set, Part Number 3823286, can be used to inspect the bend and twist of the connecting rod.



Measure the connecting rod piston pin bushing inside diameter.

Connecting Rod Piston Pin Bushing Diameter		
mm		in
45.023	MIN	1.7726
45.035	MAX	1.7730

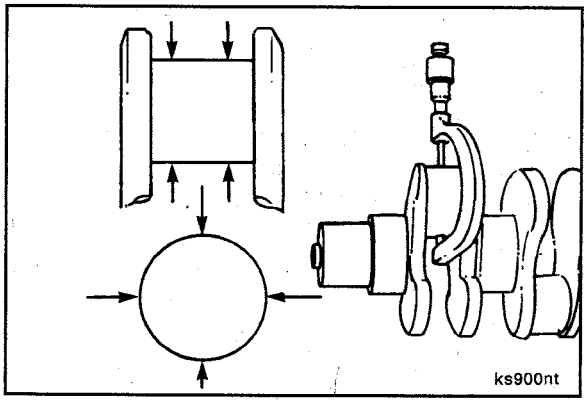




Measure the connecting rod crankshaft bore with the bearing shells removed and caps tightened.

Torque Value: Step1 60 N•m [44 ft-lb]
Step2 Loosen Capscrews
Step3 70 N•m [52 ft-lb]
Step4 Advance 60-degrees

Connecting Rod Crank Bore Diameter (Bearings Removed)		
mm		**in**
80.987	MIN	3.1885
81.013	MAX	3.1895



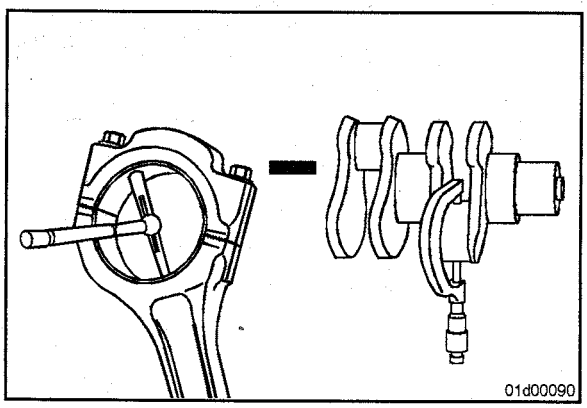
Measure the diameter of the rod journal on the crankshaft.

Crankshaft Rod Journal Diameter		
mm		**in**
CM554 Control Module (No Speed Indicator Ring On Crankshaft)		
75.962	MIN	2.9906
76.013	MAX	2.9926
CM850 Control Module (Speed Indicator Ring Mounted to Rear of Crankshaft		
76.000	MIN	2.9921
76.026	MAX	2.9931

Out-of-Roundness		
mm		**in**
0.050	MAX	0.002

Taper		
mm		**in**
0.013	MAX	0.0005

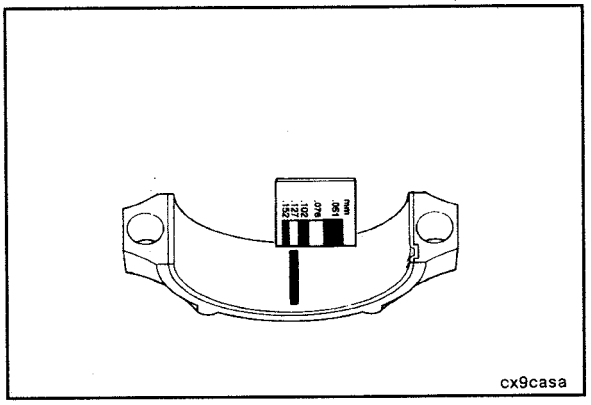
NOTE: If crankshaft rod journals are **not** within the given specifications, the crankshaft **must** be replaced.



Bearing Clearance		
mm		**in**
0.038	MIN	0.0015
0.116	MAX	0.0045

Bearing clearance: rod inside diameter (with bearing) minus crankshaft journal diameter.

Bearing clearance can also be determined with plastigauge during engine assembly.



Finishing Steps

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

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

Install the lubricating oil suction tube. Refer to Procedure 007-035.

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

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

Fill the lubricating oil pan. Refer to Procedure 007-037.

Fill the cooling system. Refer to Procedure 008-018.

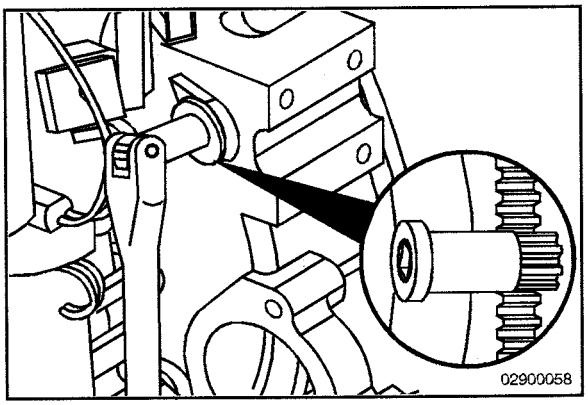
Operate the engine to normal operating temperature and check for leaks.

Crankshaft (001-016)

Rotation Check

Barring Tool, Part Number 3824591

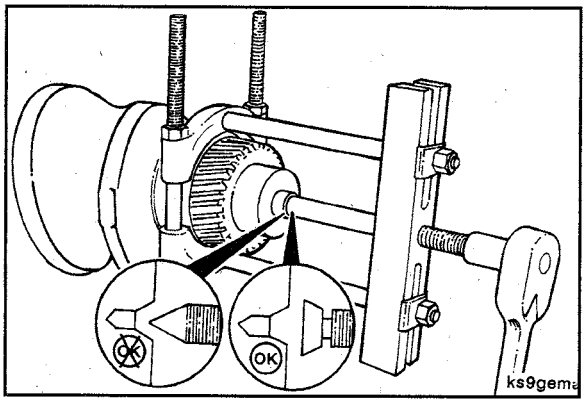
The barring tool inserts into the flywheel housing and engages the flywheel ring gear. The crankshaft can then be rotated by hand using a 1/2-inch ratchet or breaker bar.



Crankshaft Gear, Front (Crankshaft Removed) (001-019)

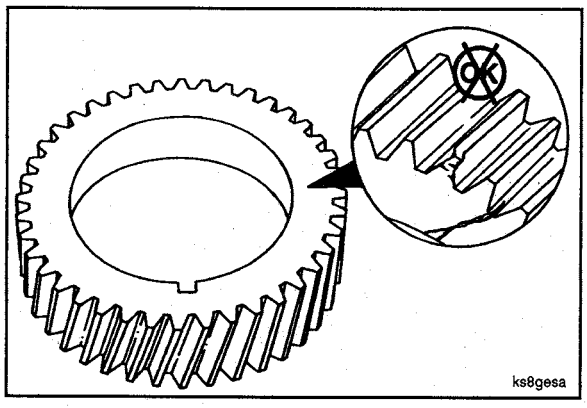
Preparatory Steps

Remove the crankshaft.



Remove

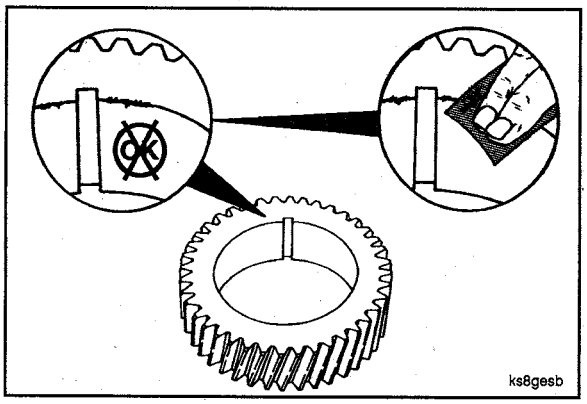
Use a heavy-duty bearing separator or gear puller, as illustrated, to remove the crankshaft gear.



Clean and Inspect for Reuse

Visually inspect for cracks and broken or chipped teeth.

The gear **must** be replaced if it is damaged.

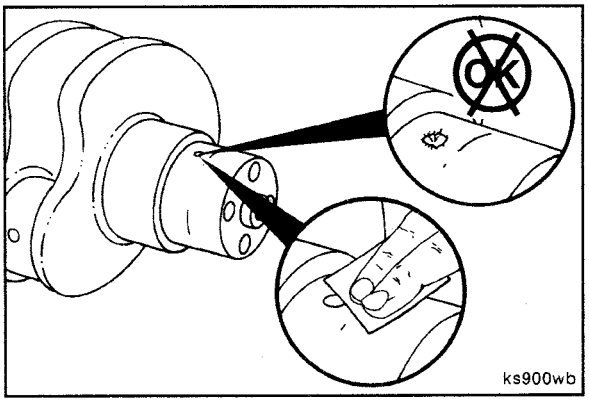


Visually inspect the gear and keyway for nicks or burrs.

Use fine crocus cloth to remove nicks and burrs.

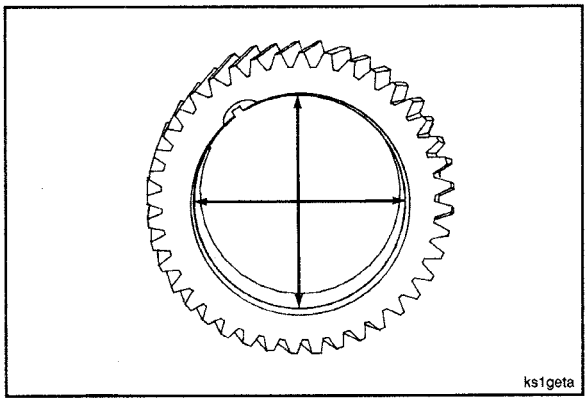
Visually inspect the crankshaft gear journal and the gear alignment dowel pin hole for burrs or damage.

Use fine crocus cloth to remove burrs.



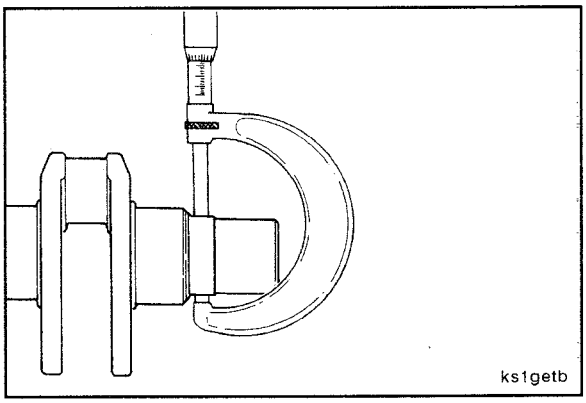
Measure the crankshaft gear bore inside diameter.

Crankshaft Gear Bore I.D.		
mm		in
75.898	MIN	2.9881
75.923	MAX	2.9891



Measure the crankshaft gear journal outside diameter.

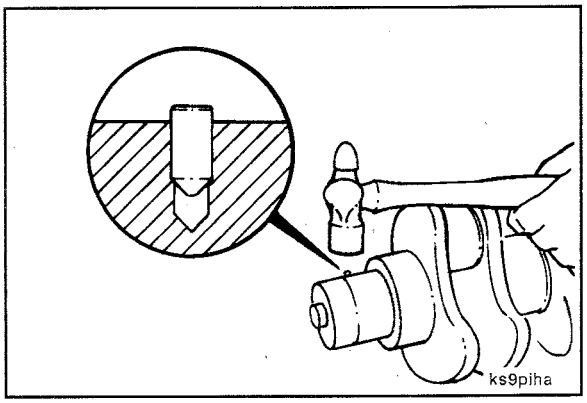
Crankshaft Gear Journal O.D.		
mm		in
75.987	MIN	2.9916
76.006	MAX	2.9924

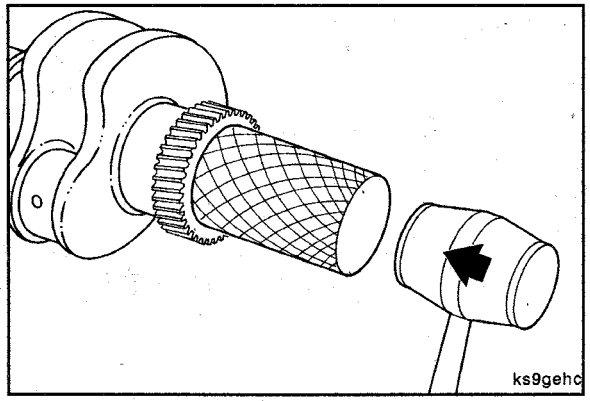


Install

Use a soft hammer to install the gear alignment dowel into the crankshaft.

The pin **must** be 1.02 mm [0.040 in] above the crankshaft surface.



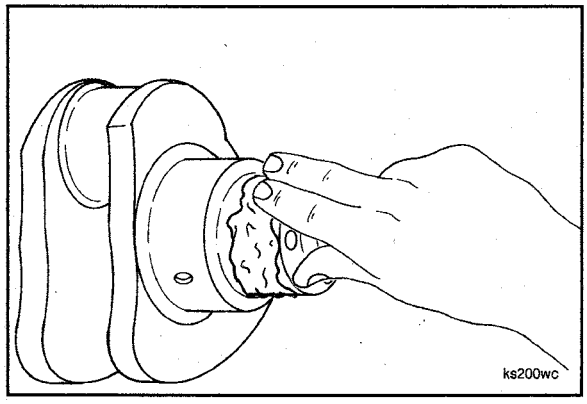


⚠CAUTION⚠
Do not exceed the specified heating time or temperature. The crankshaft teeth can be damaged.

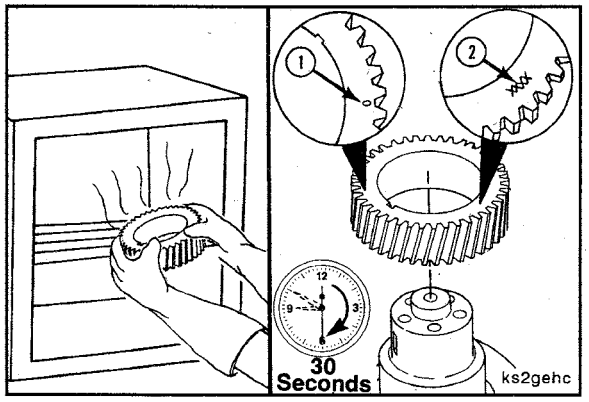
Heat the gear in an oven for a minimum of 45 minutes, but **not** more than 2 hours.

Temperature

Steel Gear	177 °C	[350 °F]



Use Lubriplate™ 105, Part Number 3163087 or equivalent, to lubricate the outside diameter of the crankshaft gear journal.



⚠WARNING⚠
Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.

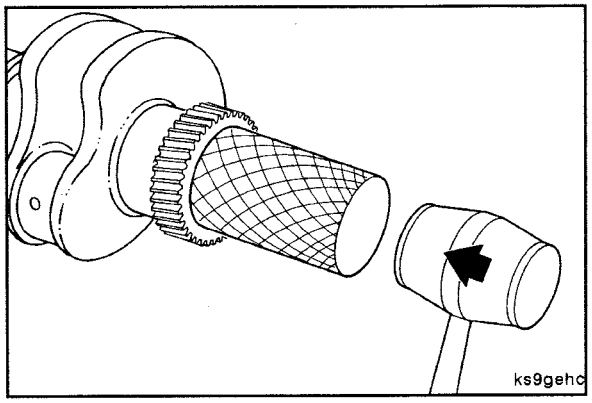
⚠CAUTION⚠
The timing mark (1) and part number (2) on the gear must be facing away from the crankshaft after the gear is installed. Engine damage can result if the gear is installed backwards.

⚠CAUTION⚠
Do not use water or oil to reduce the cooling time. The gear can crack. Allow the gear to air cool.

Remove the gear from the oven.

Align the keyway of the gear with the alignment dowel pin in the crankshaft and install the gear within 30 seconds.

If the gear cools and stops on the crankshaft before it is fully installed, use a driver to complete the installation.



Finishing Steps

Install the crankshaft.

Operate the engine and check for leaks.

Crankshaft Seal, Front (001-023)

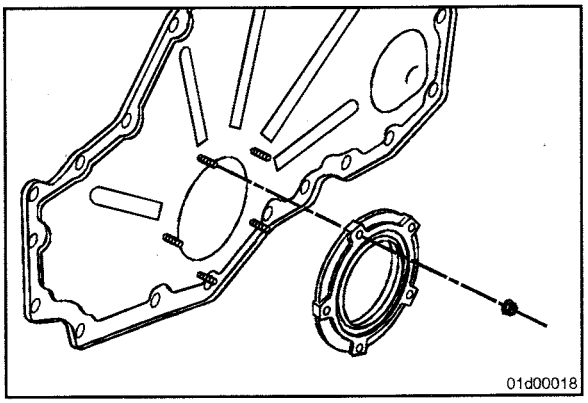
Preparatory Steps

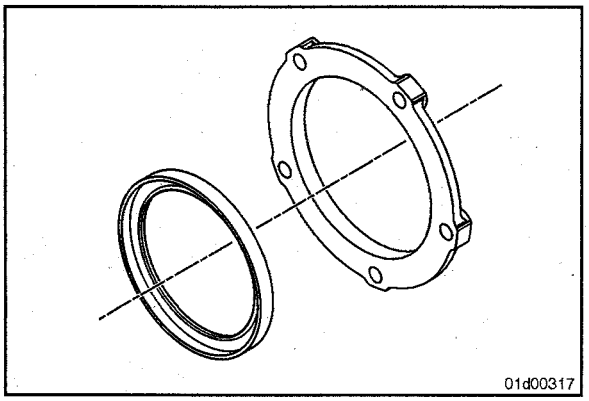
Remove the drive belt. Refer to Procedure 008-002.

Remove the vibration damper. Refer to Procedure 001-052.

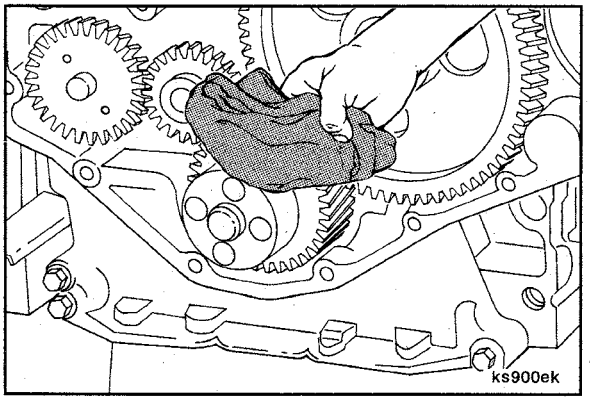
Remove

Remove the crank seal carrier.



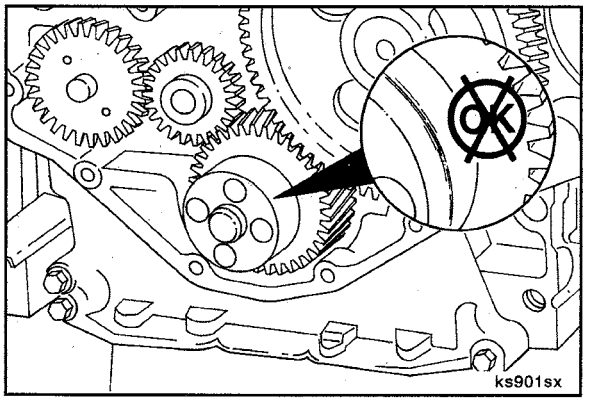


Remove the oil seal from the carrier. Drive the oil seal from the back side of the carrier toward the front side of the carrier, while supporting the carrier.



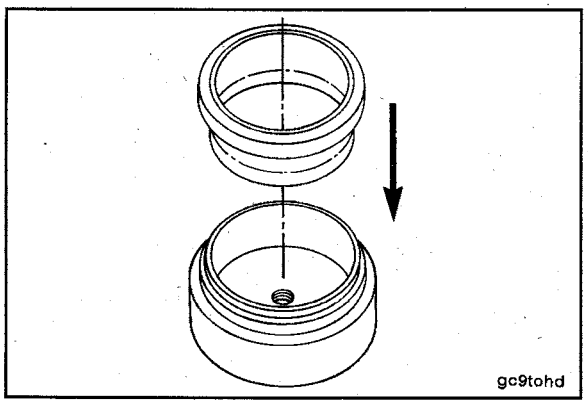
Clean and Inspect for Reuse

Clean the gear cover seal bore and the crankshaft surface of all oil and seal residue.



Inspect the crankshaft for excessive wear.

NOTE: If the crankshaft has excessive wear, a service wear sleeve is available.



Install

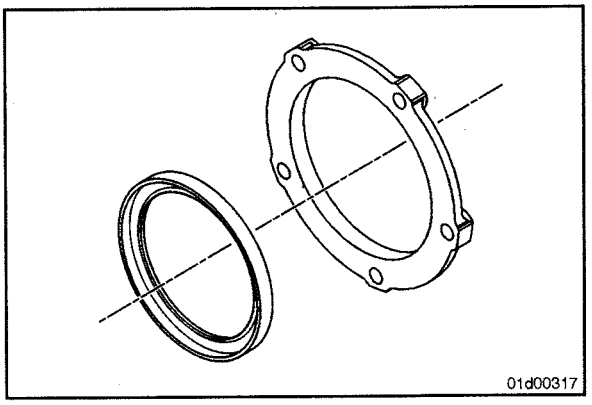
Leave the plastic pilot installation tool in the lubricating oil seal.

Position the seal on the service tool, Part No. 3824499, with the lubricating oil seal dust lip facing outward.

NOTE: Properly support the carrier lubricating oil seal flange to prevent damage to the lubricating oil seal and carrier.

Press the lubricating oil seal into the carrier from the back side of the carrier toward the front side of the carrier.

Press the lubricating oil seal until the seal is flush on front of the carrier.

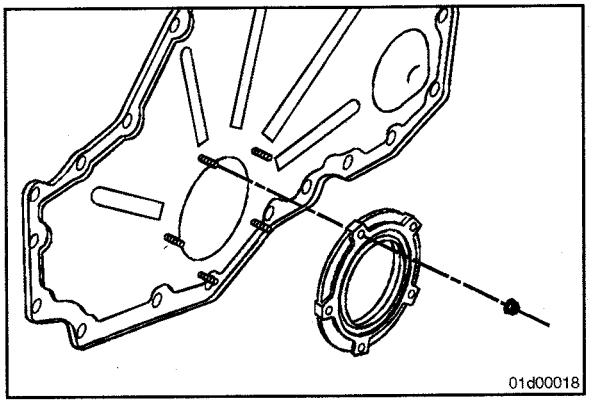


Apply bead of sealant to the inside of the carrier to make sure that there is sealant inside of all through holes. Install seal carrier on front cover.

Remove the plastic installation tool.

Tighten the carrier mounting nuts in a star pattern.

Torque Value: 10 N•m [88 in-lb]



Finishing Steps

Install the vibration damper. Refer to Procedure 001-052.

Install the drive belt. Refer to Procedure 008-002.

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

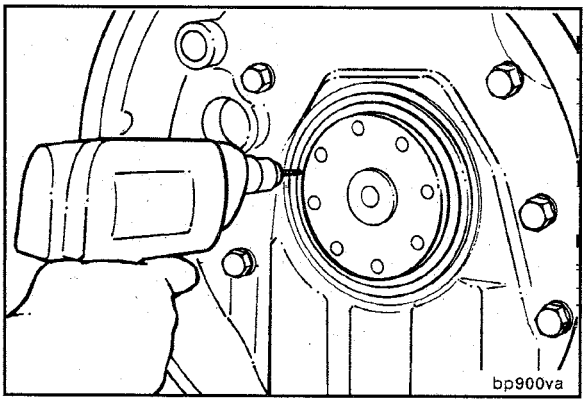
Crankshaft Seal, Rear (001-024)

Preparatory Steps

Remove the clutch and transmission. Refer to the OEM service manual.

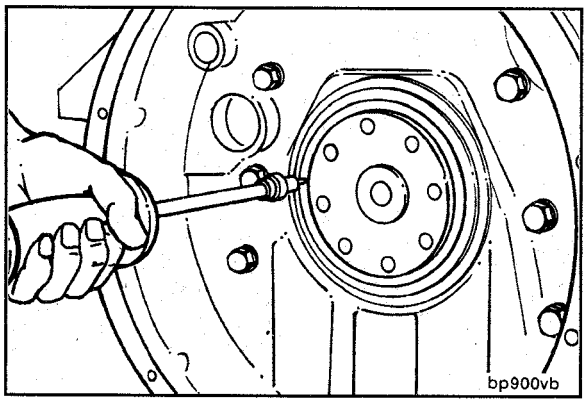
Remove the starting motor. Refer to Procedure 013-020.

Remove the flywheel. Refer to Procedure 016-005.

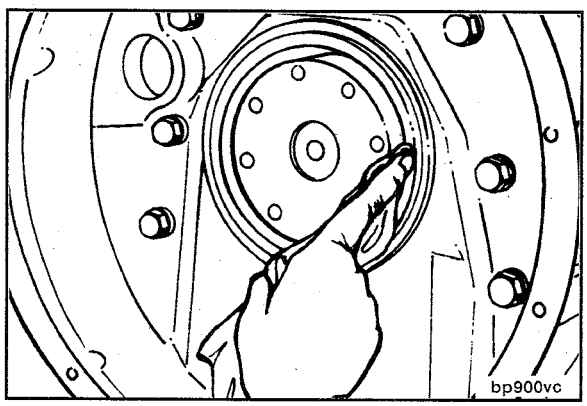


Remove

Drill two (2) holes 180-degrees apart into the seal carrier.



Remove the rear seal using a screwdriver and slide hammer.

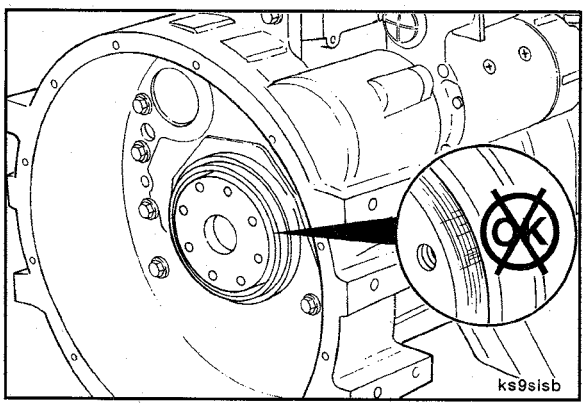


Clean and Inspect for Reuse

⚠CAUTION⚠

The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Clean and dry the rear crankshaft sealing surface.



Inspect the crankshaft for excessive wear.

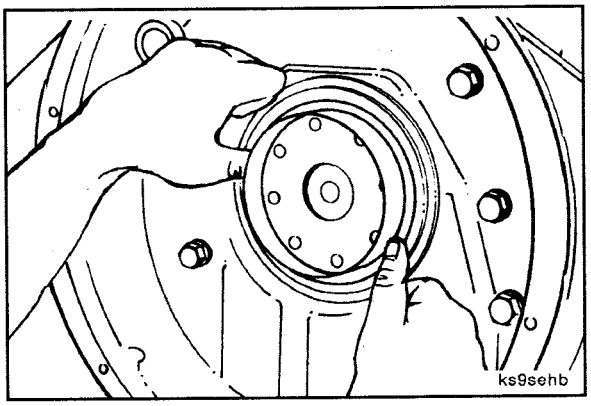
NOTE: If the crankshaft has excessive wear, a service wear sleeve is available.

Install

NOTE: For installation, the lubricating oil seal requires a mild soap on the outside diameter of the seal case.

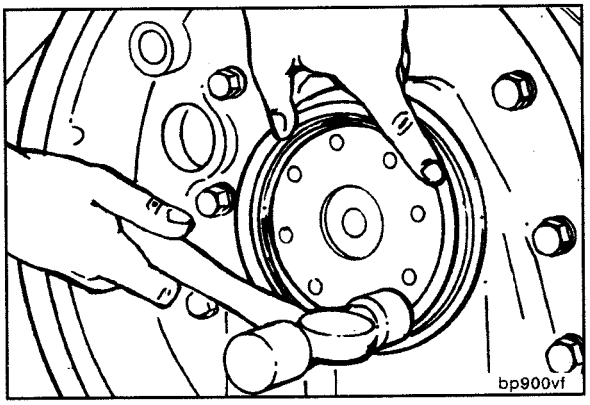
Install the seal pilot, provided in the replacement kit, onto the crankshaft. Push the seal onto the pilot and crankshaft.

Remove the seal pilot.



Use the alignment tool to install the seal to the correct depth in the housing. Use a hammer to drive the seal into the housing until the alignment tool stops against the housing.

Hit the tool at 12, 3, 6 and 9 o'clock positions to drive the seal evenly and to prevent bending the seal carrier.



Finishing Steps

Install the flywheel. Refer to Procedure 016-005.

Install the starting motor. Refer to Procedure 013-020.

Install the clutch and transmission. Refer to the OEM service manual.

Operate the engine and check for leaks.

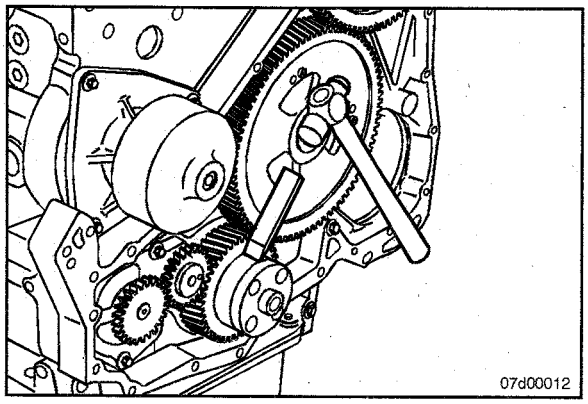
Crankshaft Wear Sleeve, Front (001-025)

Preparatory Steps

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

Remove the vibration damper. Refer to Procedure 001-052.

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

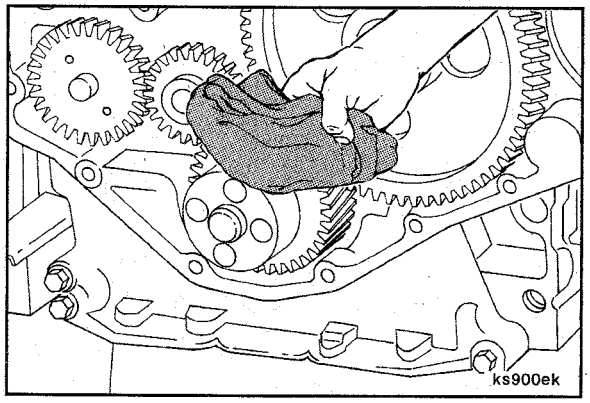


Remove

⚠CAUTION⚠

Do not nick or gouge the crankshaft with the chisel. If the crankshaft is severely damaged, it must be replaced.

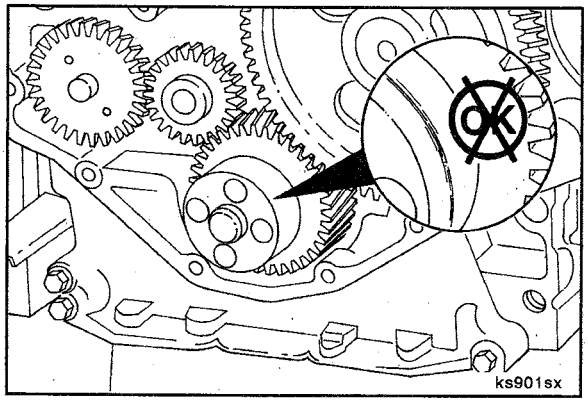
Use a hammer and a chisel that is only as wide as the wear sleeve. Make one or two chisel marks across the wear sleeve. This will expand the wear sleeve allowing the sleeve to be removed.



Clean and Inspect for Reuse

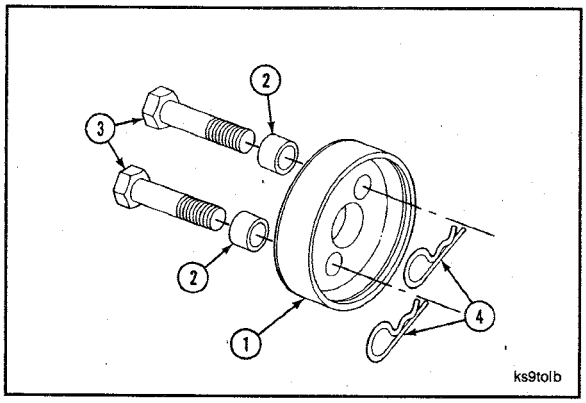
Use a crocus cloth to remove any rust or other deposits from the crankshaft flange.

Use a clean cloth to clean the crankshaft flange.



Inspect the seal contact area of the crankshaft for a wear groove. If the seal has worn a groove deep enough to be felt with a sharp object or fingernail, it will be necessary to install a wear sleeve to prevent an oil leak.

The oil seal used with the wear sleeve has a larger inside diameter than the standard seal. The two seals are **not** interchangeable. Refer to the appropriate parts catalog for the correct part number.



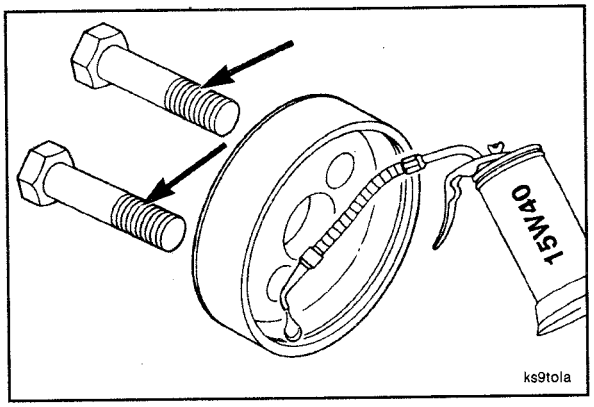
Install

NOTE: The ISC engine uses two (2) capscrews with sleeve installation kit, Part Number 3165112, and the ISL engine uses three (3) capscrews.

Use the wear sleeve installation kit, Part Number 3165112, to install the wear sleeve to the correct position on the crankshaft. The kit consists of the following:

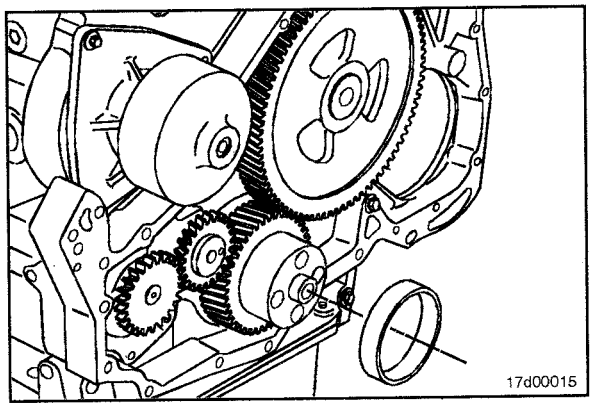
Ref. No.	Description	Qty.
1	Driver	1
2	Spacer	3
3	Capscrew M14x1.5x60 mm	3

Apply a thin coat of clean 15W-40 lubricating oil to the inside diameter and capscrew threads.

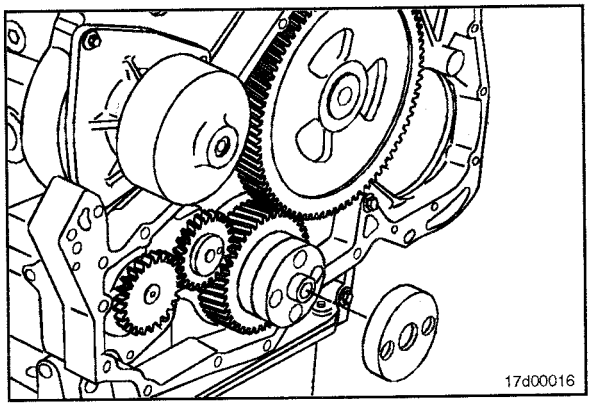


Apply a thin coat of clean 15W-40 lubricating oil to the crankshaft flange.

Position the chamfered end of the wear sleeve onto the end of the crankshaft.

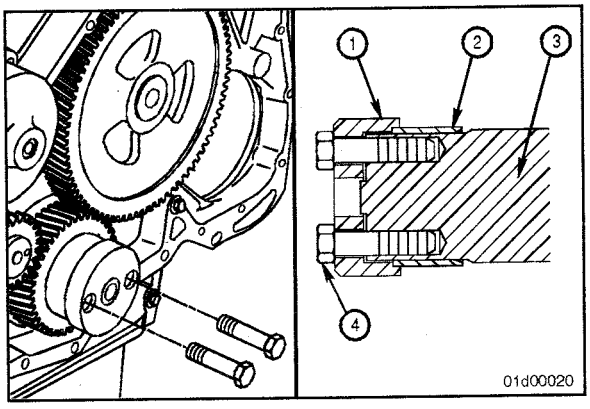


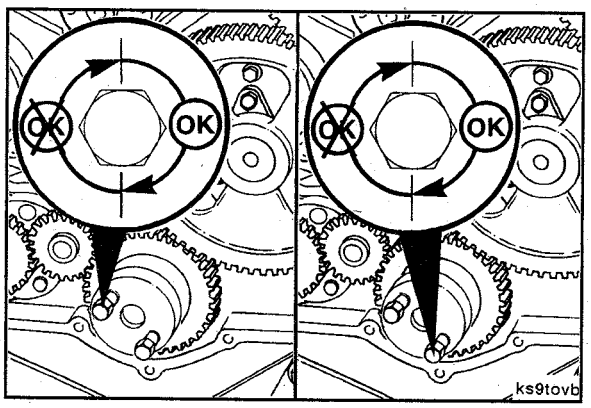
Position the counterbore end of the driver onto the wear sleeve.



Install the capscrews (without spacers) through the driver and into the crankshaft capscrew holes. Align the wear sleeve and driver perpendicular with the crankshaft. Tighten the capscrews "finger tight".

1. . Driver
2. . Wear Sleeve
3. . Crankshaft
4. . Capscrew

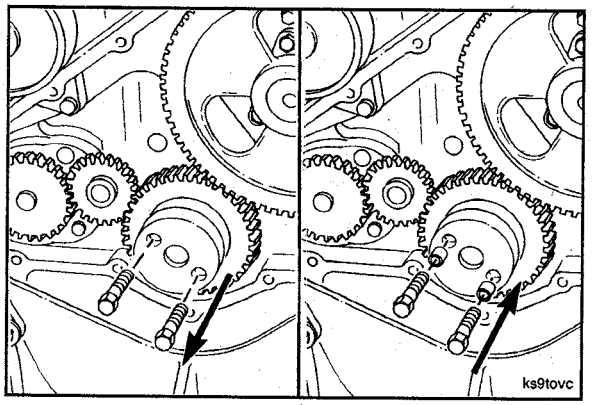




NOTE: To prevent damage to the wear sleeve, do **not** exceed 1/2 revolution of each capscrew.

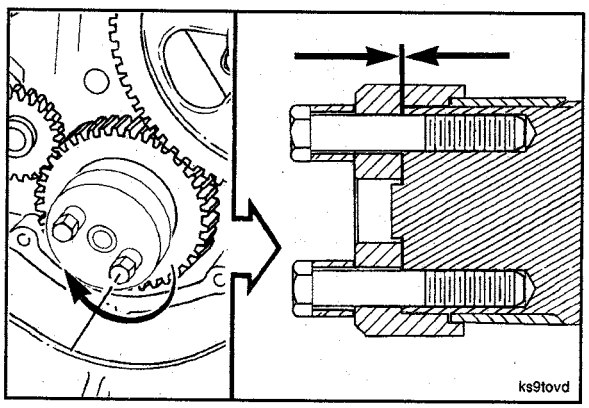
Alternately tighten the capscrews until the sleeve is installed to a depth of approximately 16 mm [0.625 in].

Torque Value: 20 N•m [15 ft-lb]

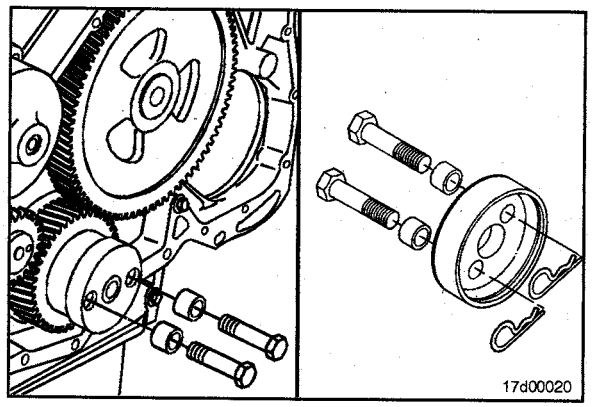


Remove the two (2) capscrews and install the spacer on each capscrew.

Install the two (2) capscrews again.



Continue to alternately tighten the capscrews until the bottom of the driver contacts the end of the crankshaft.



Remove the driver.

Finishing Steps

Install a new seal into the seal carrier. Refer to Procedure 001-023.

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

Install the seal carrier. Refer to Procedure 001-023.

Install vibration damper. Refer to Procedure 001-052.

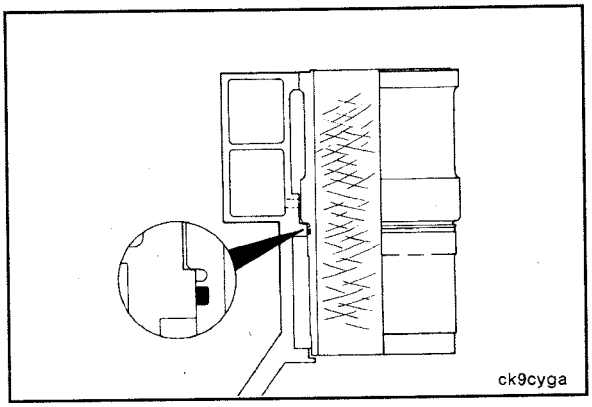
Install drive belts. Refer to Procedure 008-002.

Operate the engine and check for leaks.

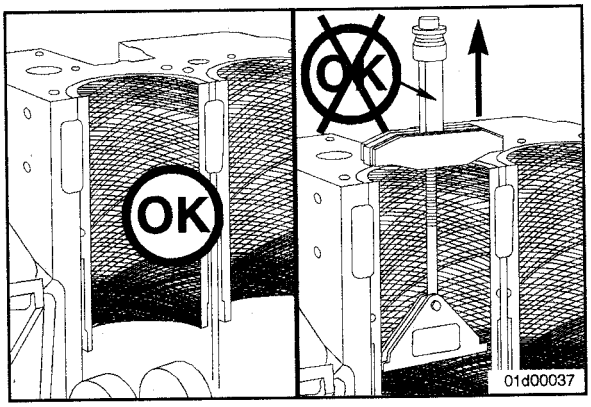
Cylinder Liner (001-028)

General Information

The cylinder block has a replaceable cylinder liner. A mid-stop design is used to locate the liner in the block. A press fit between the liner and the block provides coolant sealing at the top of the liner. A rectangular ring seal (liner seal) is used for sealing at the mid-stop portion of the liner.



NOTE: Cummins Inc. does **not** recommend removing the cylinder liners to repair an oil consumption problem if the inside diameters of the liners are within the inspection limits included in this procedure. Careful analysis of the condition of the liner bores, piston rings, and pistons can result in the restoration of cylinder sealing with a minimum replacement of parts.



Preparatory Steps

⚠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.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠
Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

Drain the cooling system. Refer to Procedure 008-018.

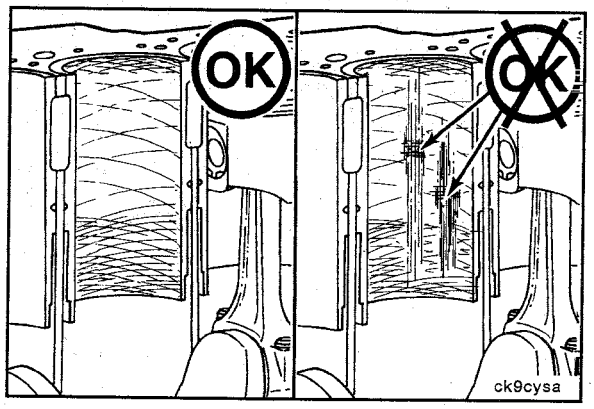
Remove valve cover. Refer to Procedure 003-011.

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

Drain the lubricating oil. Refer to Procedure 007-037.

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

Remove the piston and connecting rod assemblies. Refer to Procedure 001-054.



Initial Check

NOTE: Before removing the cylinder liners, inspect the condition to determine reuse.

Inspect the inside diameters of the liners for cracks, scuffing, and scoring.

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

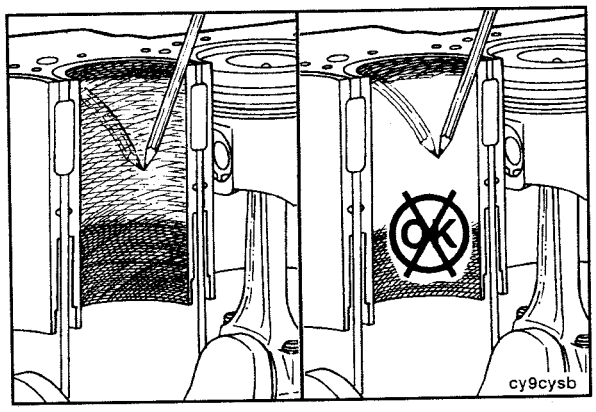
NOTE: If a fingernail catches in the scratch, the liner **must** be replaced.

Inspect the inside diameter for liner bore polishing.

A moderate polish 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 produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.

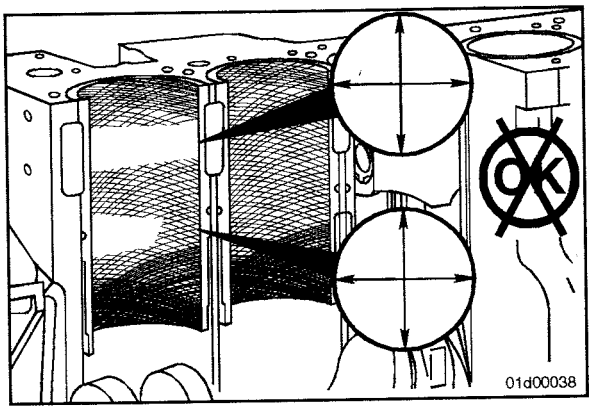
Do **not** reuse liners exhibiting heavy polish or any indications of particle embedment from a failure. Severely worn liners will have a ridge near the top of the liner bore.



If the wear pattern indicates the liner bore is **not** straight or **not** round, use a dial bore gauge to measure the liner inside diameter in four places 90 degrees apart at the top and bottom of the piston travel area.

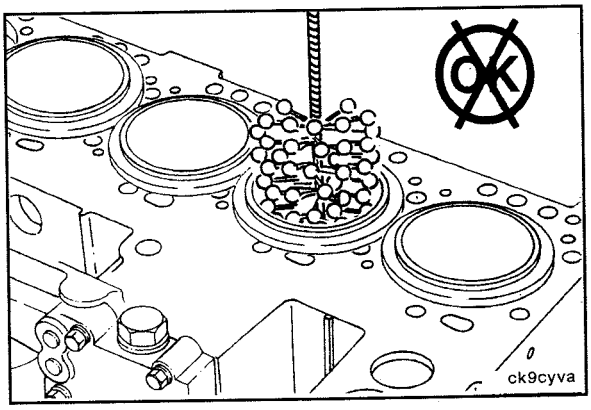
Cylinder Liner Dimensions

	mm		in
Taper	0.04	MAX	0.0016
Out Of Round	0.04	MAX	0.0016
Bore Diameter	114.04	MAX	4.4898



NOTE: If a liner bore is **not** acceptable for reuse, it **must** be replaced. Damaged liners can **not** be honed or deglazed. This would destroy the cross-hatch pattern needed for oil control.

NOTE: Do **not** remove or disturb the liner seals for liners which pass the inspection criteria.

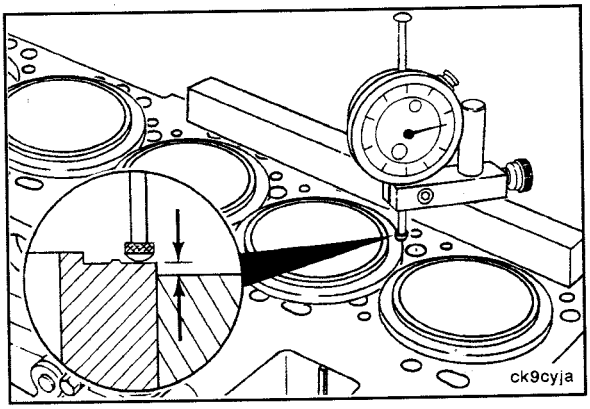


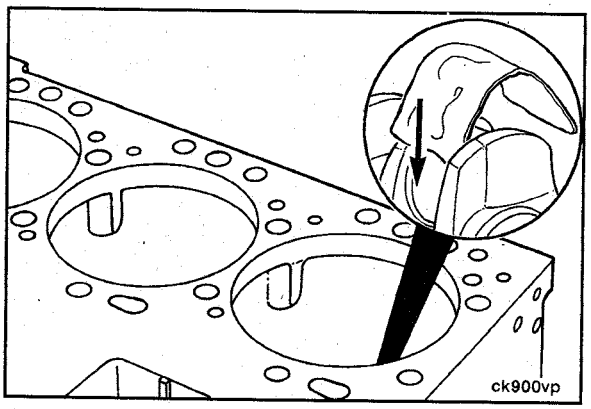
Liner protrusion is the distance the liner protrudes above the block face. Before removing the liners, check the protrusion in the "unclamped" stage. Use liner protrusion gauge, Part Number 3164438, to measure the liner protrusion.

Cylinder Liner Protrusion

mm		in
0.026	MIN	0.0010
0.122	MAX	0.0048

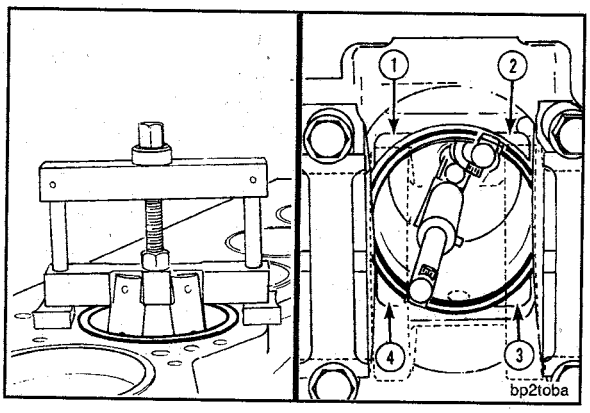
If the liner was installed correctly and the liner protrusion is out of limits, it will be necessary to machine the counterbore and add shims to restore to the original specifications.





Remove

Use clean shop rags to cover the crankshaft to prevent debris from falling into the main journal area or into the connecting rod journal oil drilling.



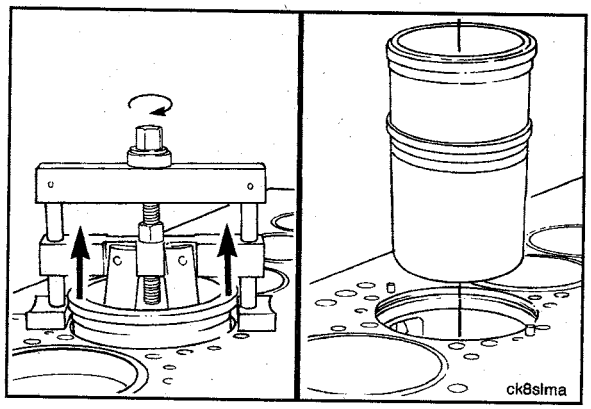
Standard Cylinder Liner Puller Method

⚠CAUTION⚠

The liner puller must be installed and used as described to avoid damage to the cylinder block. The puller must not contact the block casting at points (1), (2), (3), and (4).

Cylinder Liner Puller, Part Number 3376015

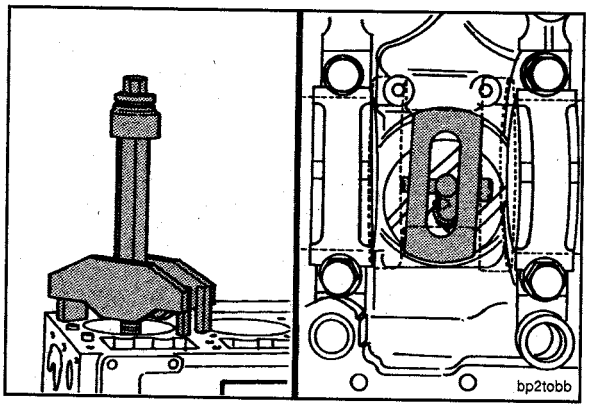
Insert the liner puller into the top of the cylinder block.



NOTE: 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.



Universal Liner Puller Method

⚠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.

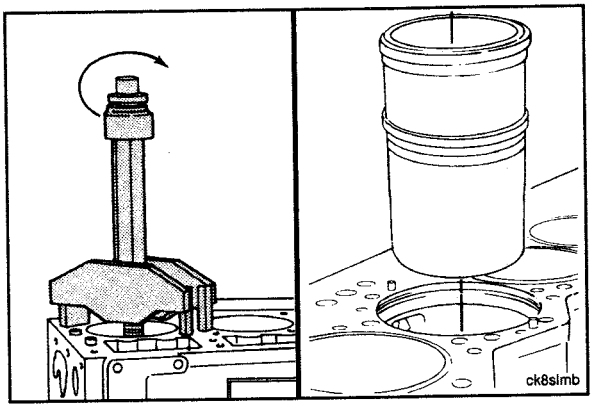
Universal Liner Puller, Part Number 3163745, may be used as an alternative to the standard puller. The universal puller **must** be used with remover plate, Part Number 3822786.

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

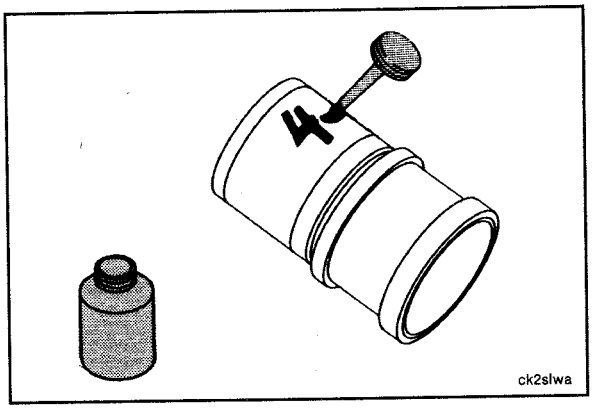
NOTE: The liner puller **must** be centered on the top of the cylinder block.

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

Use both hands to remove the liner.



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

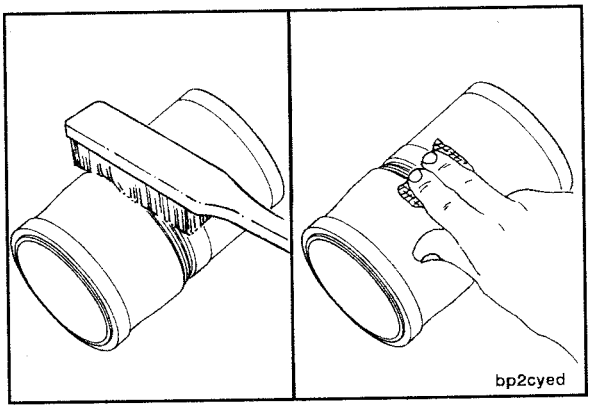


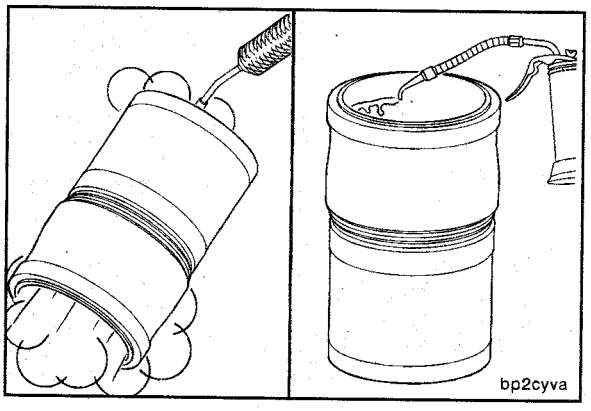
Clean and Inspect for Reuse

⚠CAUTION⚠

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

Use a soft wire brush or a fine fibrous abrasive pad such as Scotch-Brite® 7447, Part Number 3823258 or equivalent, to clean the flange seating area.





⚠ 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.

⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

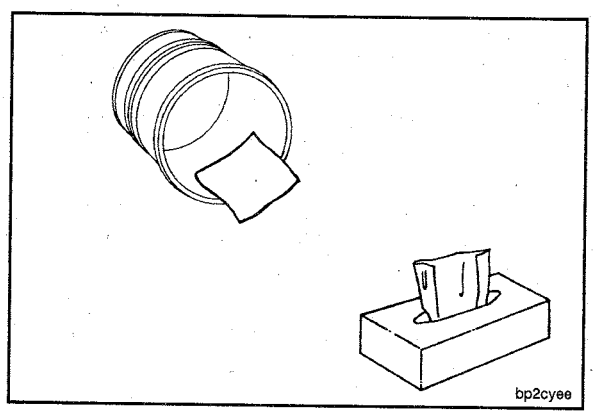
⚠ WARNING ⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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

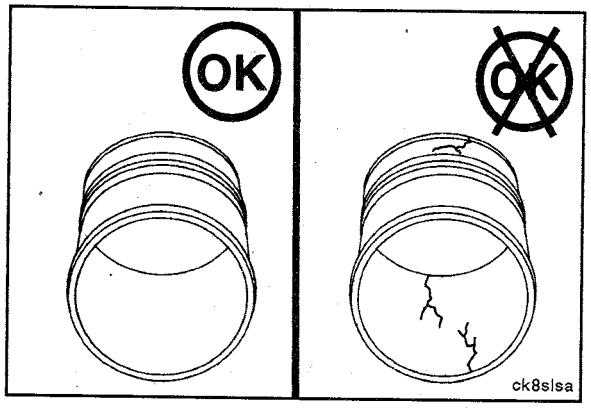
Use clean 15W-40 oil to lubricate the inside diameter of the liners.

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



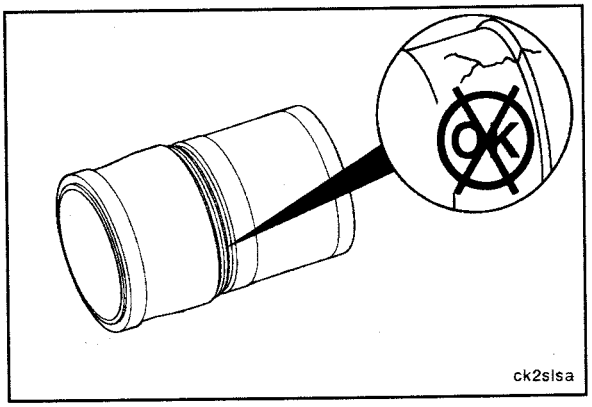
NOTE: Use "lint-free" paper towels to wipe the oil from the inside of the liners.

Continue to lubricate the inside of the liners and wipe clean until the paper towel does **not** show gray or black residue.



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

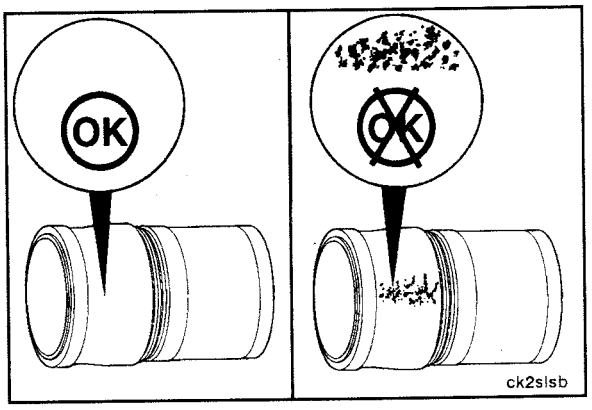
Inspect for cracks under the flange.



Inspect the outside diameter and seat area for excessive corrosion or pitting.

NOTE: Pits must **not** be more than 1.6 mm [0.06 in] deep.

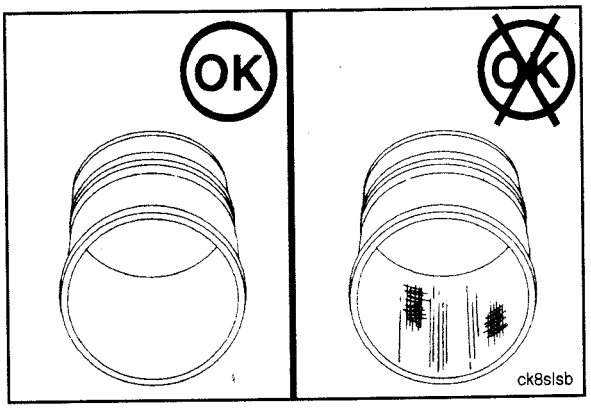
Replace the liner if the pits are too deep or if the corrosion can **not** be removed with fine emery cloth.



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

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

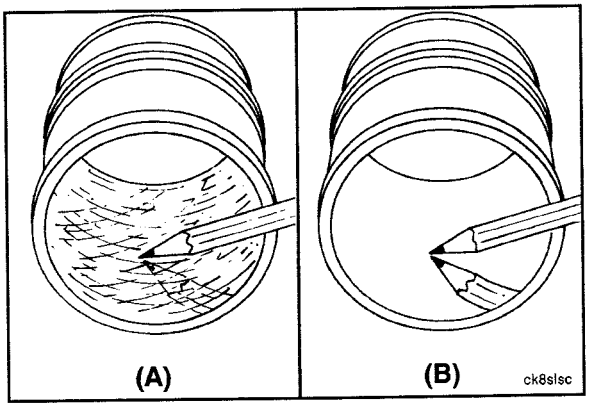
Inspect the inside diameter for scuffing or scoring.

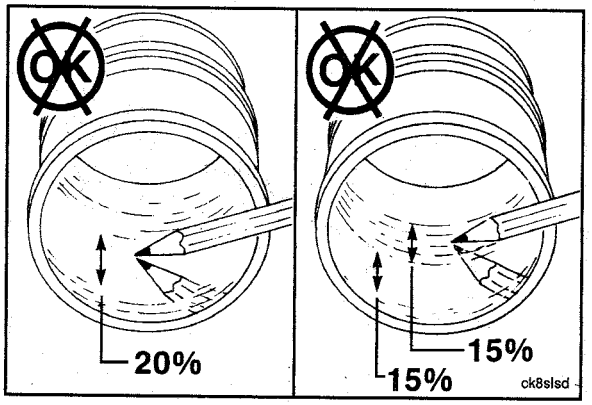


Inspect the inside diameter for liner bore polishing.

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

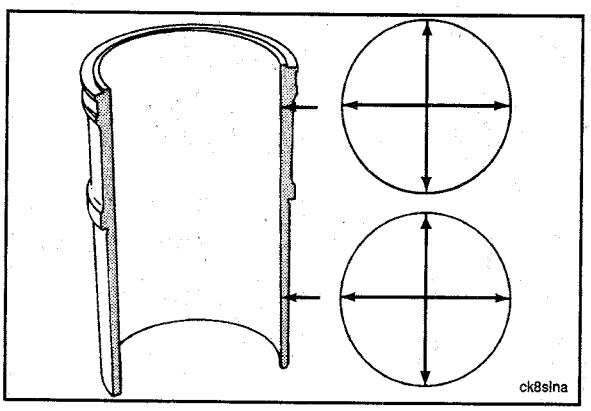
A **heavy polish** produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.





Replace the liner if:

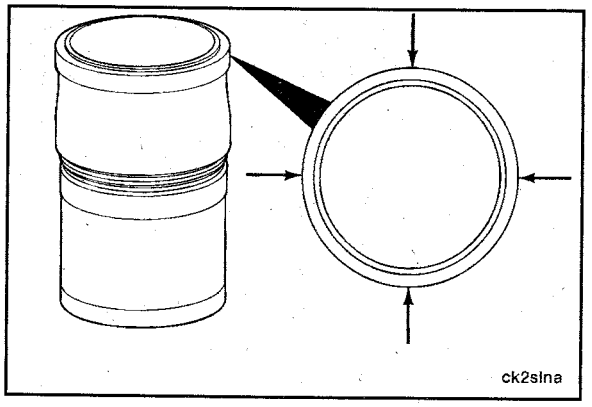
- A heavy polish is present over 20 percent of the piston ring travel area.
- Both moderate and heavy polish over 30 percent of the piston ring travel area and one half (15 percent) is heavy polish.



Dial Bore Gauge, Part No. 3376619

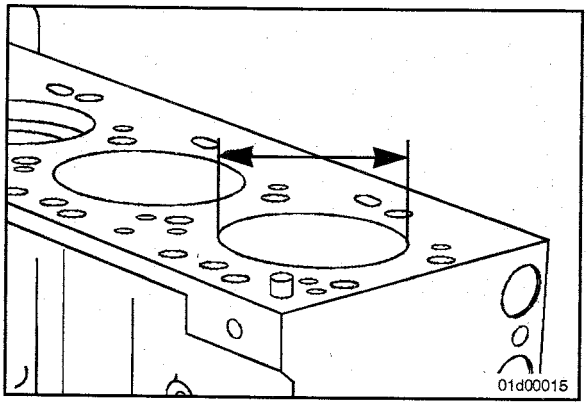
Measure the liner inside diameter in four places 90 degrees apart at the top and bottom of the piston travel area.

Cylinder Liner Inside Diameter		
mm		in
114.000	MIN	4.4882
114.040	MAX	4.4898



Measure the outside diameter of the liner top press fit area.

Cylinder Liner Out Diameter (Top Press Fit)		
mm		in
130.938	MIN	5.1550
130.958	MAX	5.1558



Measure the cylinder liner bore in the block.

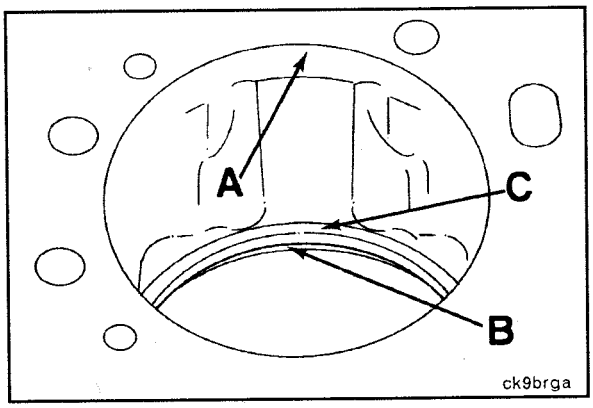
Cylinder Liner Bore in Block (Press Fit Bore)		
mm		in
130.900	MIN	5.1535
130.950	MAX	5.1555

Install

⚠CAUTION⚠

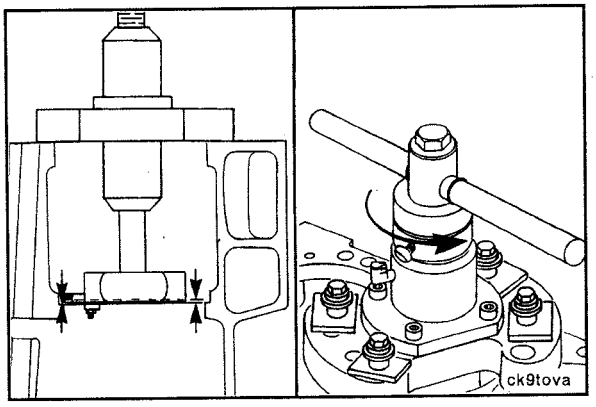
Clean all deposits and debris from sealing surfaces A, B, and C. Use Scotch-Brite® 7447, Part Number 3823258 or equivalent, and cleaning solvent to polish the surfaces. Due to the critical machined tolerances, care should be taken not to remove any additional material.

If surface C has cracks or signs of extreme wear, the counterbore will require machining and the installation of shims for the correct liner protrusion.



Using the Counterbore Cutter, Part Number 3163785, machine the counterbore to the proper depth.

NOTE: Part No. 3823567, cutter plate, and Part No. 3823570, cutter bit, **must** be used with the counterbore machining tool.



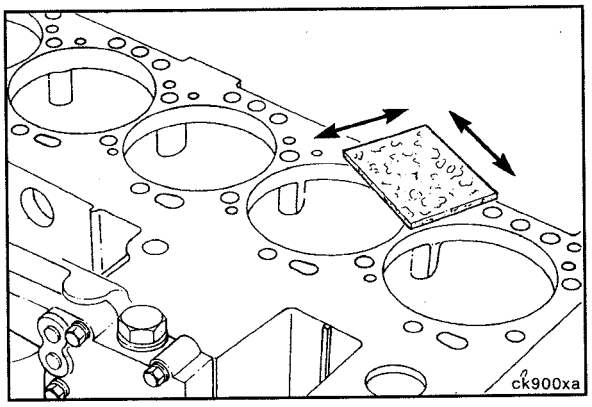
⚠WARNING⚠

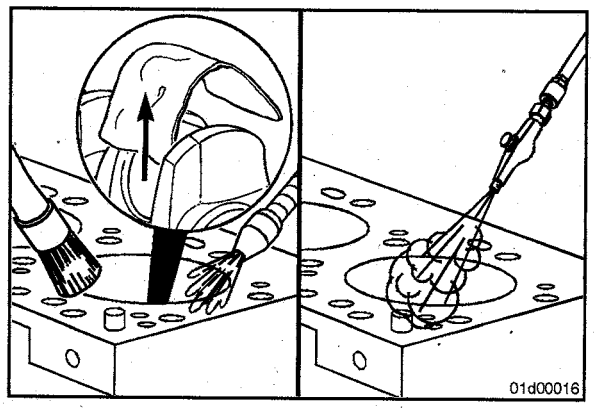
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean the combustion deck with a gasket scraper or Scotch-Brite® 7447, Part Number 3823258 or equivalent, and diesel fuel or solvent.





⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

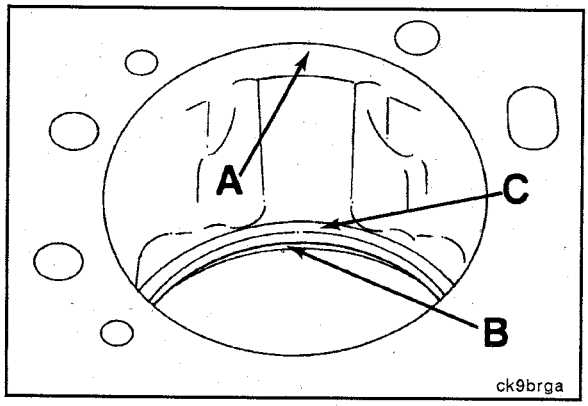
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

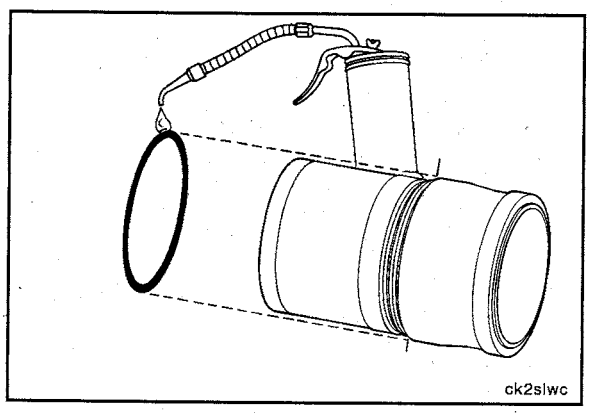
Thoroughly flush the block with mineral spirits or cleaning solvent.

Remove the shop rags and clean the crankshaft with a cleaning solvent.

Blow the cylinder bores and crankshaft dry and wipe them clean with a lint-free cloth.



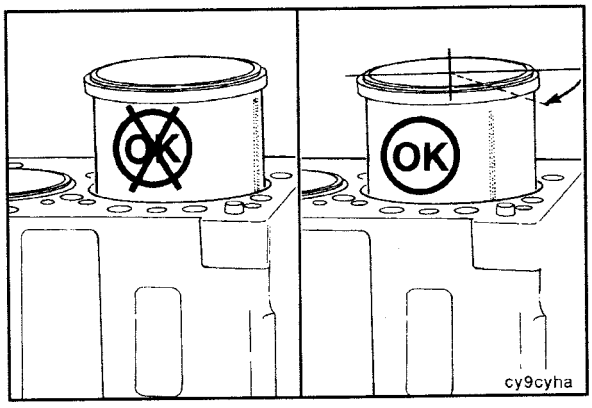
Lubricate surfaces A and B with clean 15W-40 engine oil.



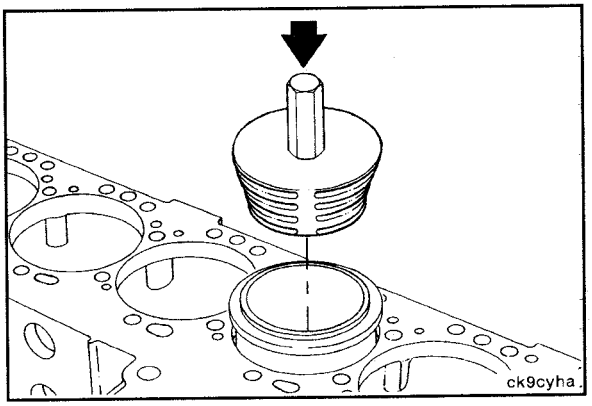
Use clean 15W-40 oil to coat the liner o-ring seals.

Install new o-ring seals on the liners.

When reusing liners, install them in the same cylinder from where they were removed and rotate them 45 degrees (1/8 turn) from their original position. When correctly installed, any liner pitting **must** be positioned as illustrated so the pitted surface is rotated away from the location where pitting occurs.



Install the liner into the bore of the cylinder block using liner driver, Part Number ST-1229.

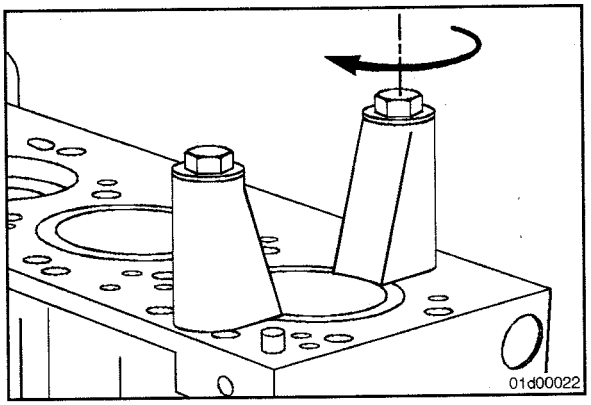


Use two (2) cylinder head capscrews and position the two (2) liner clamps, Part Number 3822503, as illustrated.

Tighten the capscrews.

Torque Value: 68 N•m [50 ft-lb]

Remove the clamps and repeat this procedure until all liners have been clamped and released.

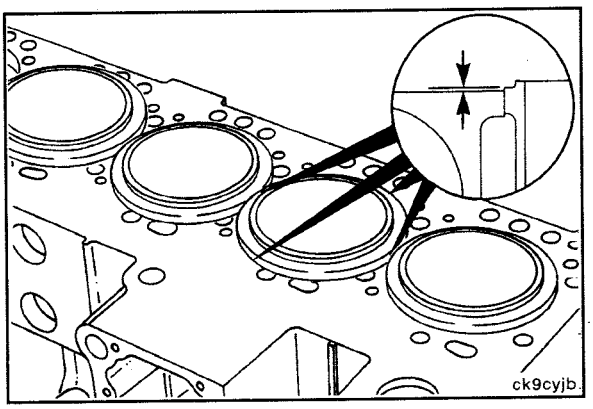


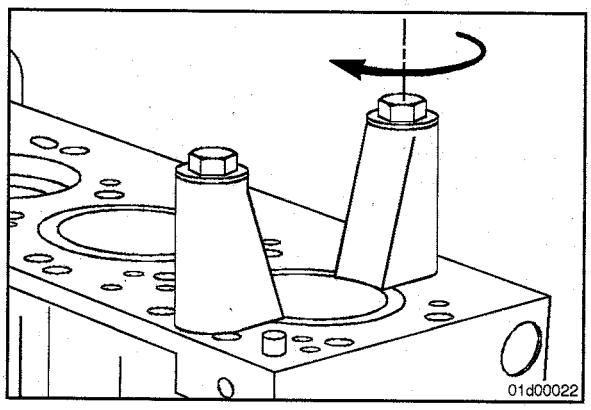
Liner protrusion is the distance the liner protrudes above the block face.

Measure the liner protrusion at four points 90 degrees apart using gauge, Part Number 3164438.

Cylinder Liner Protrusion

mm		in
0.026	MIN	0.0010
0.122	MAX	0.0048

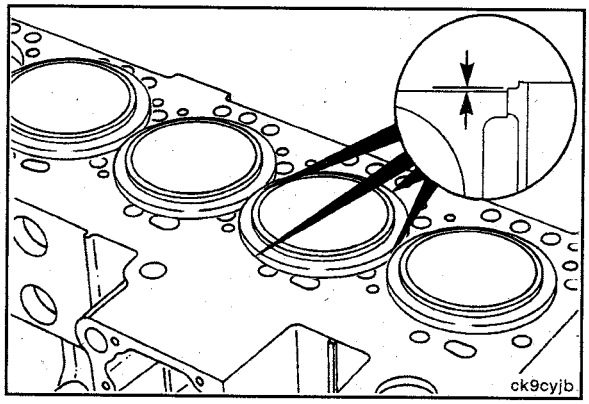




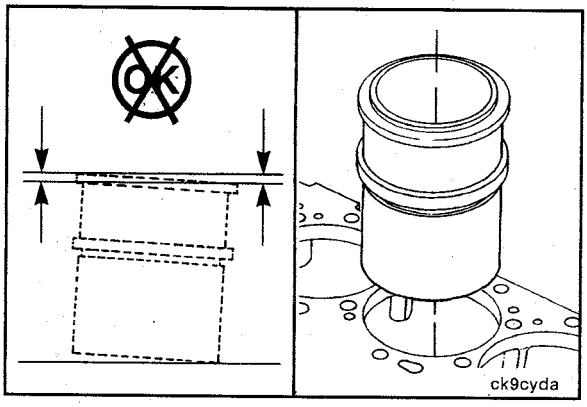
NOTE: If the liner protrusion varies more than 0.025 mm [0.0010 in] for 180 degrees:

- Install and tighten the liner clamps again.

Torque Value: 68 N•m [50 ft-lb]

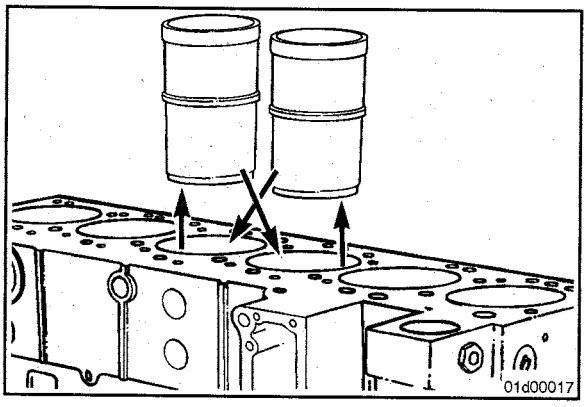


- Measure the liner protrusion again.



NOTE: If the protrusion still varies more than 0.025 mm [0.0010 in]:

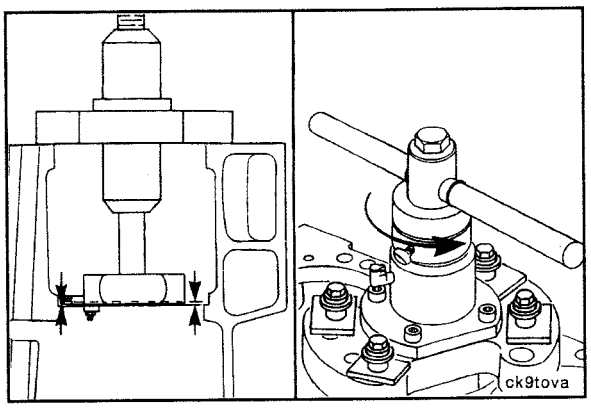
- Remove the liner
- Inspect the liner sealing edge for burrs, dirt, or damage
- Replace the liner if it is damaged
- Install the liner again
- Measure the liner protrusion.



Service Tip: If the out-of-limit condition is minimal, tolerance stack-up may allow the protrusion limits to be obtained by installing other new liners in the out-of-limit bore.

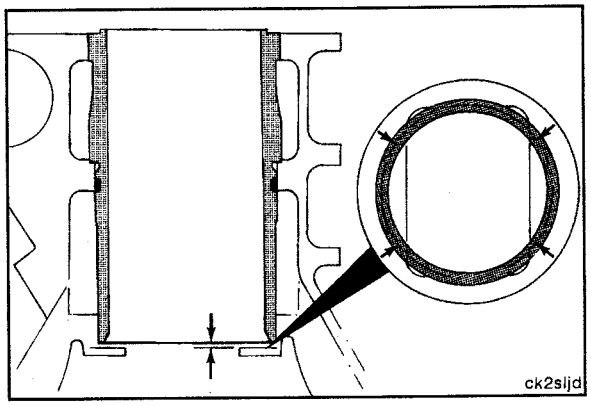
NOTE: If the liner protrusion still does **not** meet the specifications, machine the cylinder block liner bore for shims using the following tools:

Drive unit, Part Number 3163785
Cutter plate, Part Number 3823567
Cutter bit, Part Number 3823570



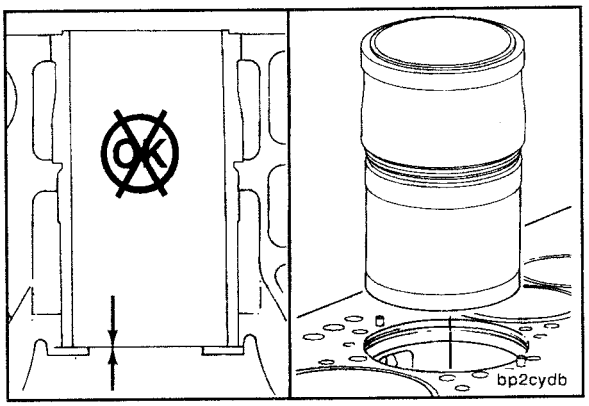
Use a feeler gauge to inspect the liner to block clearance at the four block casting points.

Cylinder Liner to Block Clearance		
mm		in
0.229	MIN	0.009

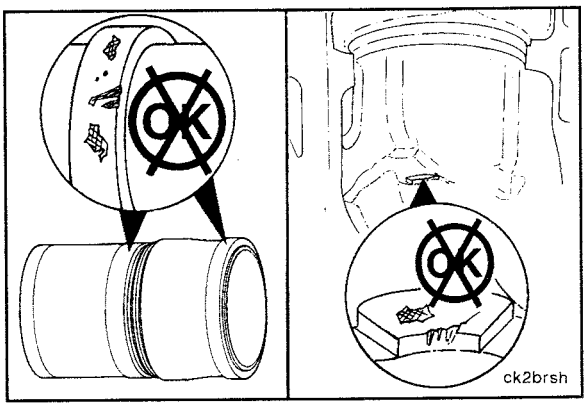


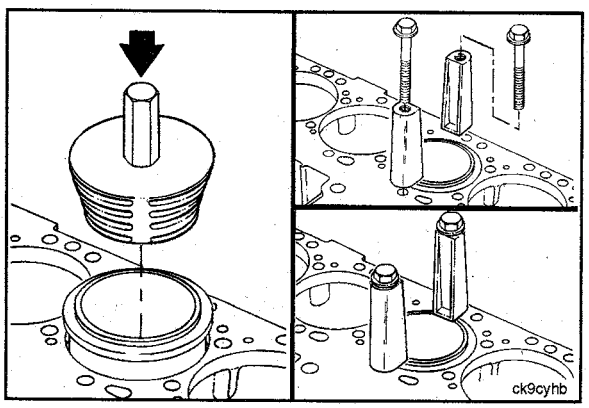
NOTE: If the clearance is **less** than 0.229 mm [0.009 in]:

- Remove the liner.

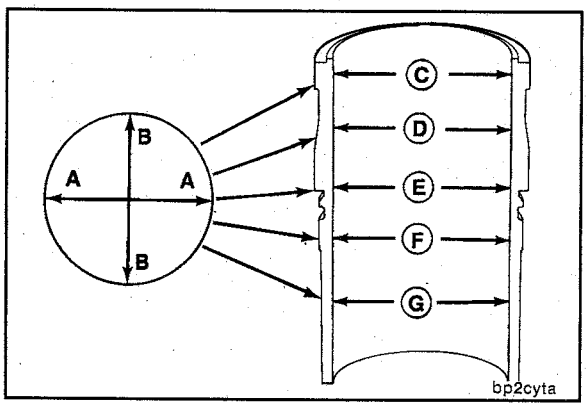


- Inspect the liner and cylinder block for dirt or damage.

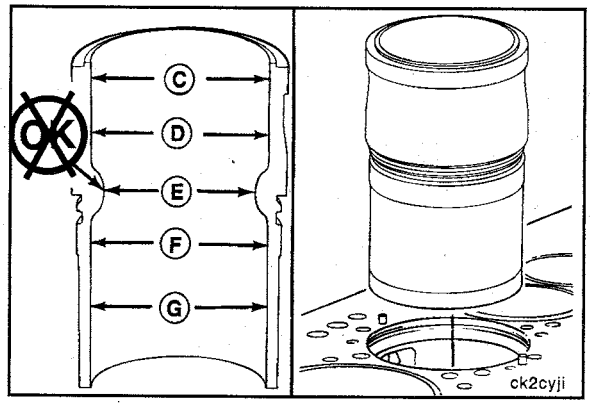




- Replace the liner if it is damaged.
- Install the liner again.



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 0.04 mm [0.002 in] out-of-round.



NOTE: If the liner bore is more than 0.04 mm [0.002 in] out-of-round:

- Remove the liner so the cylinder block liner bore can be measured.

Finishing Steps

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

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

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

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

Fill and vent the cooling system. Refer to Procedure 008-018.

Fill lubricating system with oil. Refer to Procedure 007-037.

Operate the engine until the coolant temperature reaches 82°C [180°F] and check for leaks and proper operation.

Gear Cover, Front (001-031)

Preparatory Steps

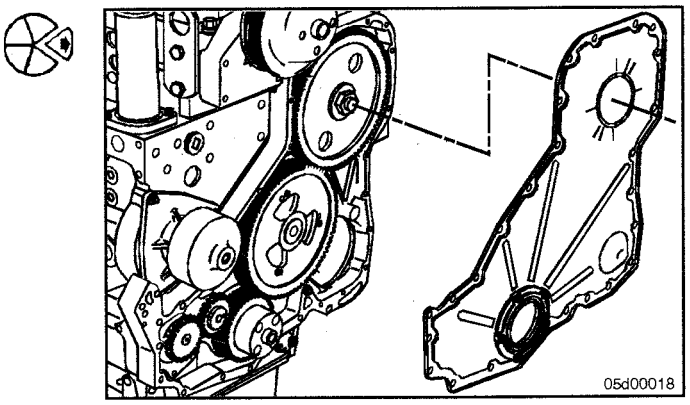
Remove the drive belt. Refer to Procedure 008-002.

Remove the vibration damper. Refer to Procedure 001-051 or 001-052.

If required, remove the fan hub pulley. Refer to Procedure 008-039.

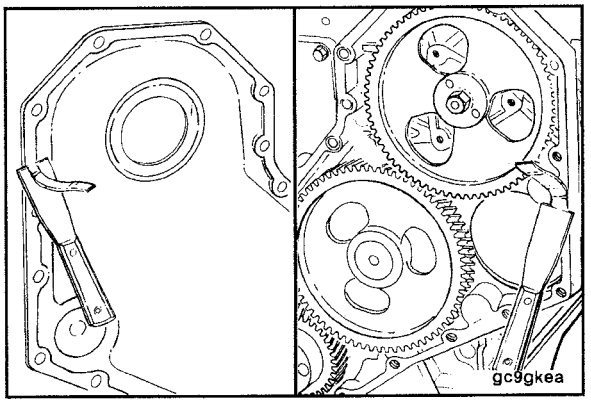
Remove

Remove the front gear cover.

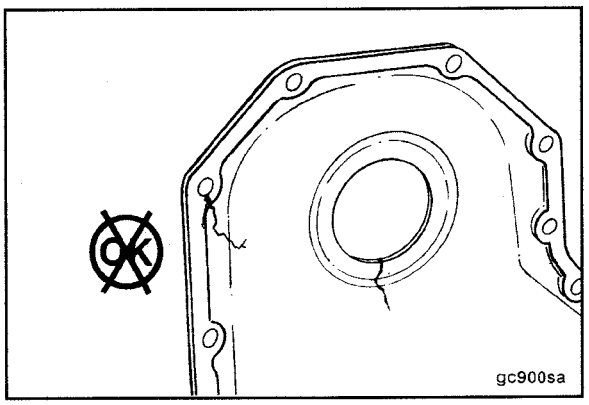


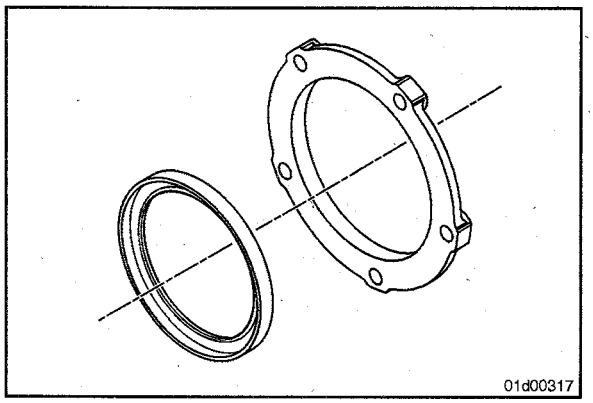
Clean and Inspect for Reuse

Clean sealant from the gear cover and gear housing gasket surface.



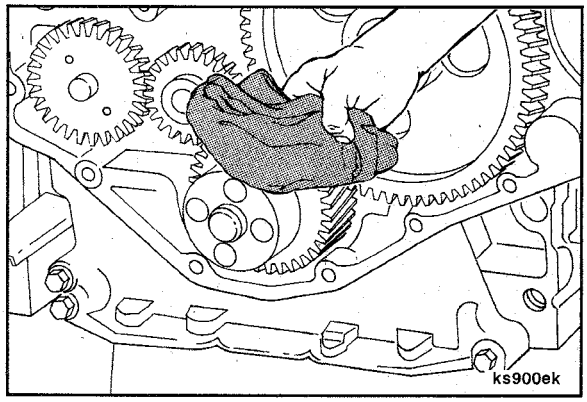
Inspect the gear cover for cracks or damage.





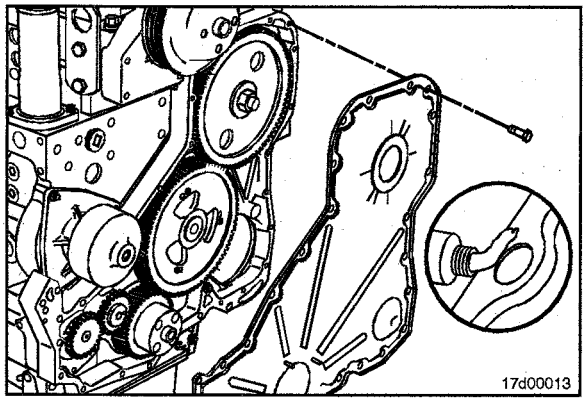
Install

Install a new seal in the carrier. Refer to Procedure 001-023.



⚠CAUTION⚠

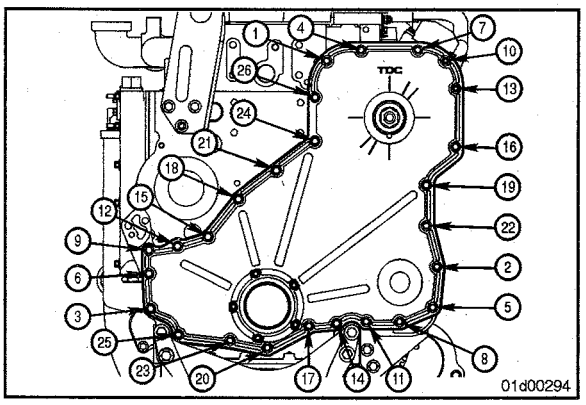
The crankshaft must be clean, dry and oil free before installing the gear cover. Failure to properly clean the sealing surface will result in an oil leak.



Apply a thin bead of Three-Bond™, to the cover side of the front cover **only**.

Install the front cover on the engine within 10 minutes.

NOTE: Apply Three-Bond™ to inside of the bolt holes.



Tighten front cover capscrews.

Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

Install the seal carrier on the front cover. Refer to Procedure 001-023.

Install the vibration damper. Refer to Procedure 001-051 or 001-052

Install the drive belt. Refer to Procedure 008-002.

Operate the engine and check for leaks.

Gear Housing, Front (001-033)

Preparatory Steps

Remove the rocker lever cover, rocker levers, and push rods. Refer to Procedures 003-011, 003-008, and 004-014.

Remove the vibration damper. Refer to Procedure 001-052.

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

Remove the fuel pump. Refer to Procedure 005-016.

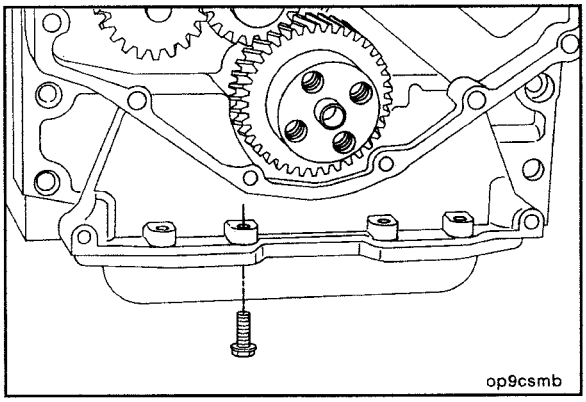
Remove the camshaft gear, if able. Refer to Procedure 001-012.

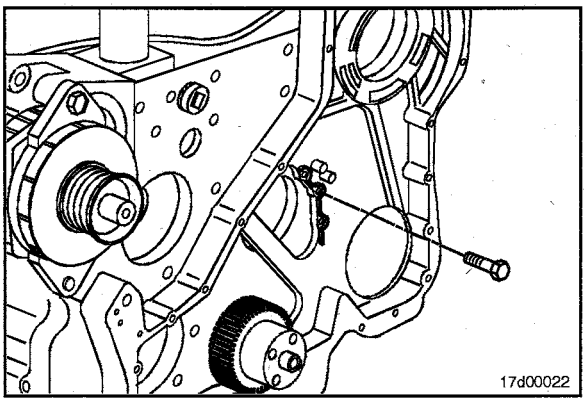
Remove the camshaft if the camshaft gear can **not** be removed. Refer to Procedure 001-008.

Remove or disconnect gear driven accessories, such as air compressor and hydraulic pump.

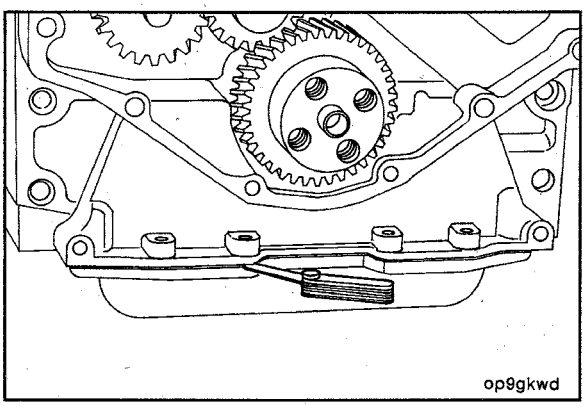
Remove

Remove the four (4) front oil pan capscrews.

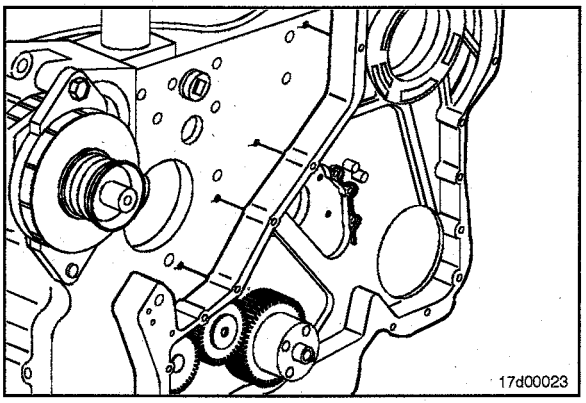




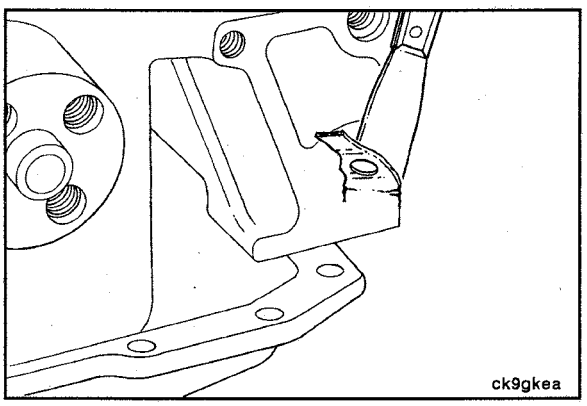
Remove the gear housing capscrews.



Using a feeler gauge, separate the lubricating oil pan gasket from the gear housing.



Remove the gear housing.

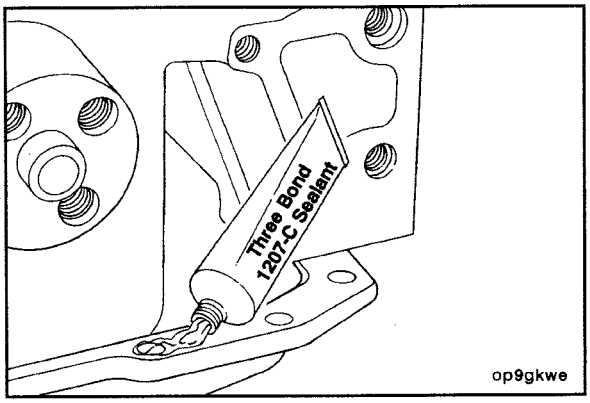


Clean and Inspect for Reuse

Clean the gasket material from the cylinder block.

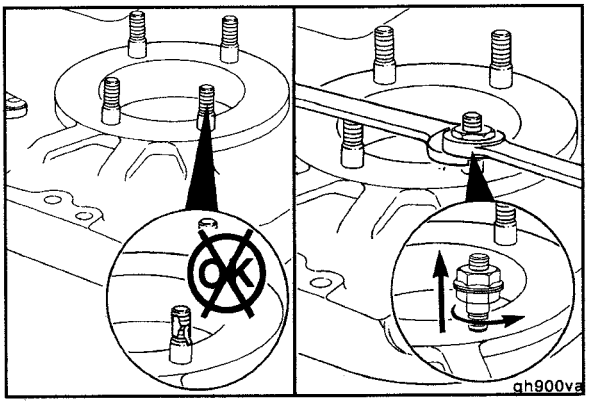
Inspect the lubricating oil pan gasket.

If it is **not** torn, coat with Three-Bond™ sealant, Part Number 3823494 or equivalent.

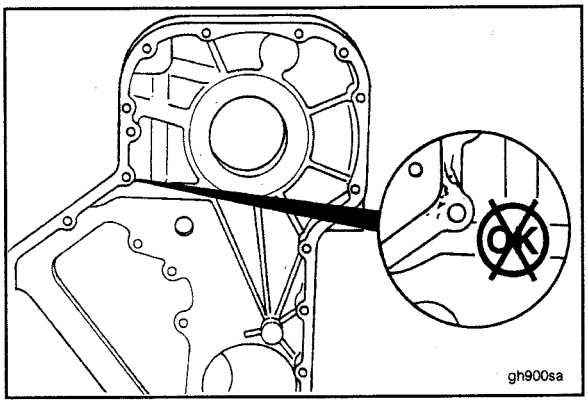


Inspect fuel pump mounting studs for damage.

To install or remove the fuel pump studs, use two nuts locked together on the stud.



Inspect gear housing for cracks or damaged sealing surfaces.

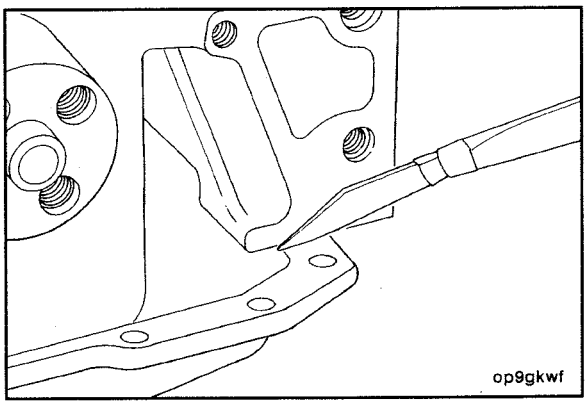


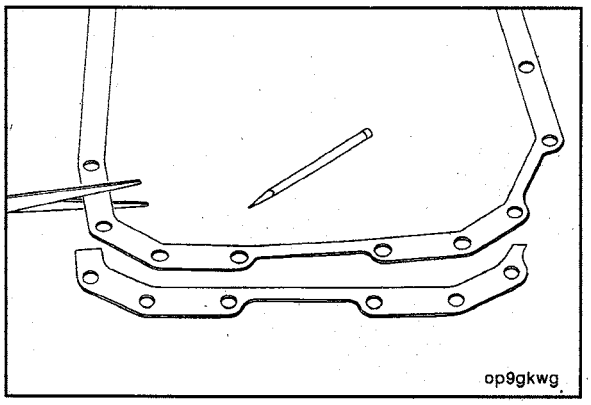
Install

Pan Gasket - Repair

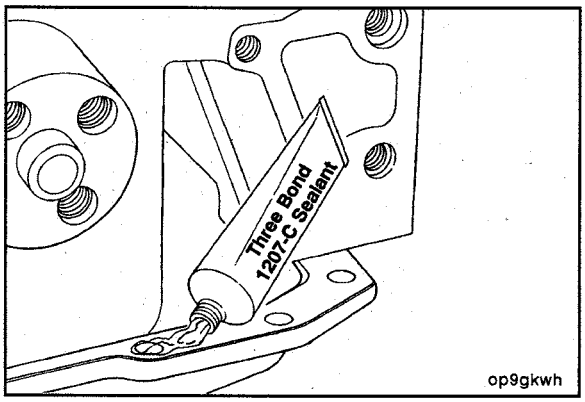
If the pan gasket is torn, it can be repaired.

Cut the torn gasket off even with the front of the cylinder block.





Using the old gasket as a pattern, cut the front section of a new gasket to the same size.

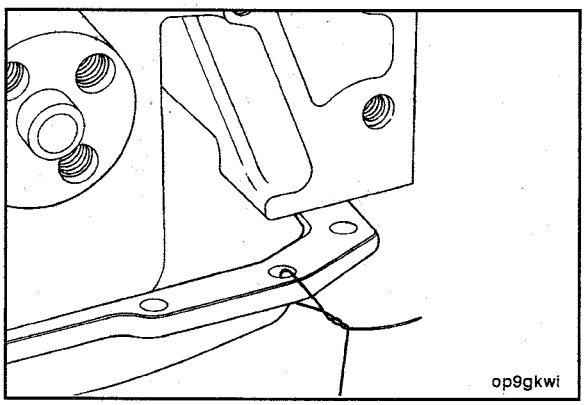


NOTE: The gear housing **must** be installed within 10 minutes of applying the sealant.

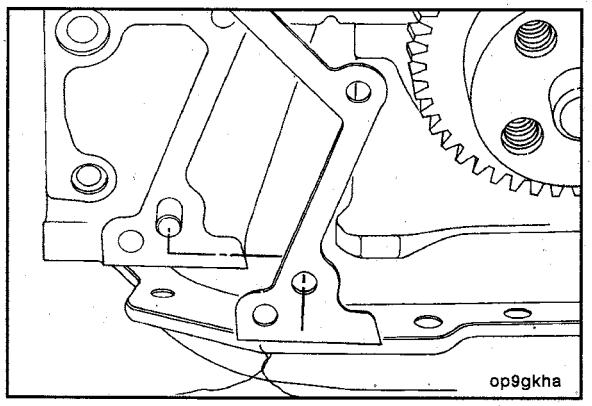
Clean the sealing surfaces.

Coat the new gasket on both sides with Three-Bond™ sealant, Part Number 3823494 or equivalent.

Be sure there is a bead of sealant at the intersecting joint of the cylinder block, oil pan, and gear housing.



Use common thread or a very fine wire to hold the new gasket splice in position as illustrated.

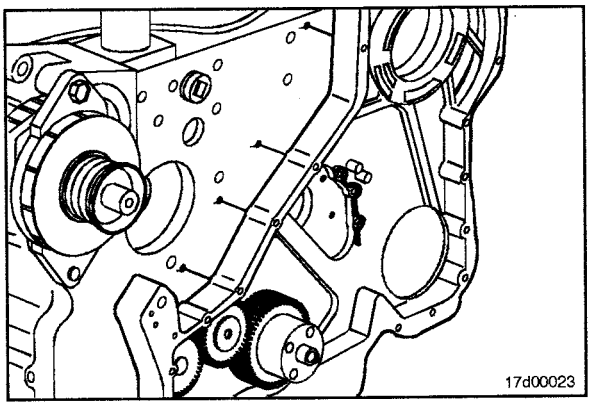


Position the gear housing gasket on the alignment dowels.

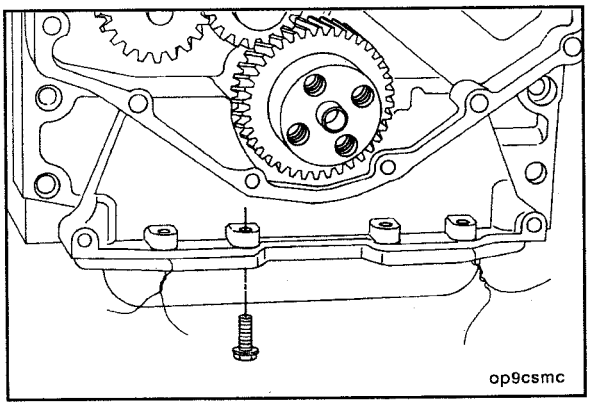
Use guide pins (M8 x 1.25 x 50) to assist in aligning the gasket and gear housing. Be sure to remove the guide pins after alignment.

Carefully install the gear housing, making sure both gaskets are in place.

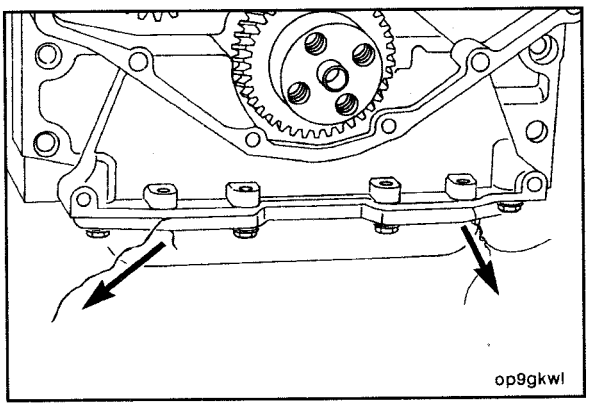
Torque Value: 40 N•m [30 ft-lb]



Start the oil pan capscrews in the holes **not** being used to tie the gasket in place.

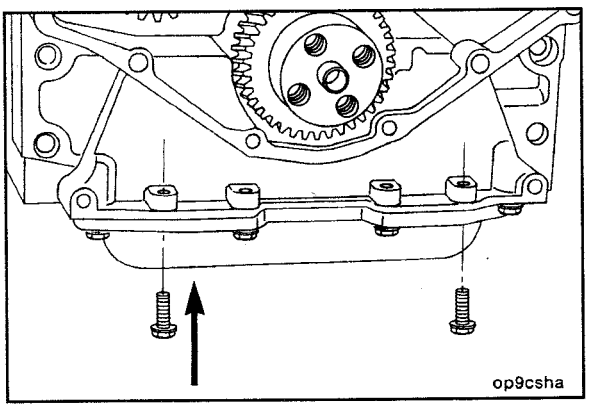


Remove the thread or wire holding the gasket in place.



Install the remaining two (2) oil pan capscrews and tighten.

Torque Value: 28 N•m [21 ft-lb]



Finishing Steps

Install the camshaft, if removed. Refer to Procedure 001-008.

Install the camshaft gear, if removed. Refer to Procedure 001-012.

Install the fuel pump. Refer to Procedure 005-016.

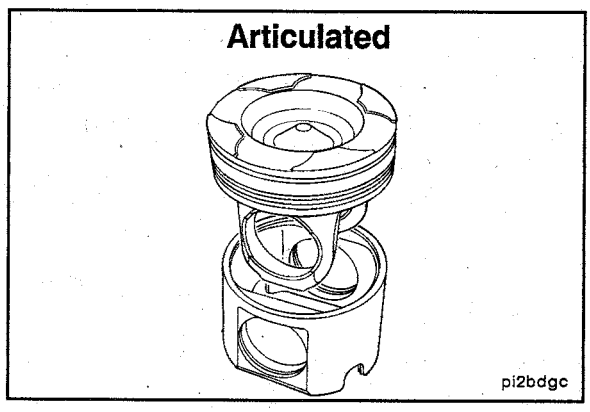
Install the gear cover. Refer to Procedure 001-031.

Install the vibration damper. Refer to Procedure 001-052.

Install the push rods, rocker levers, and rocker lever cover. Refer to Procedures 004-014, 003-008, and 003-011.

Install or connect gear driven or accessories. Refer to the OEM service manual.

Operate the engine and check for leaks.



Piston (001-043)

General Information

Some engines are equipped with articulated pistons. The articulated piston is a two (2) piece piston consisting of a forged steel crown and an aluminum skirt. An open 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.

Preparatory Steps

⚠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.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠

Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

Drain the coolant. Refer to Procedure 008-018.

Drain the lubricating oil. Refer to Procedure 007-037.

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

Remove the lubricating oil suction tube. Refer to Procedure 007-035.

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

Remove and disassemble the piston and connecting rod assemblies. Refer to Procedure 001-054.

Clean and Inspect for Reuse

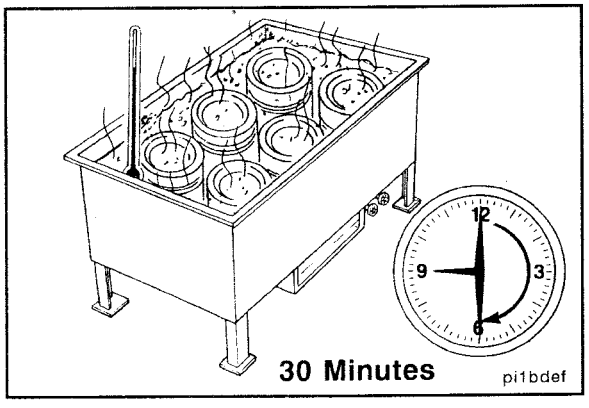
△CAUTION△

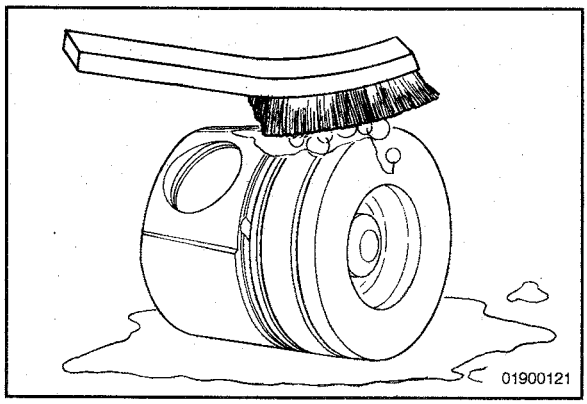
Do not use the bead blast method to clean the piston. The piston will be damaged by blast material embedded in the aluminum.

△CAUTION△

Do not clean the pistons and rods in an acid tank.

Allow the piston to soak for a minimum of 30 minutes in a tank containing a cleaning solvent suitable for steel.

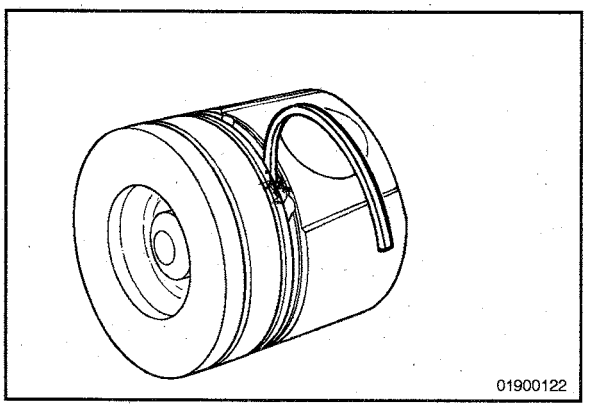




⚠CAUTION⚠

Do not use a metal brush. A metal brush will damage the piston ring grooves.

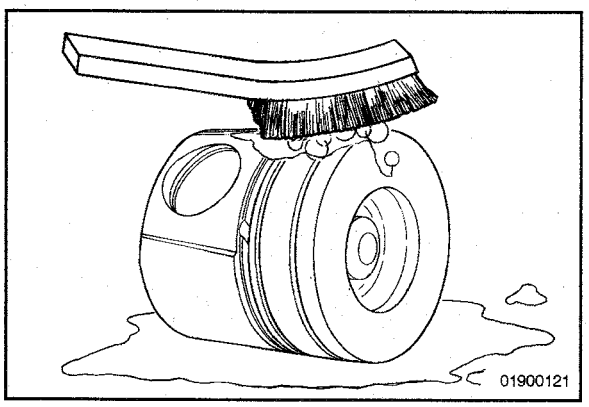
Wash the pistons and rods in a strong solution of laundry detergent in hot water. Use a non-metallic brush to remove carbon deposits.



⚠CAUTION⚠

Do not use a ring groove cleaner to clean the ring grooves. Do not to scratch the ring sealing surface in the piston groove.

Clean the remaining deposits from the ring grooves with the square end of a broken piston ring.



⚠WARNING⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠

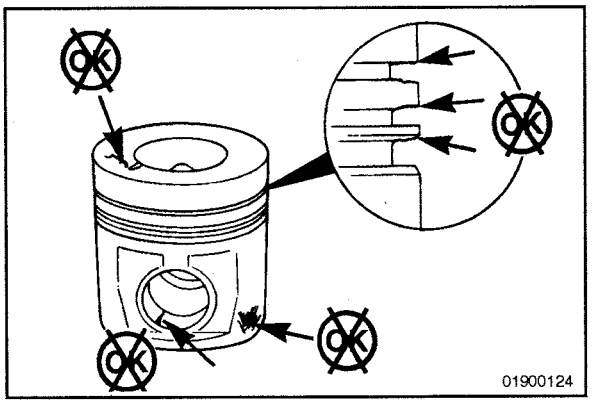
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Wash the pistons again in a detergent solution or solvent.

After rinsing, used compressed air to dry.

Inspect the piston for damage and excessive wear. Check the top, ring grooves, skirt, and pin bore for cracks or damage.

NOTE: If severe piston damage has occurred, check the turbocharger and other exhaust components for damage from debris.

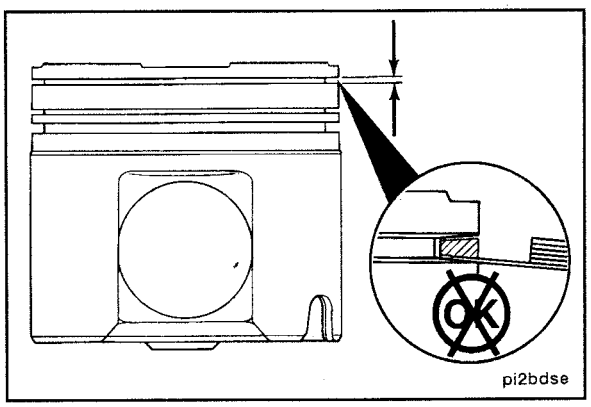


The ring groove can be inspected with a new ring and a feeler gauge.

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.

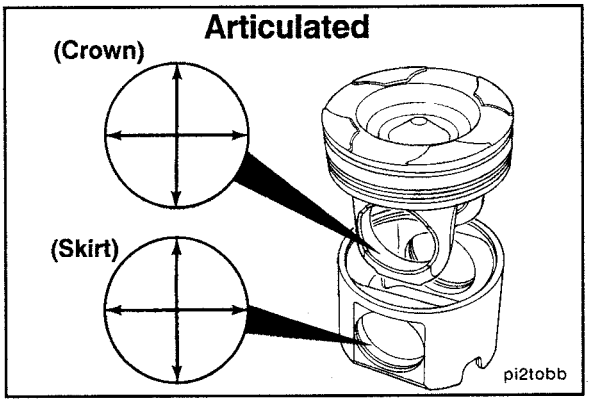
If the feeler gauge enters the groove without resistance, there is too much wear. Replace the piston.



Articulated Pistons

Measure the piston pin bore inside diameter on both the crown and skirt.

Articulated Piston Pin Bore Inside Diameter			
	mm		in
Crown	45.016	MIN	1.7723
	45.036	MAX	1.7731
Skirt	45.012	MIN	1.7721
	45.026	MAX	1.7727

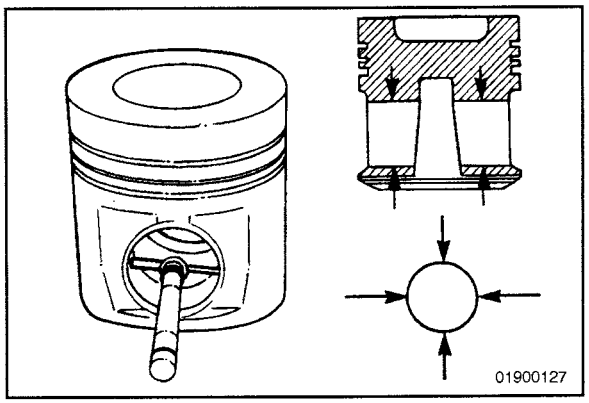


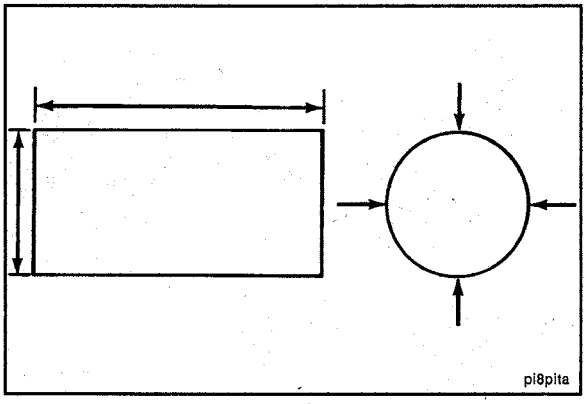
Single Piece Pistons

Measure the pin bore when the piston temperature is at 20°C [68°F].

Piston Pin Bore Diameter		
mm		in
45.006	MIN	1.7719
45.012	MAX	1.7721

NOTE: Add 0.013 mm [0.0005 in] to the bore diameter per 5°C [10°F] temperature rise up to 32°C [90°F].





Inspect the piston pin for nicks, gouges, and excessive wear.

Measure the piston pin outside diameter.

Piston Pin Diameter		
mm		in
44.997	MIN	1.7715
45.003	MAX	1.7718

Discard the piston pin if it is more than 0.003 mm [0.0001 in] out of round.

Finishing Steps

Assemble and install the piston and connecting rod assemblies. Refer to Procedure 001-054.

Install the lubricating oil suction tube. Refer to Procedure 007-035.

Install the lubricating oil pan. Refer to Procedure 007-037.

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

Fill the engine with coolant. Refer to Procedure 008-018.

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

Operate the engine and check for leaks.

Piston Cooling Nozzle (001-046)

Preparatory Steps

⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠
Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

Drain the lubricating oil. Refer to Procedure 007-037.

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

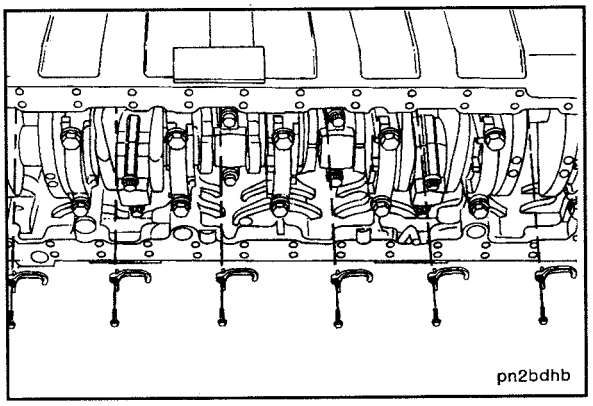
Remove the lubricating oil suction tube. Refer to Procedure 007-035.

Remove

Banjo Bolt Mounted

Remove the piston cooling nozzle capscrews and nozzles.

NOTE: The crankshaft **must** be rotated to allow access to remove the nozzles.

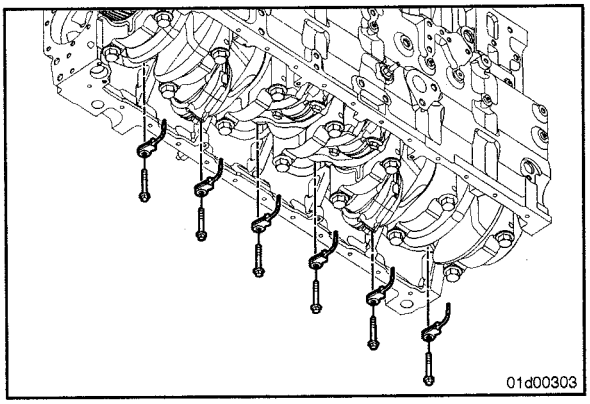


Flange Head Capscrew Mounted

Remove the piston cooling nozzle capscrews and nozzles.

NOTE: The crankshaft **must** be rotated to allow access to remove the nozzles.

NOTE: On engines with the speed indicator ring mounted to the crankshaft, the number six (6) piston cooling nozzle can **not** be removed without first disconnecting the connecting rod from the crankshaft and moving the piston out of the way. Also, a crows foot socket will be required to access the capscrew.

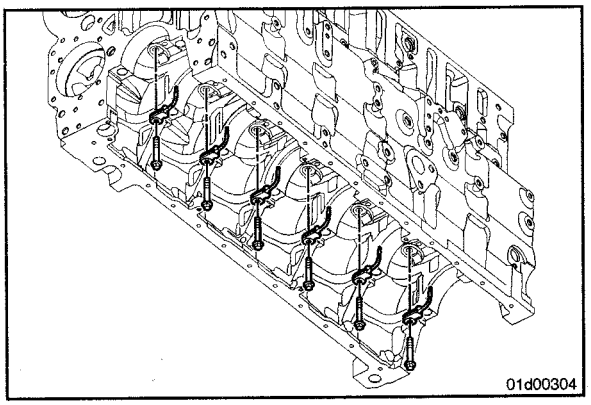


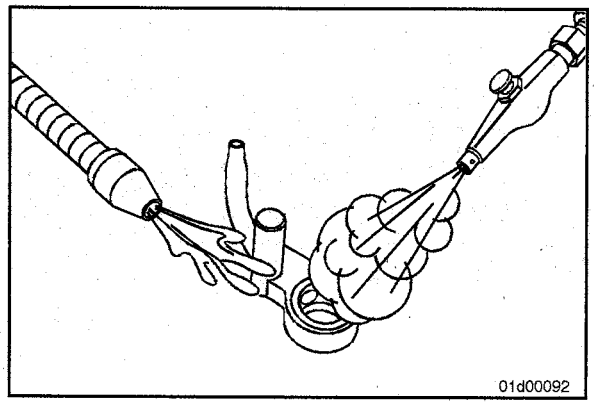
Main Bearing Saddle Mounted

Remove the crankshaft.

Remove the piston cooling nozzles.

NOTE: Number three saddle does **not** have nozzles.





Clean and Inspect for Reuse

⚠WARNING⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggle and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠

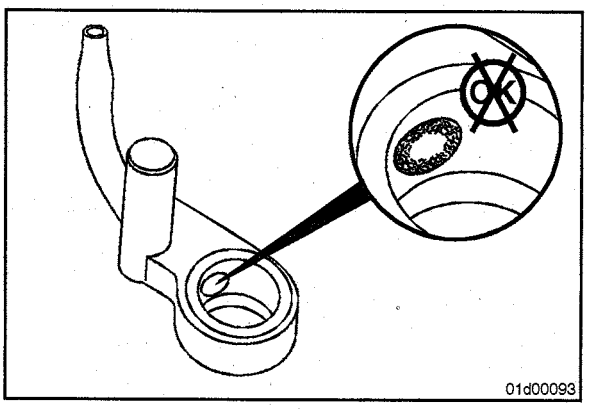
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠

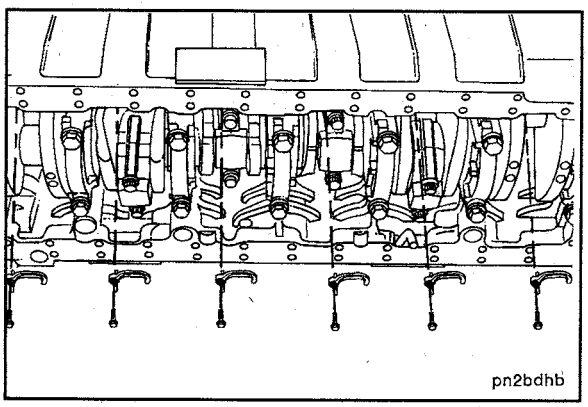
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the piston cooling nozzles and capscrew with solvent.

Dry with compressed air.



Inspect the piston cooling nozzles for flow restriction or any other damage. Replace if necessary.



Install

Banjo Bolt Mounted

⚠CAUTION⚠

Properly align nozzles in the locator notch before tightening the capscrews.

Install the nozzle, washers, and capscrews.

Tighten the capscrews.

Torque Value: 25 N•m [18 ft-lb]

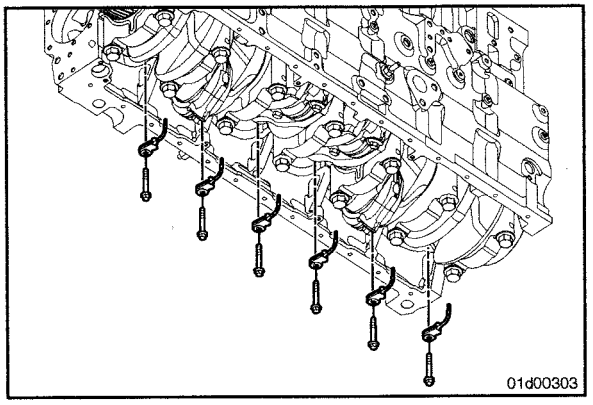
NOTE: The crankshaft **must** be rotated to allow access to install all the nozzles.

Flange Head Capscrew Mounted

Install the nozzles and capscrews.

Tighten the capscrews.

Torque Value: 33 N•m [24 ft-lb]

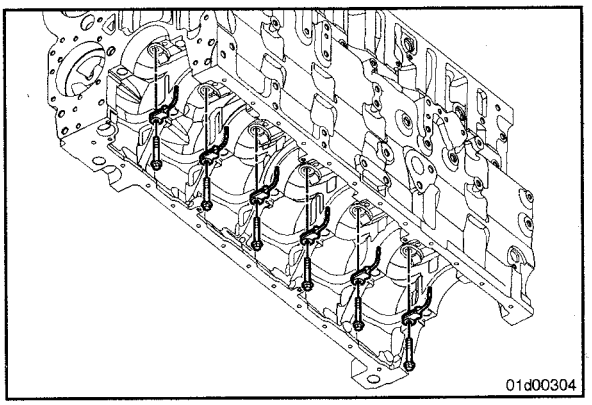


Main Bearing Saddle Mounted

Install the nozzles, two per saddle.

NOTE: Number three saddle does **not** have nozzles.

Install the crankshaft.



Finishing Steps

Install the lubricating oil suction tube. Refer to Procedure 007-035.

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

Fill the engine with lubricating oil. Refer to Procedure 007-037.

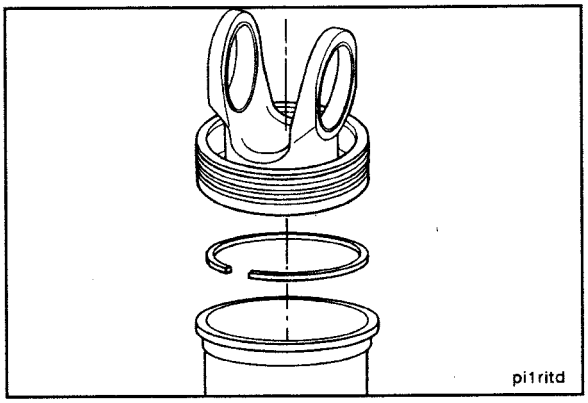
Operate the engine to normal operating temperature and check for oil leaks.

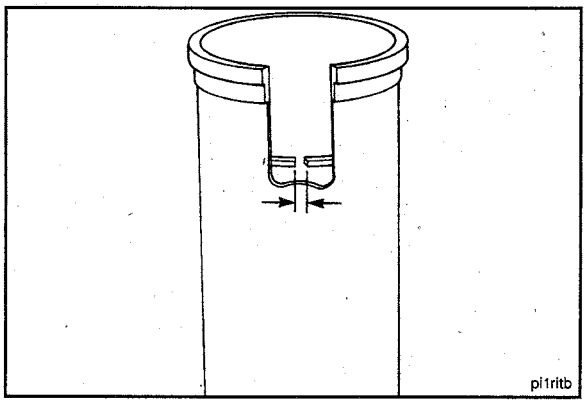
Piston Rings (001-047)

Failure Analysis Inspection

To check the ring gap, install the piston rings into the cylinder liner in which they were used. Position the rings below the ring reversal area.

Use the top part of the piston to correctly position the ring in the liner.



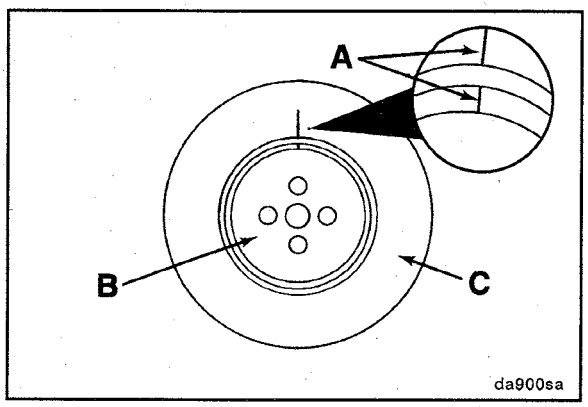


Use a feeler gauge to inspect the ring end gap.

Ring Gap, Engines with CM550 Control Module			
	mm		in
Top Ring	0.35	MIN	0.014
	0.50	MAX	0.020
Intermediate Ring	0.85	MIN	0.033
	1.15	MAX	0.045
Oil Control Ring	0.30	MIN	0.012
	0.73	MAX	0.028

Ring Gap, QSC Marine Engines with CM850 Control Module			
	mm		in
Top Ring	0.35	MIN	0.014
	0.65	MAX	0.025
Intermediate Ring	0.40	MIN	0.016
	0.70	MAX	0.027
Oil Control Ring	0.30	MIN	0.012
	0.73	MAX	0.028

Ring Gap, All Other Engines with CM850 Control Module			
	mm		in
Top Ring	0.30	MIN	0.012
	0.45	MAX	0.018
Intermediate Ring	0.85	MIN	0.033
	1.15	MAX	0.045
Oil Control Ring	0.30	MIN	0.012
	0.73	MAX	0.028



Vibration Damper, Rubber (001-051)

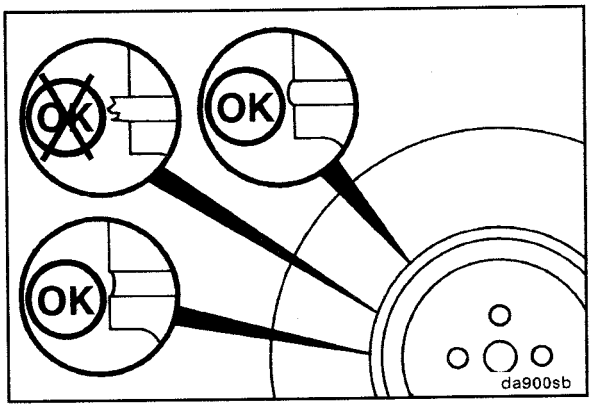
Inspect for Reuse

Check the index lines (A) on the damper hub (B) and the inertia member (C). If the lines are more than 1.59 mm [1/16 in] out of alignment, replace the damper.

Inspect the vibration damper hub (B) for cracks. Replace the damper if the hub is cracked.

Inspect the rubber member for deterioration. If pieces of rubber are missing or if the elastic member is more than 3.18 mm [1/8 in] below the metal surface, replace the damper.

NOTE: Also look for forward movement of the damper ring on the hub. Replace the damper if any movement is detected.



Vibration Damper, Viscous (001-052)

Preparatory Steps

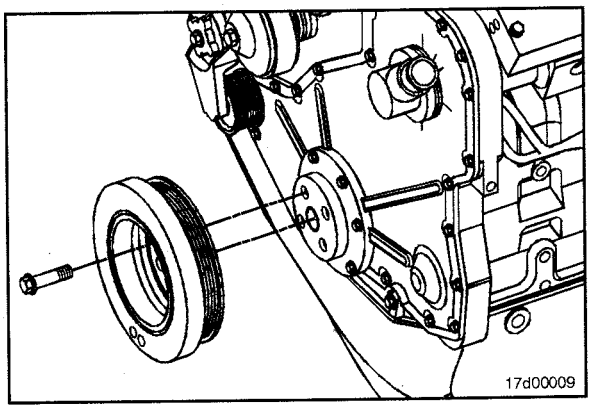
Remove the drive belt. Refer to Procedure 008-002.

Remove the fan and fan shroud, if necessary.

Remove

NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Remove vibration damper.

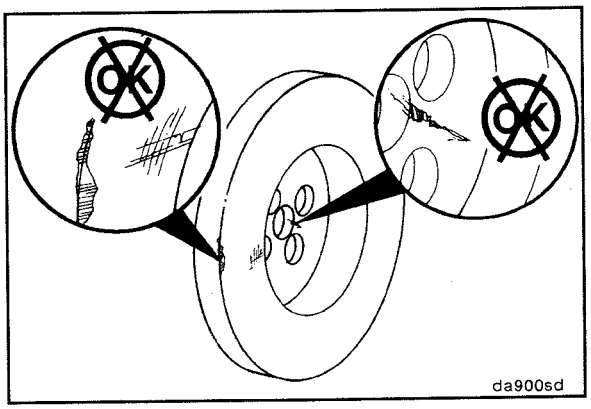


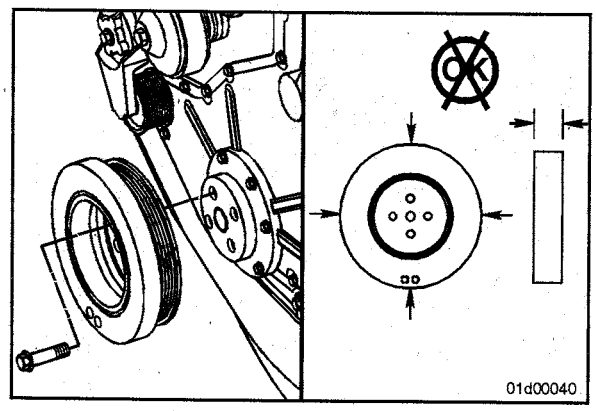
Clean and Inspect for Reuse

Check the mounting web for cracks.

Check the housing for dents or raised surfaces.

Replace the damper if any of these defects are identified.



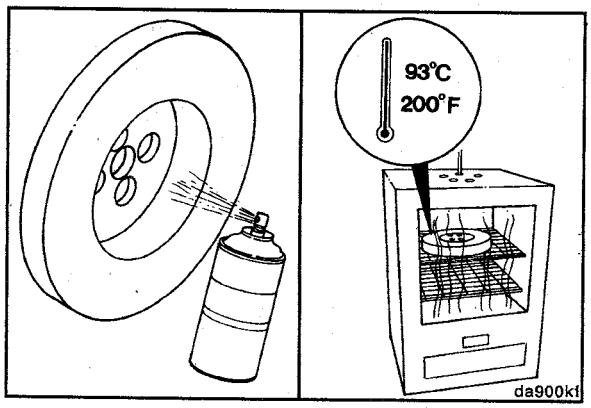


The viscous damper is filled with a silicone fluid. After many hours of use, the silicone fluid may become thicker and expand.

To determine if the damper thickness is correct, remove the paint from the damper in four locations on either side of the damper. Measure and record the thickness of the damper in four places.

Measure the thickness 3.175 mm [0.125 in] from the outside of the damper.

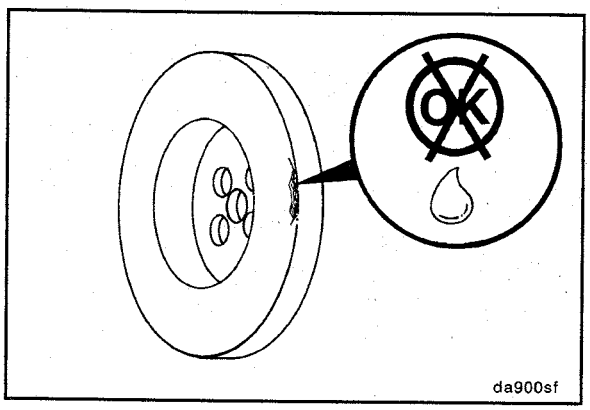
Replace the damper if its thickness varies by more than 0.25 mm [0.010 in].



Spray the damper with spot check developer, type SKD-NF, or equivalent.

Heat the damper in an oven (rolled lip side down) for two (2) hours.

Temperature 93 °C [200 °F]

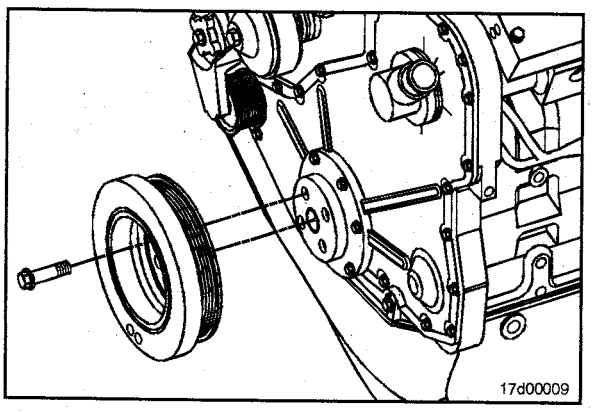


⚠WARNING⚠

Wear protective gloves to prevent personal injury when handling parts that have been heated.

Remove the damper from the oven and check for fluid leakage.

If there is leakage, replace the damper.



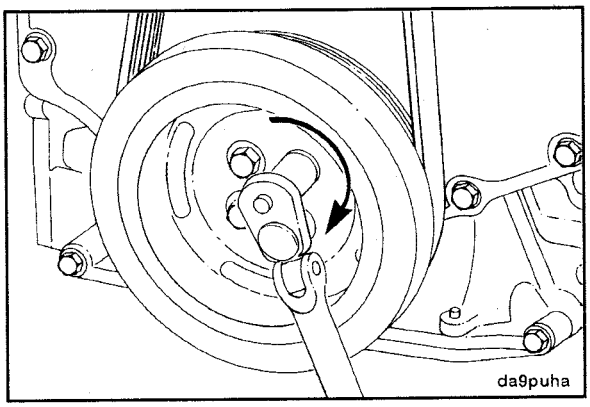
Install

NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Install the vibration damper.

Tighten the capscrews in a star pattern.

Torque Value: 200 N•m [148 ft-lb]



Finishing Steps

Install the drive belt. Refer to Procedure 008-002.

Install the fan and fan shroud, if removed.

Piston and Connecting Rod Assembly (001-054)

Preparatory Steps

⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠
Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

⚠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.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain the lubricating oil. Refer to procedure 007-037.

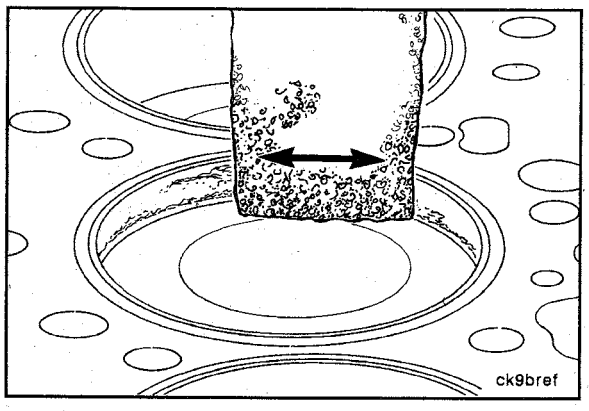
Remove the lubricating oil pan and gasket. Refer to Procedure 007-025.

Remove the lubricating oil suction tube. Refer to Procedure 007-035.

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

Drain the coolant. Refer to Procedure 008-018.

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



Remove

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

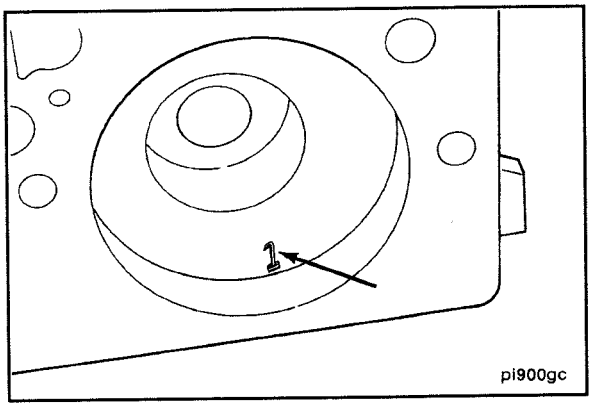
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Rotate the crankshaft until the pistons are below the carbon deposits that are found above the ring travel area.

Use a fine fibrous abrasive pad such as Scotch-Brite® 7448, Part Number 3823258 or equivalent, and solvent to remove the carbon.

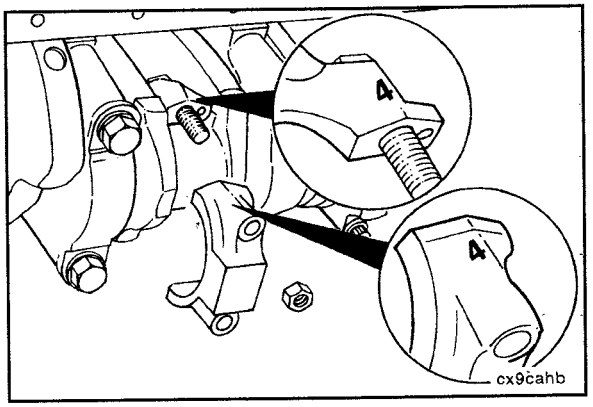
Mark each piston according to the cylinder location.

NOTE: On pistons with anodized coatings, do **not** stamp on the anodized coating or on the outer rim. Do **not** stamp on the aluminum piston crown above the piston pin axis.



Rotate the crankshaft to position the rod caps at bottom dead center for removal.

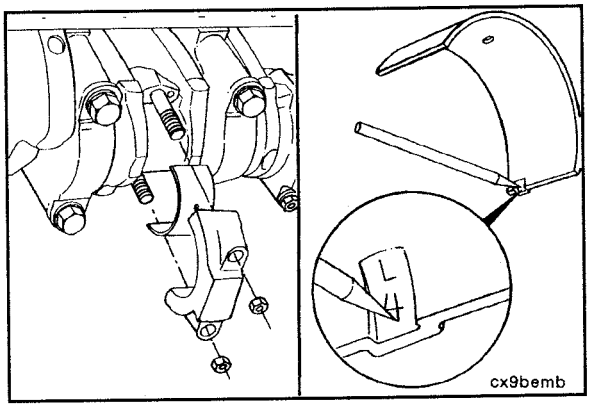
Mark each connecting rod and rod cap according to the cylinder number location.



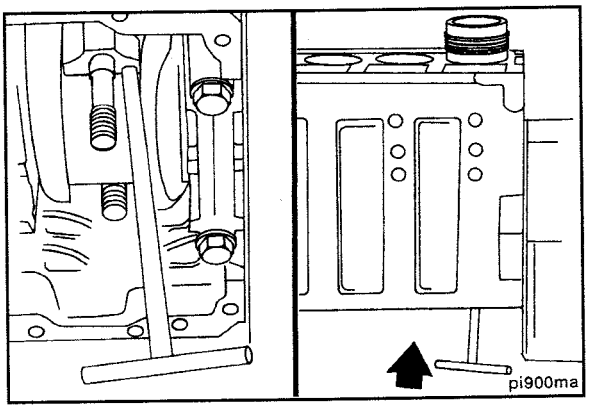
Engines with Horizontal Split Connecting Rods

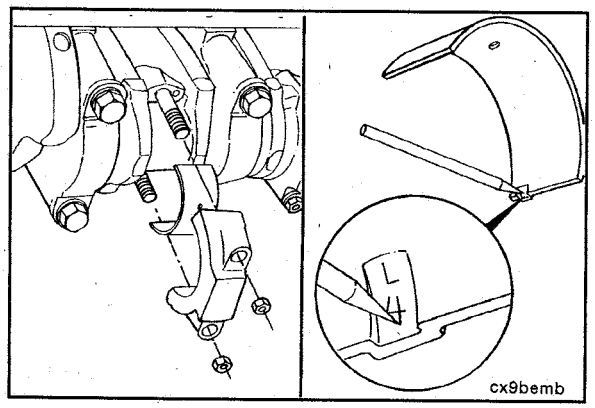
Remove the nuts, connecting rod cap and lower connecting rod bearings.

Mark the cylinder number and the letter "L" (lower) on the flat surface of the bearing tang.



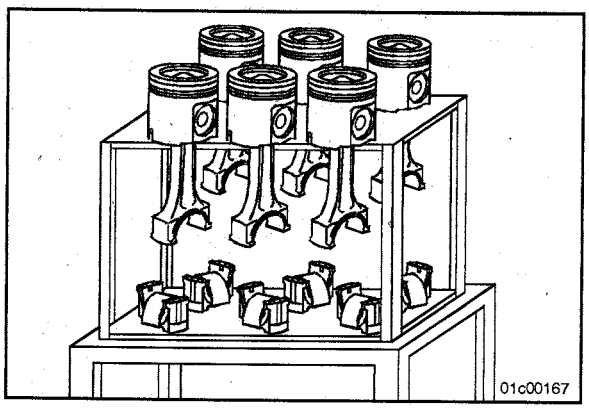
Push the connecting rod and piston assembly out of the cylinder bore. Care **must** be taken **not** to damage the connecting rod or bearing.





Remove the upper rod bearing.

Mark the cylinder number and the letter "U" (upper) on the flat surface of the bearing tang.

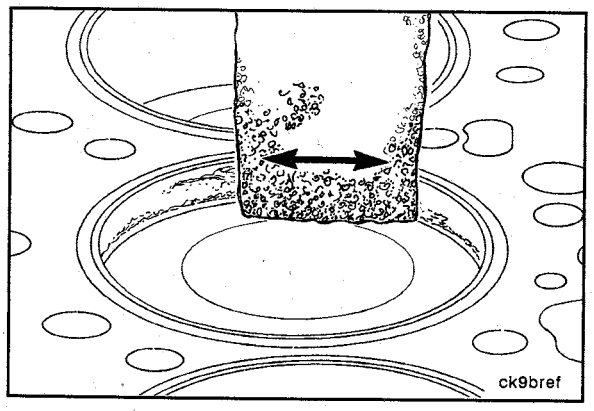


Use both hands to remove the piston and rod assembly.

The piston and connecting rod assemblies **must** be installed in the same cylinder number they were removed from to provide for proper fit of worn mating surfaces if parts are reused.

Use a tag to mark the cylinder number that each piston and rod assembly was removed from.

Place the rod and piston assemblies in a container to protect them from damage.



Engines with Angle Split Connecting Rods

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

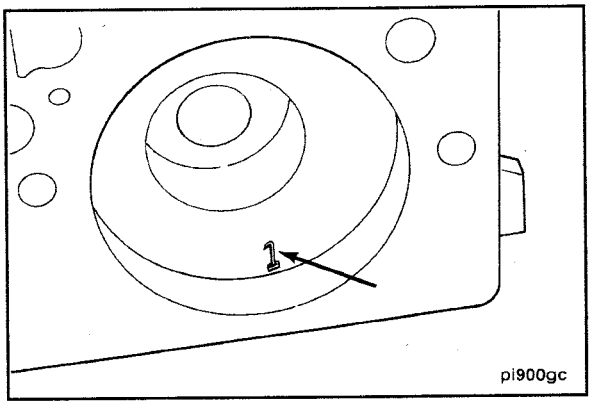
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Rotate the crankshaft until the pistons are below the carbon deposits that are found above the ring travel area.

Use a fine fibrous abrasive pad such as Scotch-Brite® 7448, Part Number 3823258 or equivalent, and solvent to remove the carbon.

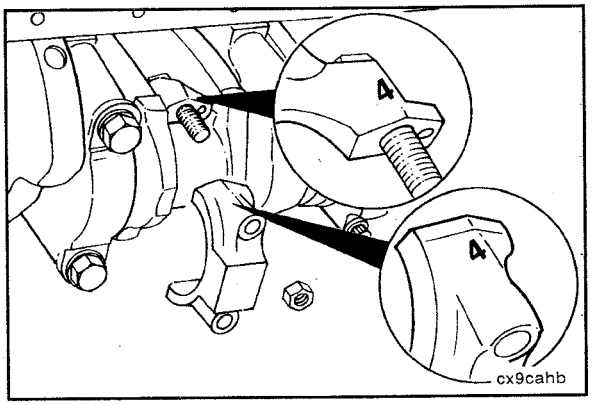
Mark each piston according to the cylinder.

NOTE: On pistons with anodized coatings, do **not** stamp on the anodized coating or on the outer rim. Do **not** stamp on the aluminum piston crown above the piston pin axis.



Rotate the crankshaft to position the rod caps at bottom dead center for removal.

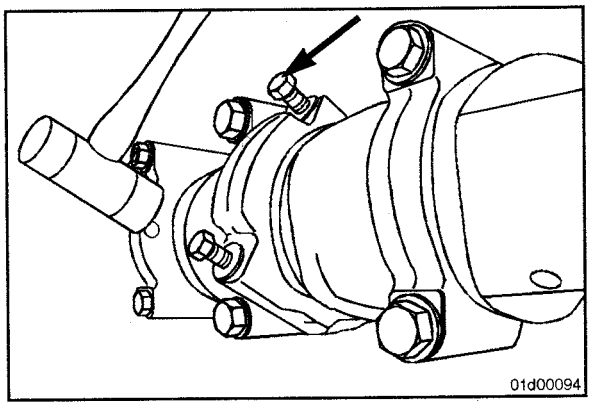
Mark each connecting rod and rod cap according to the cylinder number.



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 dowels.



⚠CAUTION⚠

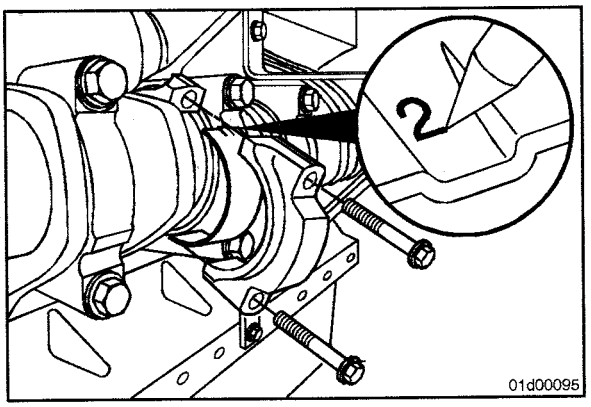
Do not damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod caps is removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage. Incorrect assembly can damage the rod.

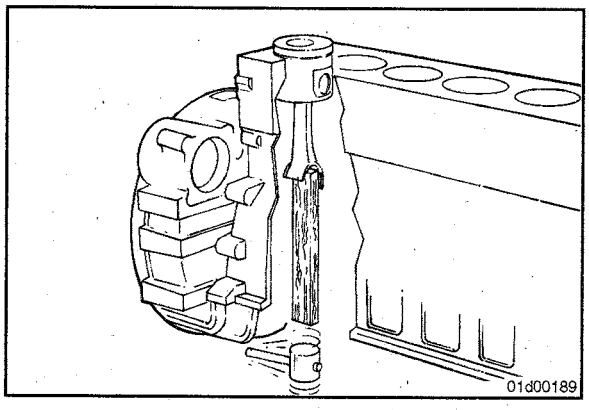
Remove the connecting rod capscrews.

Remove the rod cap.

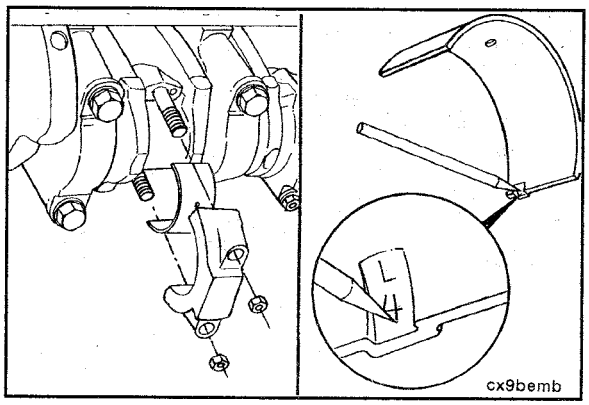
Remove the lower rod bearing.

Mark the cylinder number and the letter "L" (lower) on the flat surface of the bearing tang.



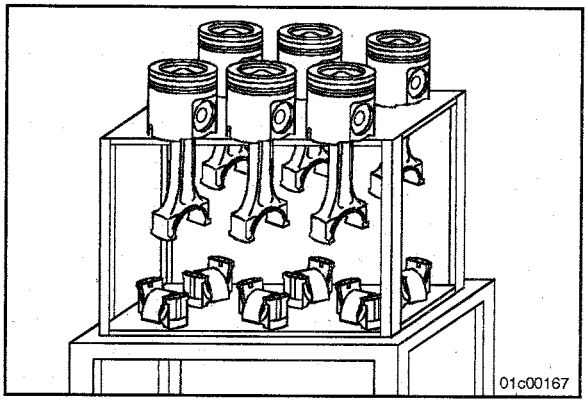


Push the connecting rod and piston assembly out of the cylinder bore. Care **must** be taken **not** to damage the connecting rod or bearing.



Remove the upper rod bearing.

Mark the cylinder number and the letter "U" (upper) on the flat surface of the bearing tang.

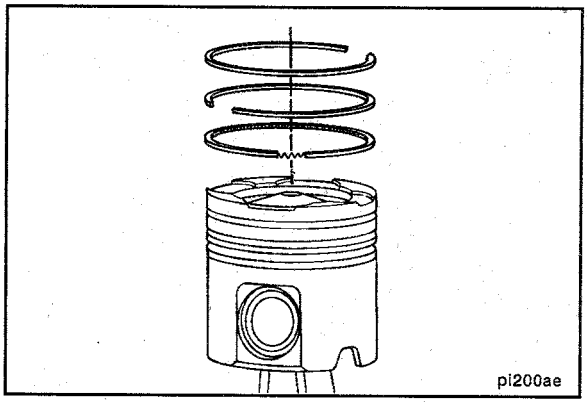


Use both hands to remove the piston and rod assembly.

The piston and connecting rod assemblies **must** be installed in the same cylinder number they were removed from to provide for proper fit of worn mating surfaces if parts are reused.

Use a tag to mark the cylinder number that each piston and rod assembly was removed from.

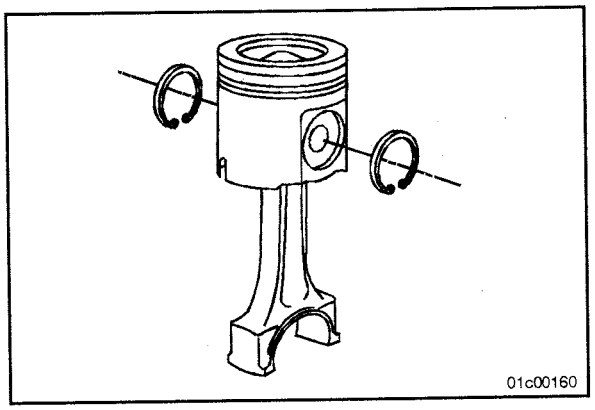
Place the rod and piston assemblies in a container to protect them from damage.



Disassemble

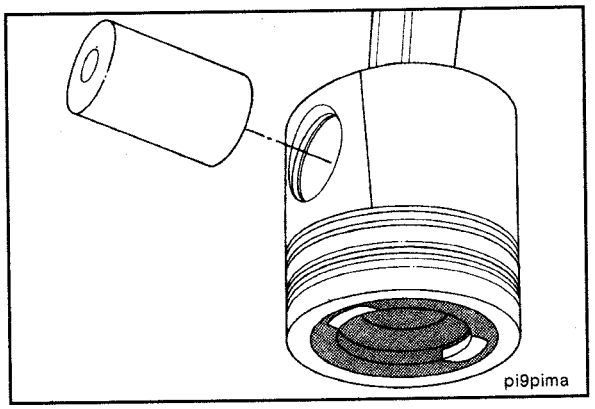
Using piston ring expander, Part Number 3823137, remove the piston rings.

Use internal snap ring pliers to remove the snap rings from both sides of the piston.



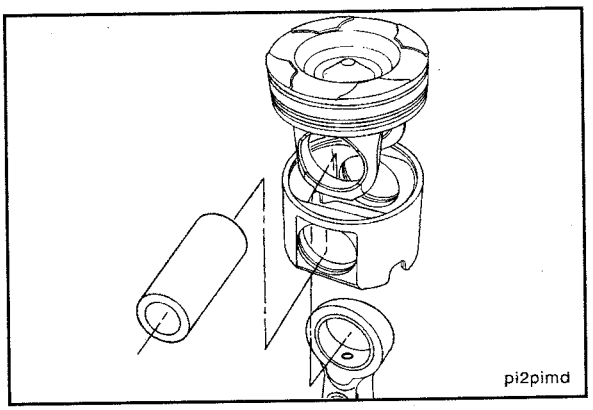
Remove the piston pin.

NOTE: Heating the piston is **not** required.



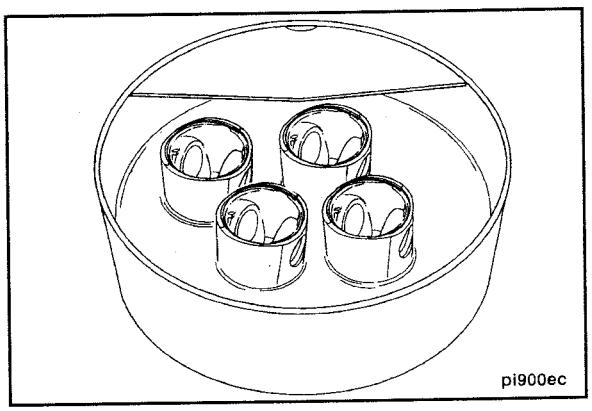
NOTE: When the piston pin is removed from an articulated piston, the skirt will separate from the crown. Use care to prevent damage to the piston.

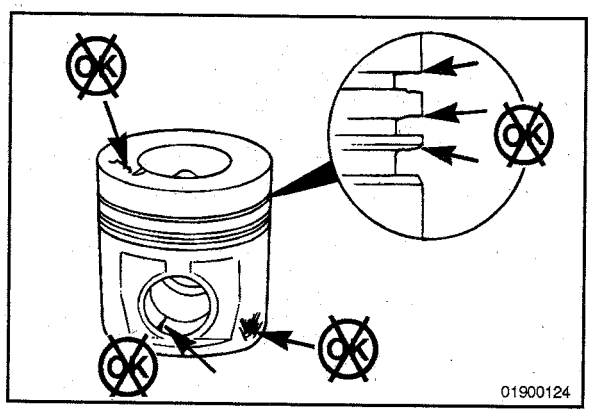
Mark the number of the cylinder that the piston, crown, skirt, and pin were removed from on the parts to make sure they are installed in the correct cylinder location if they are to be reused.



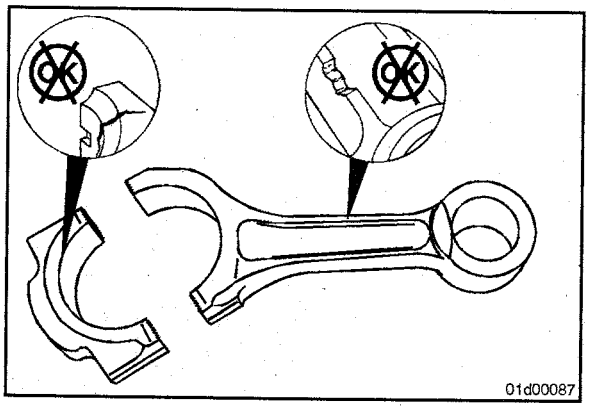
Clean and Inspect for Reuse

Clean the pistons. Refer to Procedure 001-043.

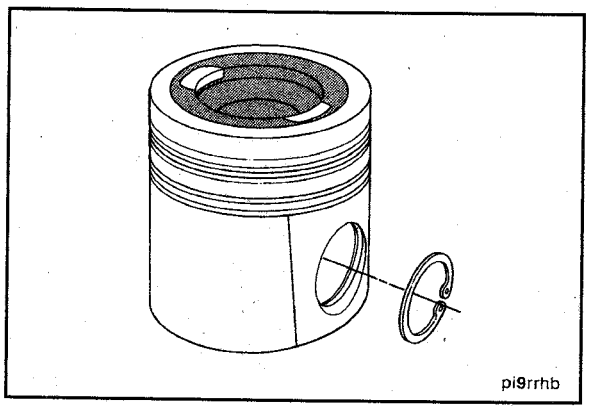




Inspect the pistons. Refer to Procedure 001-043.



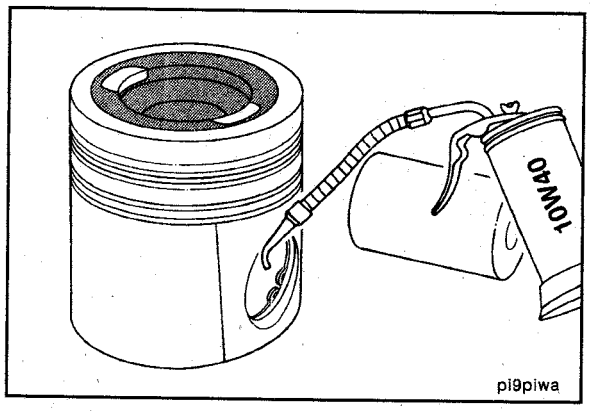
Inspect the connecting rods. Refer to Procedure 001-014.



Assemble

Single-Piece Piston

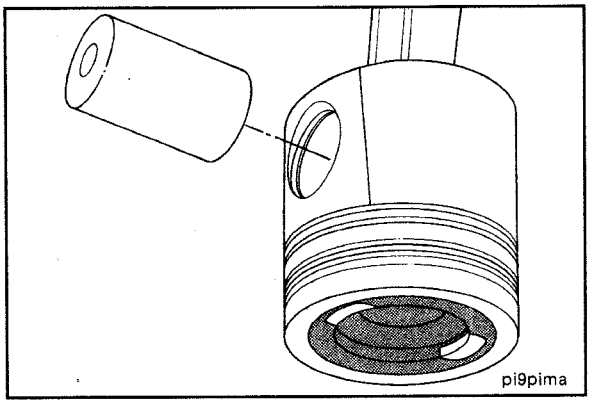
Install the retaining ring in the pin groove on one side of the piston.



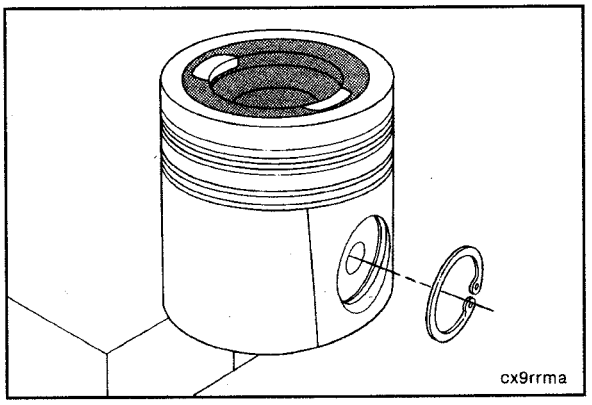
Lubricate the pin and pin bores with engine lubricating oil.

Install the pin through the piston and connecting rod.

NOTE: Pistons do **not** require heating to install the pin, however, the pistons do need to be at room temperature or above.



Install the second retaining ring.

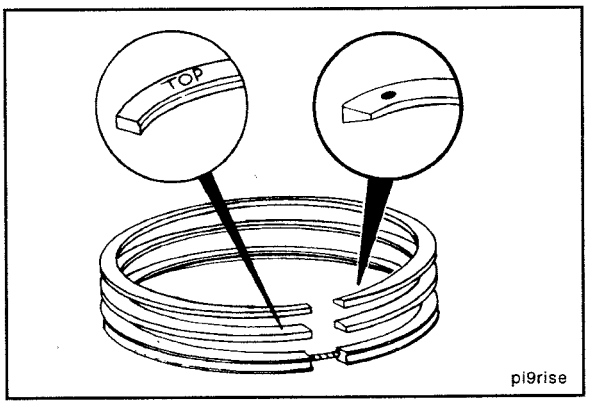


⚠CAUTION⚠

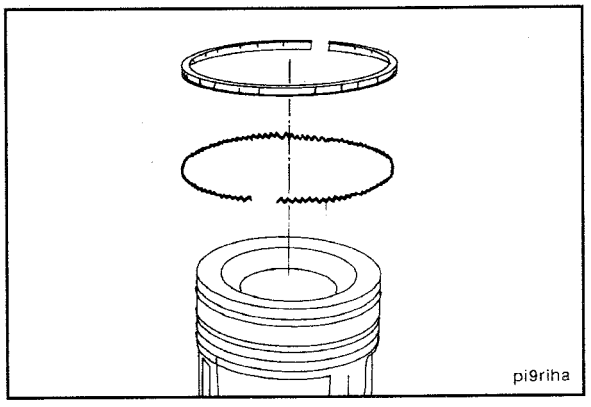
Most piston rings look similar but have significant difference. Make sure the correct part number is being used for the engine.

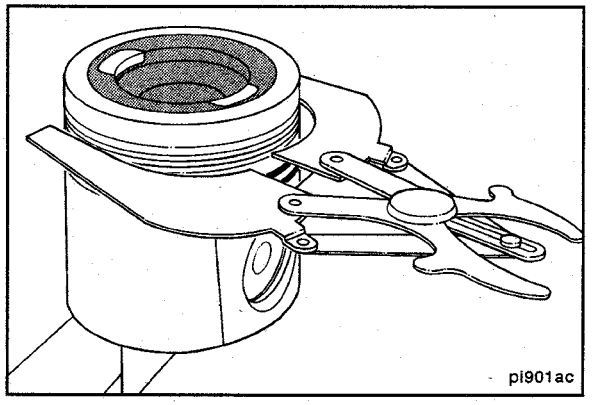
The top surface of the upper and intermediate rings are identified either with the word "TOP" or a supplier identification mark, such as a dot. Assemble with the word "TOP" or the supplier mark facing upward.

The bottom, or oil control ring, can be installed with either side up.

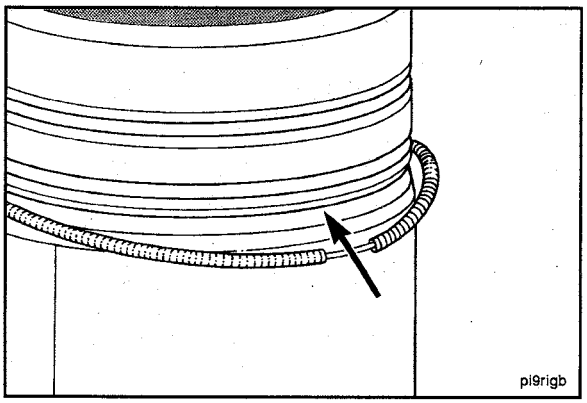


NOTE: The two-piece oil control ring **must** be installed with the expander ring gap 180-degrees from the gap or the oil ring.

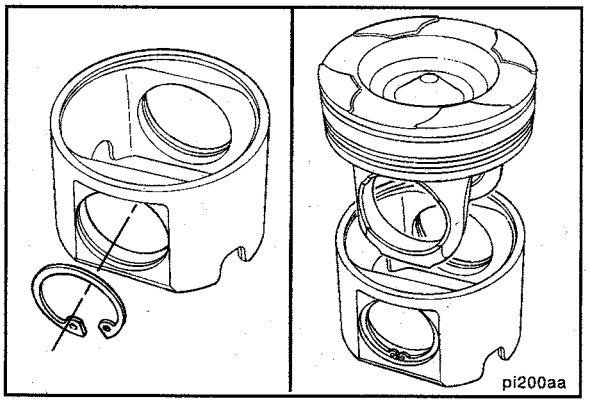




Using piston ring expander, Part Number 3823137, install the rings on the piston.



Position the oil ring expander in the oil control ring groove.



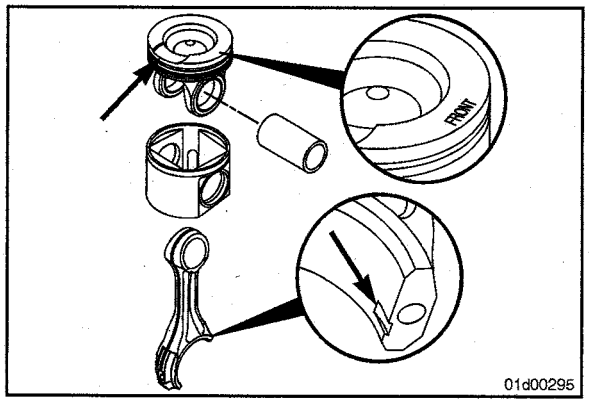
Articulated Piston

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 fit.

Install the retaining ring in the pin groove on one side of the piston.



⚠CAUTION⚠

Do not use a hammer to install the piston pin. The piston can distort, causing it to seize in the liner.

⚠CAUTION⚠

The lock tang on the connecting rod must be on the side opposite of the deep value pocket of the piston crown.

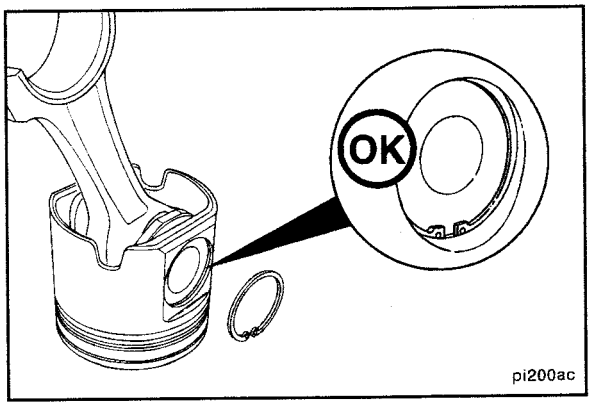
Lubricate the pin and pin bores with engine lubricating oil.

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 the second retaining ring.

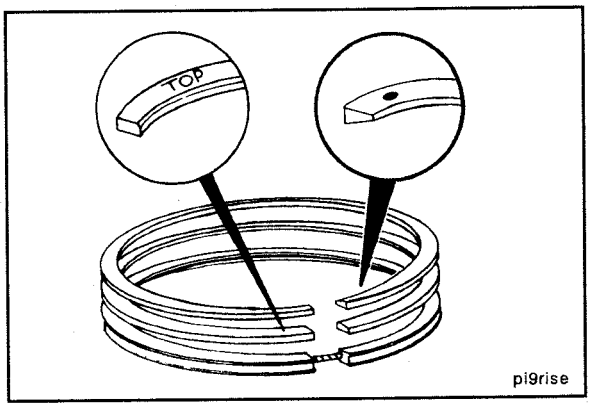


⚠CAUTION⚠

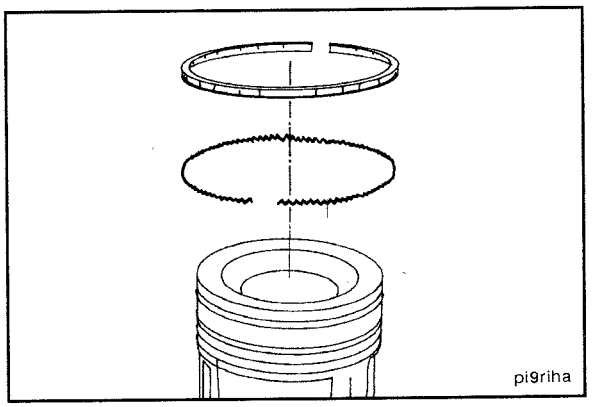
Most piston rings look similar but have significant difference. Make sure the correct part number is being used for the engine.

The top surface of the upper and intermediate rings are identified either with the word "TOP" or a supplier identification mark, such as a dot. Assemble with the word "TOP" or the supplier mark facing upward.

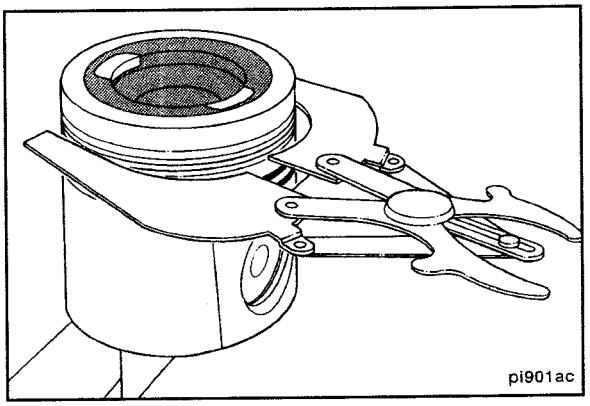
The bottom, or oil control ring, can be installed with either side up.

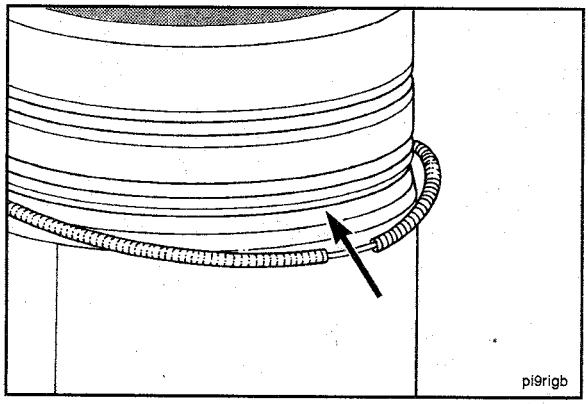


NOTE: The two-piece oil control ring **must** be installed with the expander ring gap 180-degrees from the gap or the oil ring.

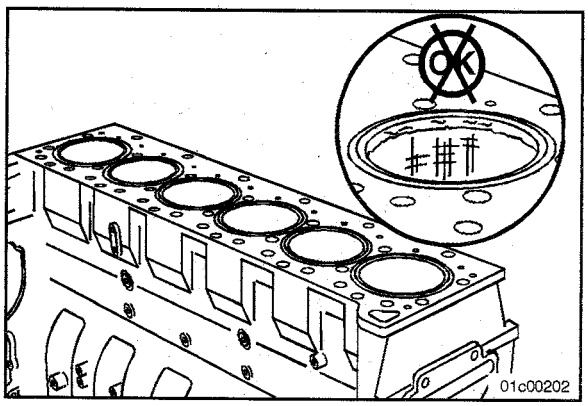


Using piston ring expander, Part Number 3823137, install the rings on the piston.





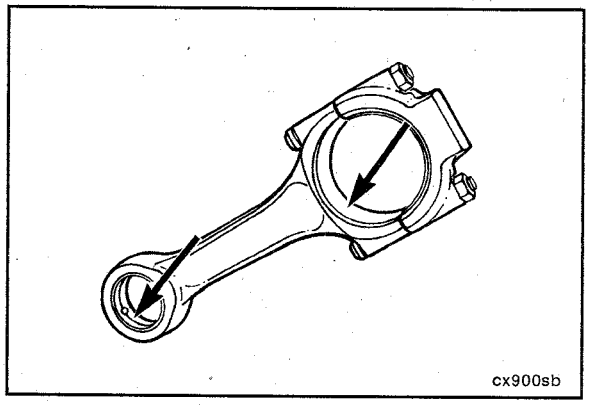
Position the oil ring expander in the oil control ring groove.



Install

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.



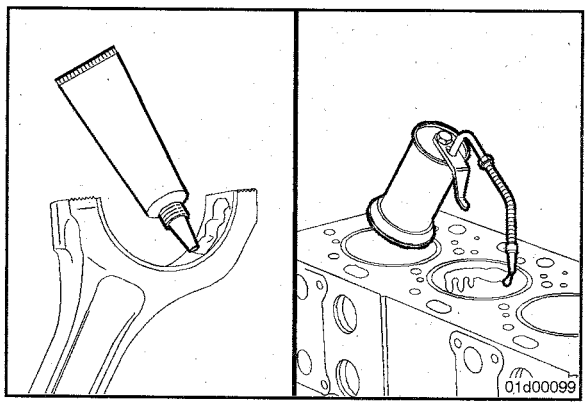
If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod and location from where they were removed.

Install the upper bearing shell into the connecting rod.

The tang of the bearing shell **must** be in the slot of the rod. The end of the bearing shell **must** be even with the cap mounting surface.

NOTE: The upper and lower rod bearing shells are **not** interchangeable on angle split connecting rods. The backs of the bearings are marked with either "UPR" or "LWR" to indicate their location.

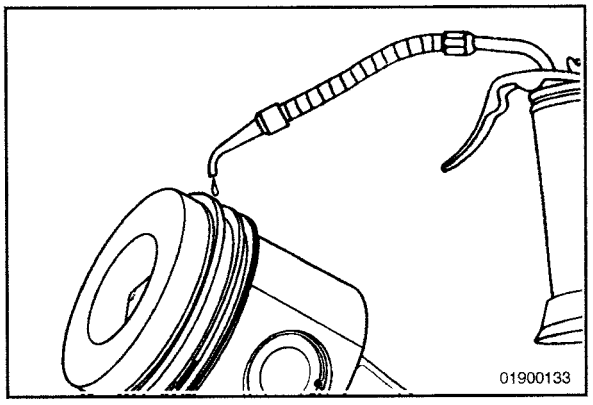
NOTE: If the connecting rod bushing is removed for any reason, a new bushing **must** be used.



Use Lubriplate® 105, or equivalent, to coat the inside circumference of the bearing shell.

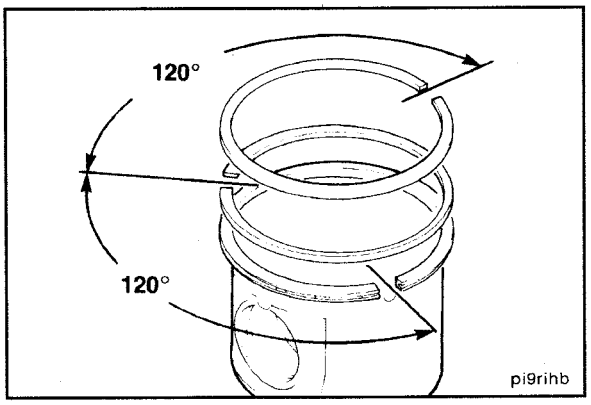
Apply a film of clean 15W-40 oil to the cylinder liner.

Lubricate the rings and piston skirts with clean engine lubricating oil.

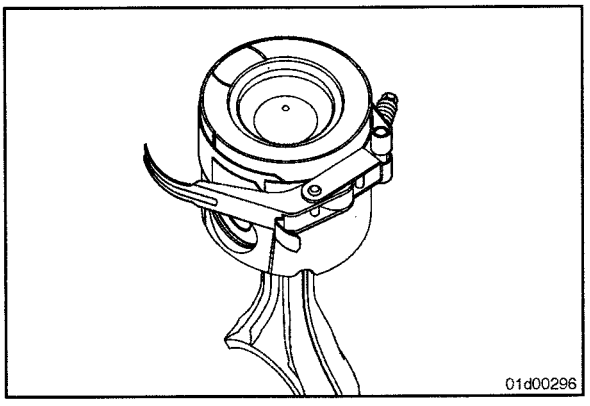


Rotate the rings to position the ring gaps as shown.

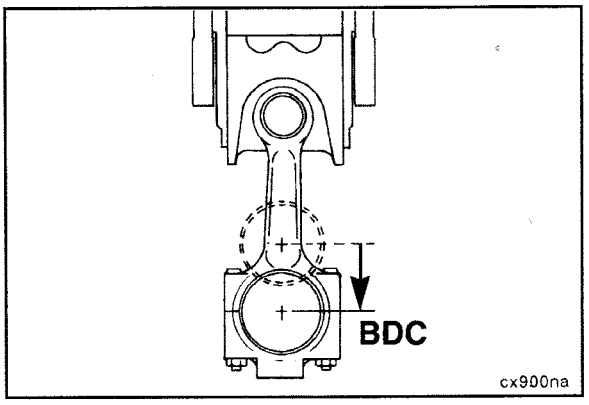
NOTE: The ring gap of each ring **must not** be aligned with the piston pin, or with any other ring. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.

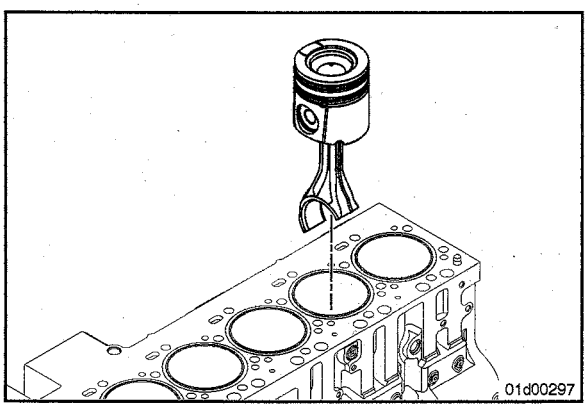


Use piston ring compressor, Part Number 3823290, to compress the rings.



Rotate the crankshaft so the connecting rod journal of the connecting rod being installed is at bottom dead center.





Engines with Angle Split Connecting Rods

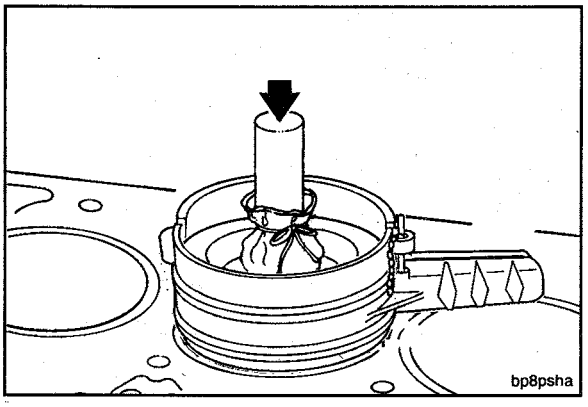
⚠CAUTION⚠

Failure to follow this step will result in extensive engine damage.

Align the piston crown deep valve pocket on the exhaust side of the engine.

Insert the connecting rod through the cylinder liner until the ring compressor contacts the top of the liner.

The angle split of the connecting rod should face the intake side.

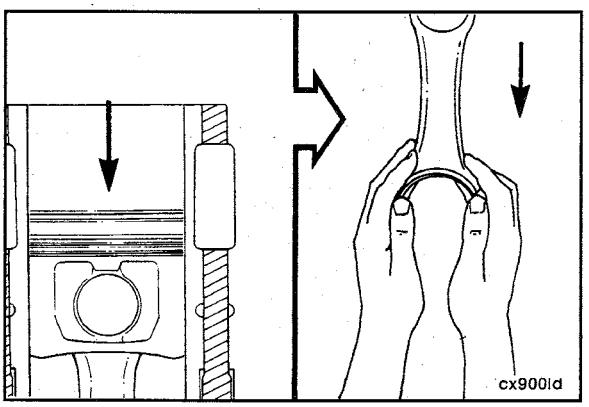


Hold the ring compressor against the cylinder liner.

Push the piston through the ring compressor and into the cylinder liner.

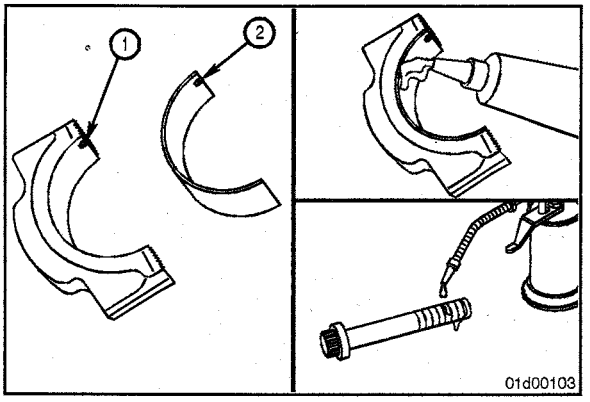
Push the piston until the top ring is completely in the cylinder liner.

NOTE: If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.



Carefully push the piston into the bore while guiding the connecting rod to the crankshaft journal.

NOTE: Connecting rod guide, Part Number 3824476, can be used aid installation on engines with connecting rod studs.



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).

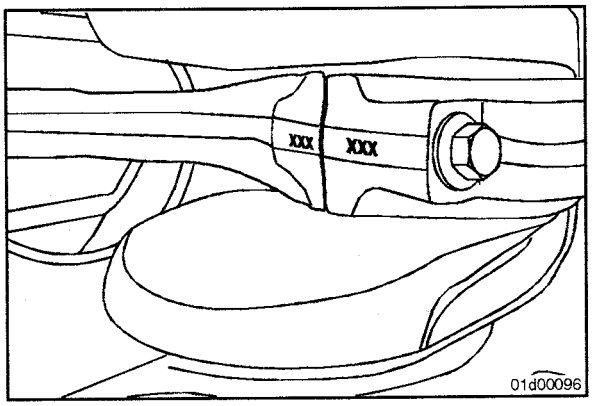
Use Lubriplate™ 105, or equivalent, to coat the inside diameter of the bearing shell.

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

⚠CAUTION⚠

Do not damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod cap is removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage.

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.



Engines With Connecting Rod Studs and Nuts

Install the connecting rod caps and nuts.

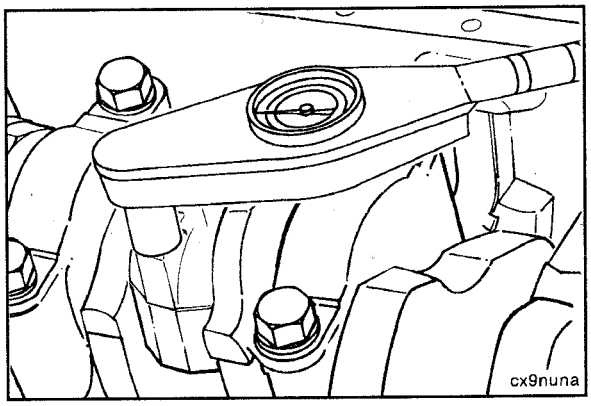
Engines With Connecting Rod Capscrews

Install the connecting rod cap and capscrews.

Use a marked socket and torque wrench to tighten the rod capscrews.

Using the torque plus angle method, tighten the connecting rod capscrews in alternating sequence.

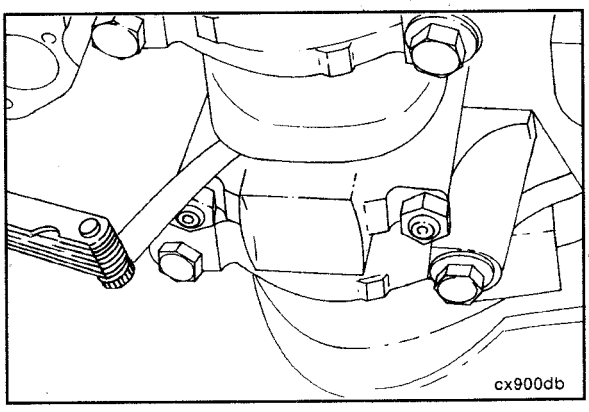
Torque Value: Step1 60 N•m [44 ft-lb]
Step2 Loosen Capscrews
Step3 70 N•m [52 ft-lb]
Step4 Advance 60-degrees

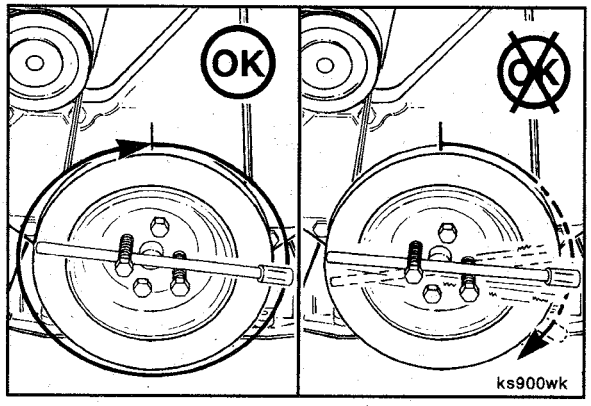


NOTE: Do **not** measure the clearance between the rod cap and crankshaft.

Measure the side clearance between the connecting rod and crankshaft.

Connecting Rod and Crankshaft Side Clearance		
mm		**in**
0.10	MIN	0.004
0.30	MAX	0.012





Check for freedom of rotation as the connecting rod caps are installed. If the crankshaft does **not** rotate freely, check the installation of the connecting rod bearings and the bearing size.

Finishing Steps

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

Install the lubricating oil suction tube. Refer to Procedure 007-035.

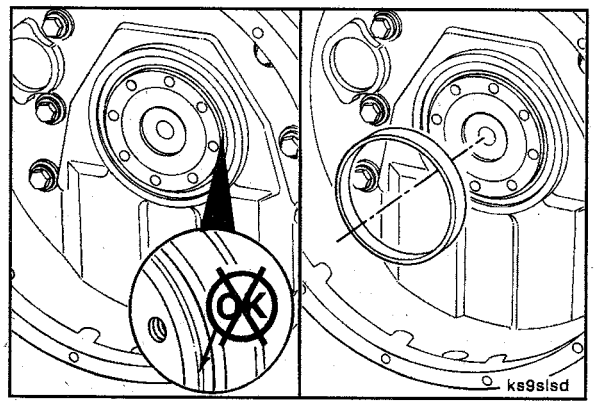
Install the lubricating oil pan. Refer to Procedure 007-025.

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

Fill the engine with lubricating oil. Refer to Procedure 007-037.

Fill the engine with coolant. Refer to Procedure 008-018.

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



Crankshaft Wear Sleeve, Rear (001-067)

Initial Check

If the crankshaft seal has worn a groove in the crankshaft flange, a wear sleeve **must** be installed to prevent oil leakage.

Preparatory Steps

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.

Remove the flywheel housing. Refer to Procedure 016-006.

Loosen the lubricating oil pan mounting capscrews four revolutions.

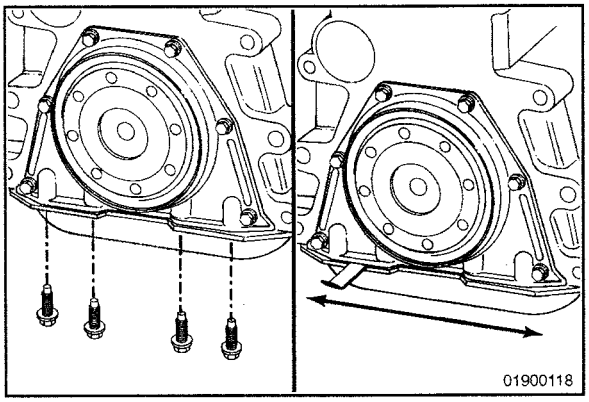
Remove

⚠CAUTION⚠

Use extreme care when releasing the oil pan gasket from the rear cover to prevent damage to the gasket. If the gasket is damaged, the oil pan must be removed and the gasket replaced. Refer to Procedure 007-025.

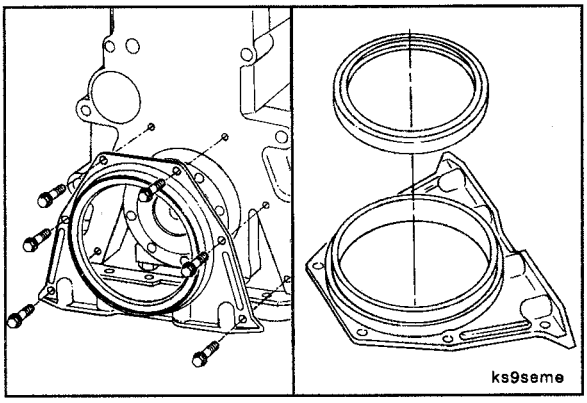
Remove the four lubricating oil pan mounting capscrews which secure the oil pan to the rear cover.

Insert a feeler gauge or shim stock between the rear cover and the oil pan gasket. Move the feeler gauge or the shim stock back and forth to release the gasket from the rear cover.



Remove the capscrews from the rear cover, and remove the cover from the crankshaft flange.

Remove the seal from the rear cover.

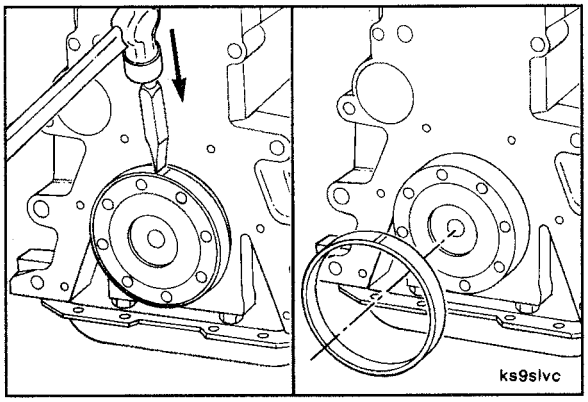


⚠CAUTION⚠

Do not nick or gouge the crankshaft with the chisel. If the crankshaft is damaged, it must be replaced.

Use a dull chisel that is **only** as wide as the wear sleeve.

Make one or two soft blows with a hammer to make chisel marks across the wear sleeve. This will expand the wear sleeve allowing the sleeve to be removed.

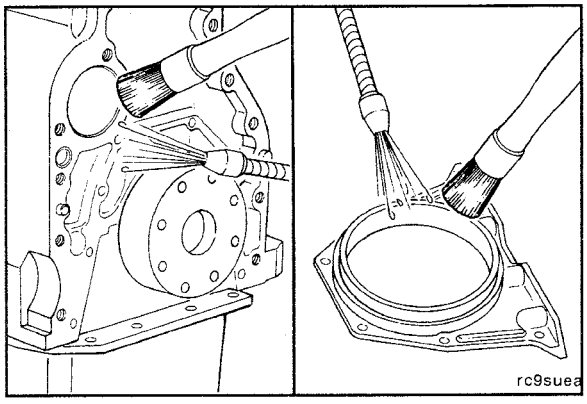


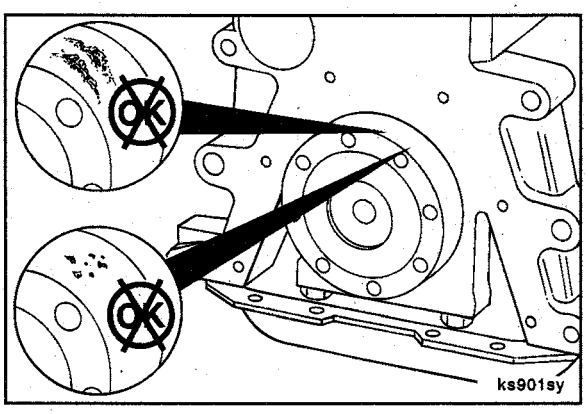
Clean and Inspect for Reuse

Clean the gasket surface of the cylinder block and rear cover.

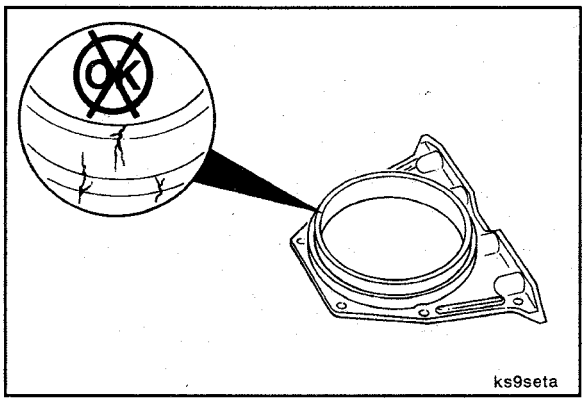
Use a crocus cloth to remove any rust or other deposits from the crankshaft flange.

Use a clean cloth to clean the crankshaft flange.

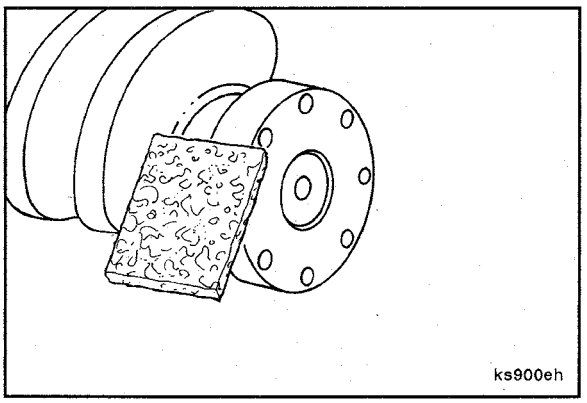




Inspect the crankshaft flange for dirt or nicks.



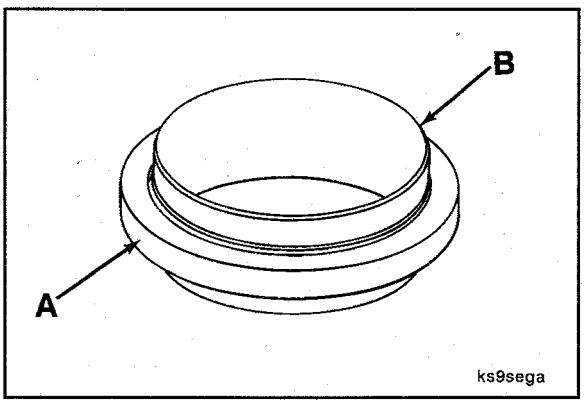
Inspect the rear cover for cracks or other damage.



Install

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

Clean any lubricant from the lip of the oil seal.

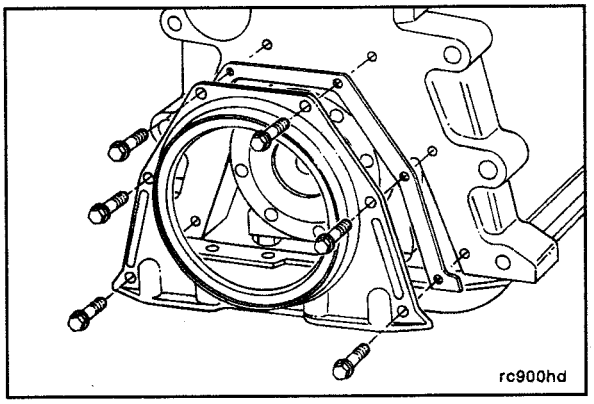


NOTE: The combination crankshaft oil seal (A) wear sleeve (B) replacement kit for service usage is installed on the crankshaft as an assembly. The crankshaft rear oil seal should **not** be removed from the crankshaft rear seal wear sleeve.

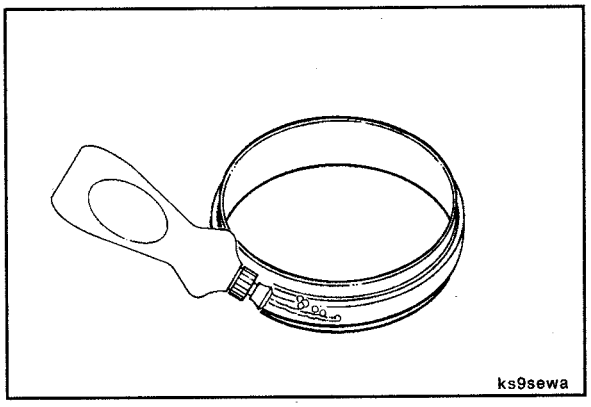
Install the rear cover and gasket.

NOTE: If the oil pan is installed, loosen the oil pan capscrews to allow clearance for rear cover and gasket clearance.

NOTE: The seal installation is being used to properly align the rear cover. Do **not** push or force the cover in any direction to prevent irregular seal lip position after seal installation.

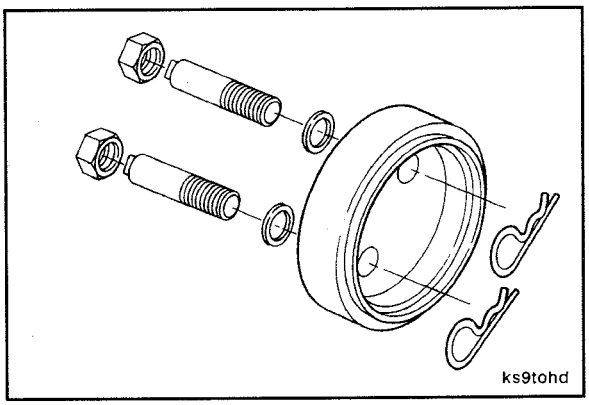


NOTE: The oil seal for a wet flywheel housing requires soap on the outside diameter of the seal case. Nothing is required on the outside diameter of the seal case for dry housings.

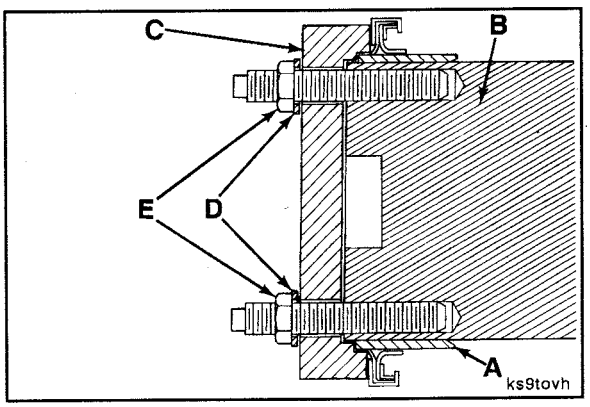


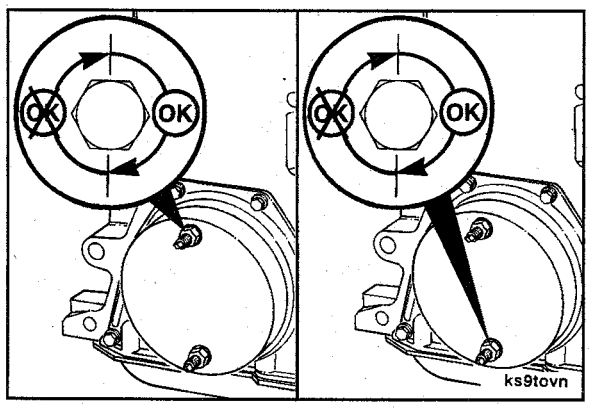
Use a service tool, Part Number 3824078, to install oil seal/wear sleeve assembly. Install two (2) threaded studs into the crankshaft capscrew holes.

Apply a small amount of clean 15W-40 engine oil to the crankshaft, threaded studs, and inside diameter of the crankshaft rear seal/wear sleeve installation tool.



Position the chamfered end of the wear sleeve (A) onto the end of the crankshaft (B). Position the counterbore end of installation tool (C) over threaded studs and align with wear sleeve, perpendicular to the end of the crankshaft. Install the washers (D) and nuts (E) onto the threaded studs.



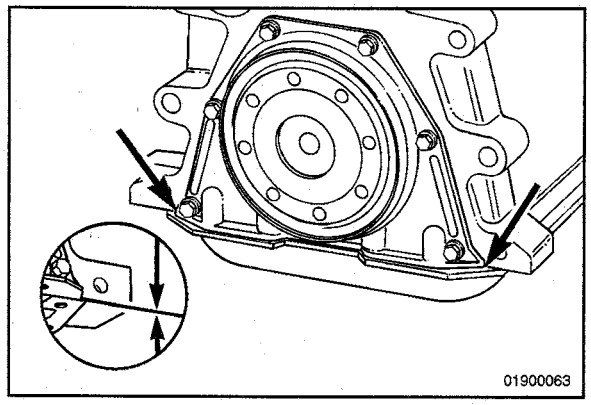


Alternately tighten the nuts until the installation tool contacts the end of the crankshaft.

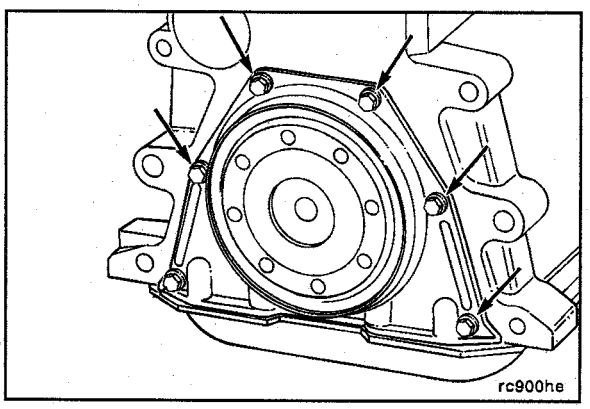
NOTE: Do **not** exceed 1/2 revolution of each nut to prevent wear sleeve binding and irregular stretch.

Torque Value: 20 N•m [15 ft-lb]

Remove the installation tool and threaded studs.

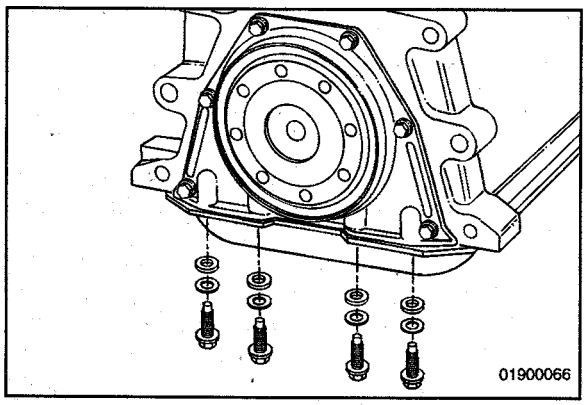


Align the rear cover even with both sides of the oil pan rail on the cylinder block.



Tighten the rear cover capscrews.

Torque Value: 10 N•m [86 in-lb]



Install the four (4) rear oil pan mounting capscrews to the pan.

Torque Value: 28 N•m [21 ft-lb]

Finishing Steps

Install the flywheel housing. Refer to Procedure 016-006.

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

Crankshaft Speed Indicator Ring (001-071)

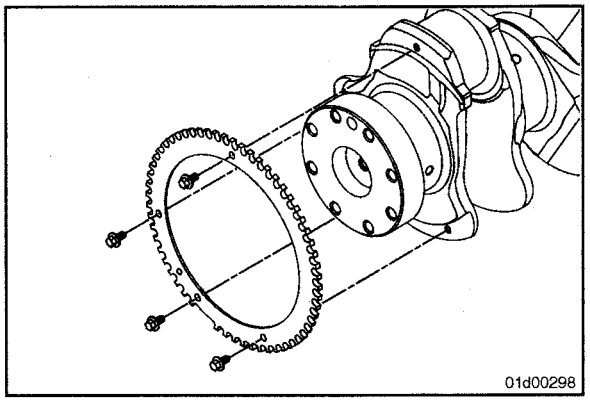
Preparatory Steps

Remove the crankshaft.

Remove

Remove and discard the four crankshaft speed indicator ring mounting capscrews.

NOTE: The capscrews are one-time use **only**. They can **not** be reused.



Clean and Inspect for Reuse

⚠WARNING⚠

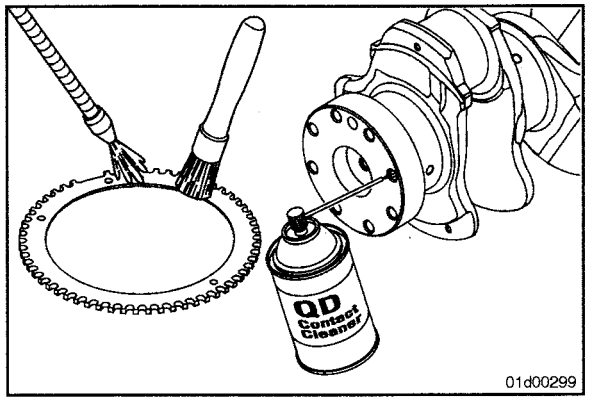
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

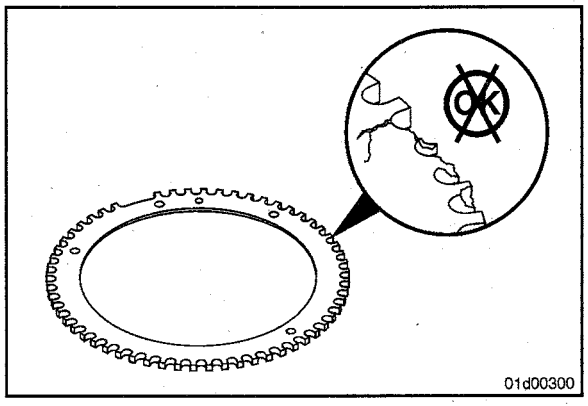
⚠WARNING⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean any oil from the speed indicator ring.

Clean the capscrew holes in the crankshaft. Use degreaser solvent such as contact cleaner, Part Number 3824510.

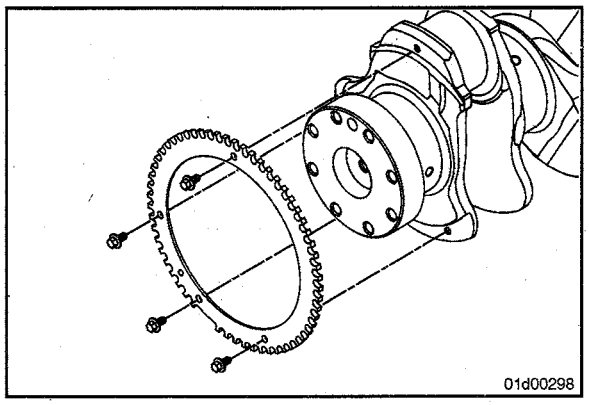




Visually inspect the speed indicator ring for missing, bent, or damaged teeth.

Inspect for cracks or damaged surfaces.

If any visual damage is found, the speed indicator ring **must** be replaced.



Install

Install the speed indicator ring.

Install new capscrews.

Tighten the capscrews in an alternating pattern.

Torque Value: 8 N•m [71 in-lb]

Finishing Steps

Install the crankshaft.

Block Stiffener Plate (001-089)

General Information

The block stiffener plate will **only** be found on some engines.

Preparatory Steps

⚠WARNING⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠

Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

Drain the lubricating oil. Refer to Procedure 007-037.

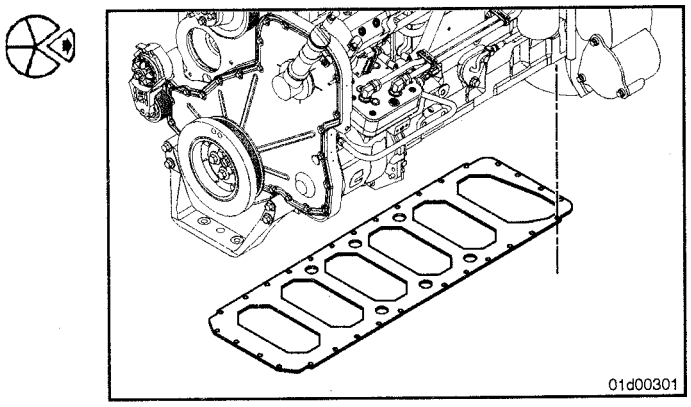
Remove the lubricating oil pan. Refer to Procedure 007-025.

Remove the lubricating oil suction tube. Refer to Procedure 007-035.

Remove

Remove the block stiffener plate.

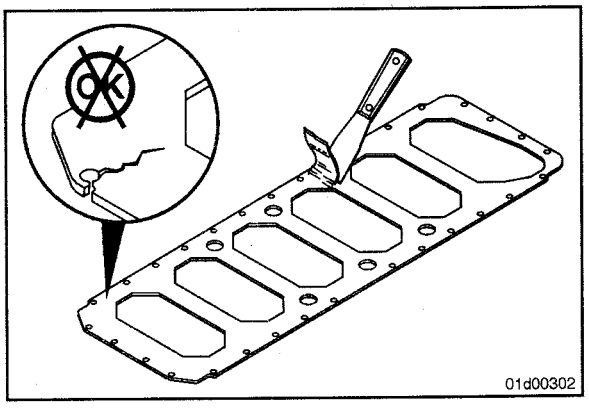
NOTE: The plate will be loose after the oil pan capscrews are removed.

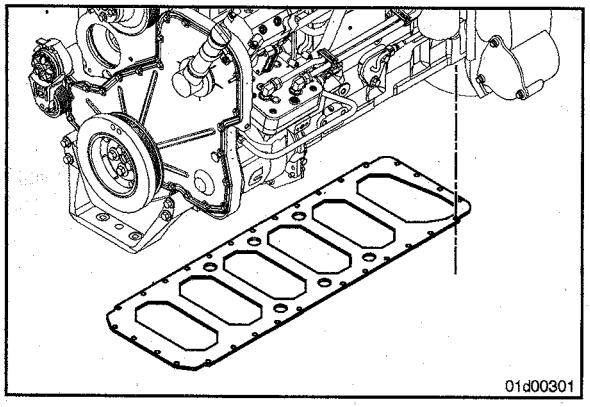


Clean and Inspect for Reuse

Remove all gasket material from both gasket surfaces.

Inspect the block stiffener plate for cracks or other damage.





Install

Install the block stiffener plate and gasket.

NOTE: The block stiffener **must** be held in place while the lubricating oil suction tube is installed. Use a few lubricating oil pan capscrews or wire ties to accomplish this.

Finishing Steps

Install the lubricating oil suction tube. Refer to Procedure 007-035.

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

Fill the engine with lubricating oil. Refer to Procedure 007-037.

Operate the engine and check for leaks.

Section 2 - Cylinder Head - Group 02

Section Contents

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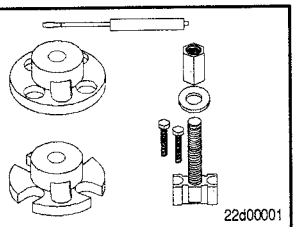
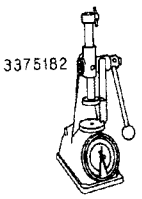
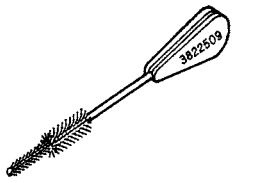
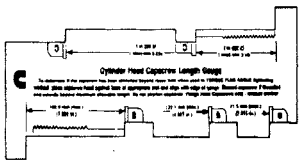
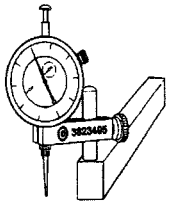
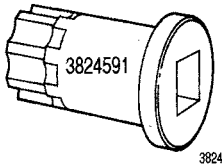
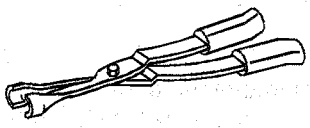
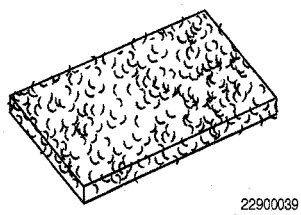
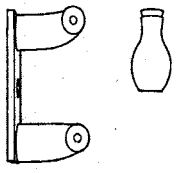
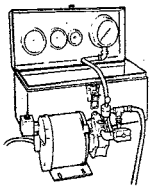
Service Tools

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
3164329	**Valve Spring Compressor** Used to remove and install valve collets.	
3375182	**Valve Spring Tester** Used to check spring tension.	
3822509	**Injector Bore Brush** Used to clean carbon from injector bores.	
3823921	**Capscrew Length Gauge** Used to measure capscrew free length.	
3164438	**Gauge Block** Used to measure the injector protrusion and valve recess in the cylinder head.	
3824591	**Engine Barring Gear** Used to engage the flywheel ring gear to rotate the crankshaft.	

Tool No.	Tool Description	Tool Illustration
3163293	**Boot Pliers** Used to remove valve stem seals. The twist and pull action frees the boot and the serrated jaws provide a secure grip.	 3163294
3823258	**Scotch-Brite™ 7448** Used to clean carbon from the upper liner bores, removing rust and corrosion, and scuffing surfaces.	 22900039
ST-1166	**Magnetic Crack Detector** Used to inspect the cylinder head combustion face for cracks in the injector bore and valve seat areas. The kit includes powder spray bulb, Part Number ST-1166-7, used for spraying the metal powder, Part Number ST-1166-8.	 kn8togo
3824277	**Valve Vacuum Tester** Used with vacuum cup, Part Number ST-1257-6. Vacuum test the cylinder head to determine if the valves are properly seated.	 kn8togr

Crosshead (002-001)

Preparatory Steps

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

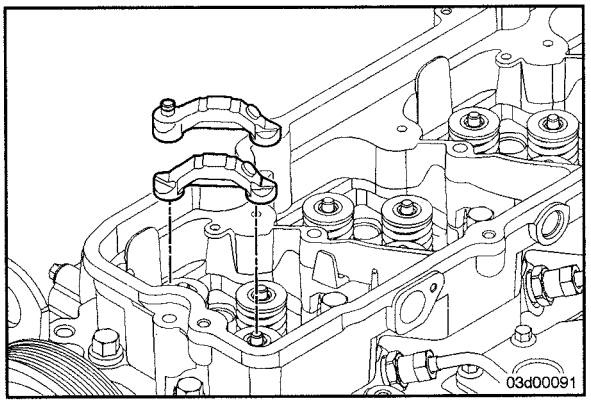
Remove the engine brake assembly, if equipped. Refer to Procedure 020-004.

Remove the rocker lever assembly. Refer to 003-008.

Remove

NOTE: Make note of the crosshead location and orientation. If the crossheads are reused, they **must** be installed in their original location and orientation.

Remove the crossheads.



Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

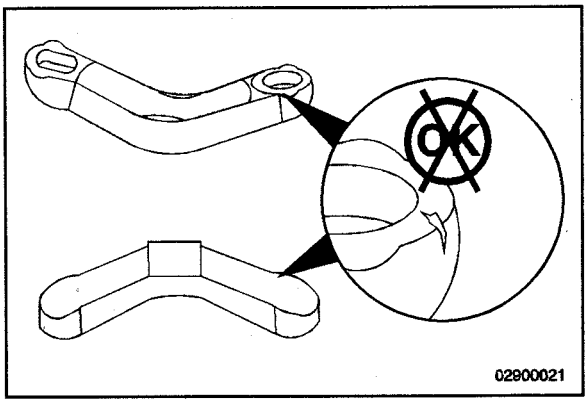
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

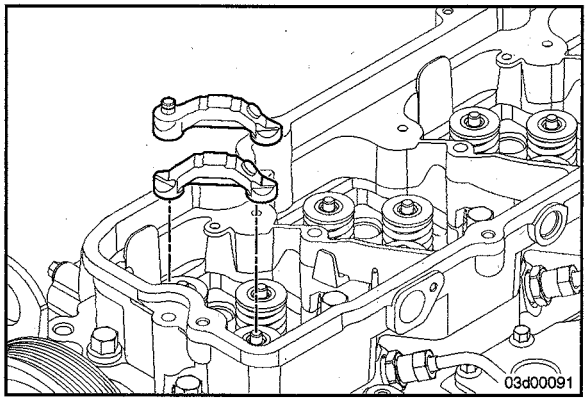
Clean the crossheads with solvent.

Dry with compressed air.

Inspect the crossheads for cracks and/or excessive wear on the rocker lever and valve tip mating surfaces.

Inspect the contact pads for cracks and other damage.





Install

NOTE: The crosshead has a round and oval hole. It is **not** required to place the holes in a particular position.

NOTE: When reusing the crossheads, make sure to install them in their original location and orientation.

Install the crossheads on the valve stems.

Finishing Steps

Install the rocker lever assembly. Refer to Procedure 003-008.

Install the engine brake assembly, if equipped. Refer to Procedure 020-004.

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

Cylinder Head (002-004)

Preparatory Steps

⚠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.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain the coolant. Refer to Procedure 008-018.

Remove the air crossover tube. Refer to Procedure 010-019.

Remove all water and heater hoses. Refer to Procedure 008-045.

Remove the turbocharger actuator air line, if equipped. Refer to Procedure 010-118.

Remove the turbocharger control valve, if equipped. Refer to Procedure 019-388 in the Troubleshooting and Repair Manual, ISC and ISL Electronic Control System, Bulletin 4021416.

Remove the intake manifold cover and intake heater. Refer to Procedures 010-023, 010-080, and 010-108.

Remove the injector supply lines. Refer to Procedure 006-051.

Remove the fuel rail from the cylinder head, if equipped. Refer to Procedure 006-060.

Remove the fuel connection tubes. Refer to Procedure 006-052.

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

Remove the engine brake assembly, if equipped. Refer to Procedure 020-004.

Remove the rocker lever housing, if equipped. Refer to Procedure 003-011.

Remove the rocker lever assembly. Refer to Procedure 003-008.

Remove the crossheads. Refer to Procedure 002-001.

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

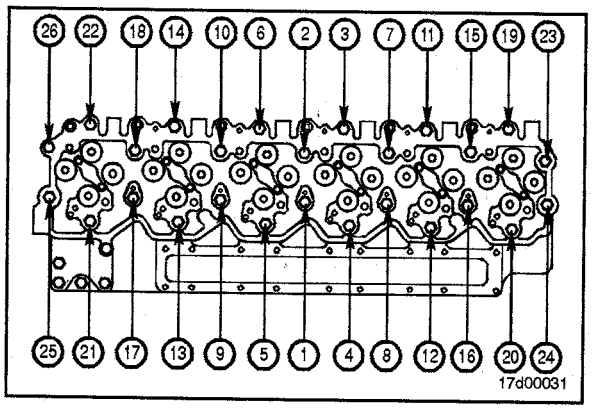
Remove the fuel return lines. Refer to Procedure 006-013.

Remove the turbocharger. Refer to Procedure 010-033.

Remove the exhaust manifold. Refer to Procedure 011-007.

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

Remove the fan hub assembly. Refer to 008-036.



Remove

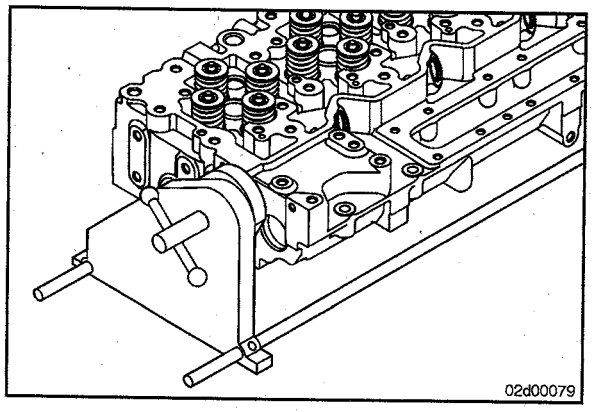
⚠WARNING⚠

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

Remove the cylinder head capscrews.

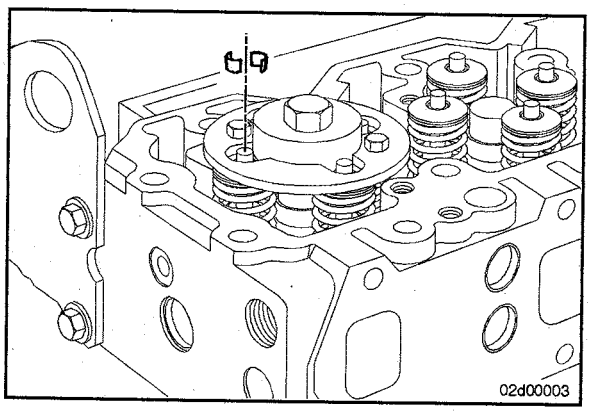
Cylinder Head Weight 71.2 kg [157 lb]

Remove the cylinder head and gasket from the cylinder block.



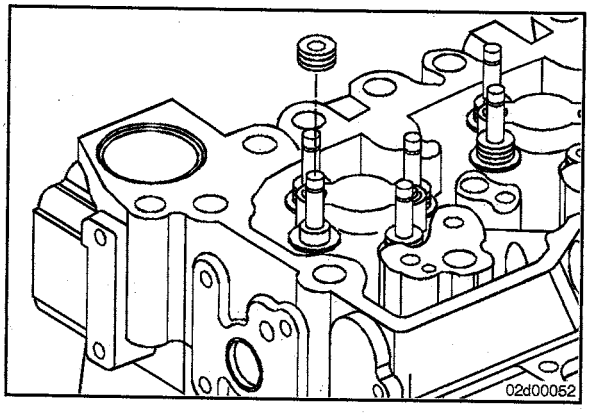
Disassemble

Install the cylinder head in the cylinder head holding fixture, Part Number ST-583.



Compress the valve springs and remove the valve stem collets. Use valve spring compressor, Part Number 3164329.

Release the valve springs and remove the spring retainers and springs.



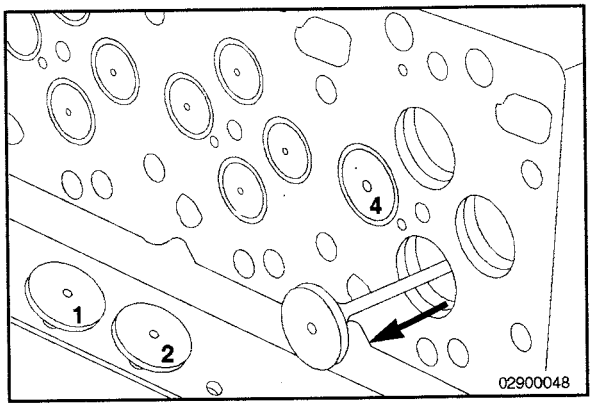
NOTE: Use boot plier, Part Number 3163293, to remove the valve stem seal.

Remove and discard the valve stem seals.

Mark the valves to identify their location. Any numbering system can be used as long as the valves are put back in the same location they came out of if they are reused.

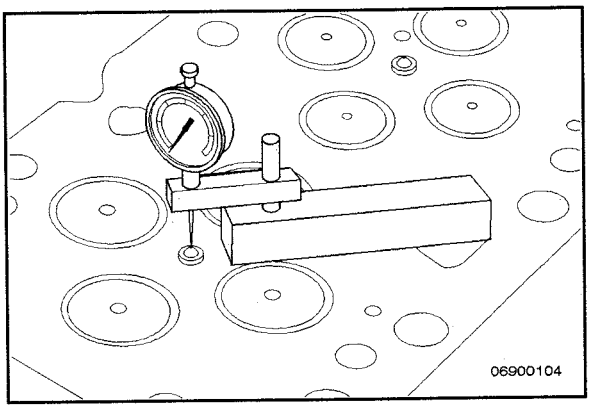
Remove the valves.

NOTE: Keep the valves in a labeled rack for a correct match with companion seats while making measurements.



Before removing the injectors, measure the injector protrusion using gauge block, Part Number 3164438.

Place the injector protrusion tool on the flat surface of the head. Measure the injector protrusion to the highest point on the injector. The protrusion **must** be within the following specifications.



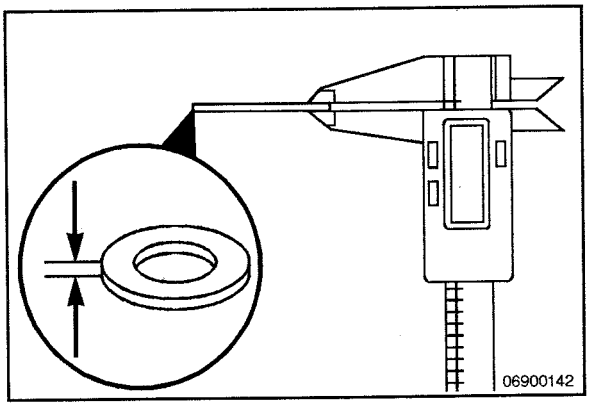
Injector Protrusion - Engines With Mechanical Injectors (CM554 Control Module)		
mm		in
2.60	MIN	0.102
3.40	MAX	0.134

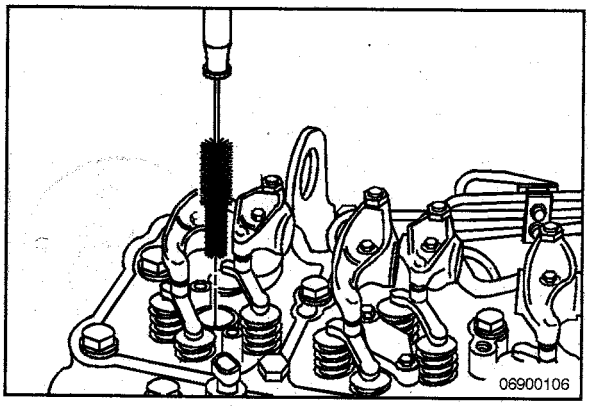
Injector Protrusion - Engines With Electronic Injectors (CM850 Control Module)		
mm		in
2.25	MIN	0.088
2.80	MAX	0.110

Remove the injector. Refer to Procedure 006-026.

If the injector protrusion is out of specification, check the thickness of the injector sealing washer. Refer to Procedure 006-026.

If the sealing washer is the correct thickness, check to make sure the injector bore is clean and free of debris. Also make sure that sealing washers are **not** 'stacked' in the injector bore.

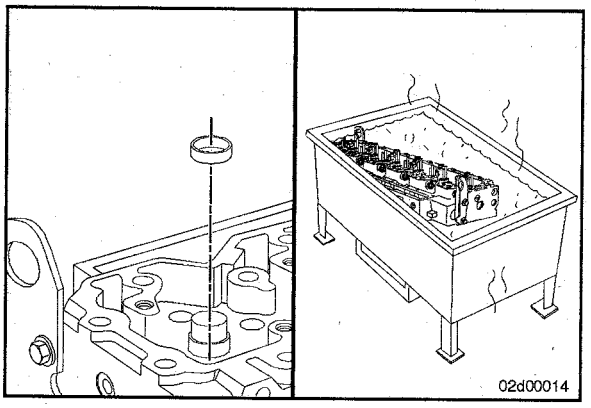




Clean and Inspect for Reuse

Use injector bore brush, Part Number 3822509, to clean the carbon from the injector nozzle seat.

Scrape the gasket material from all gasket surfaces on the block and head.



⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠WARNING⚠
Wear protective eye covering while cleaning carbon deposits to prevent injury.

Clean the buildup of deposits from the coolant passages. Excessive deposits can be cleaned in an acid tank but the expansion plugs **must** first be removed.

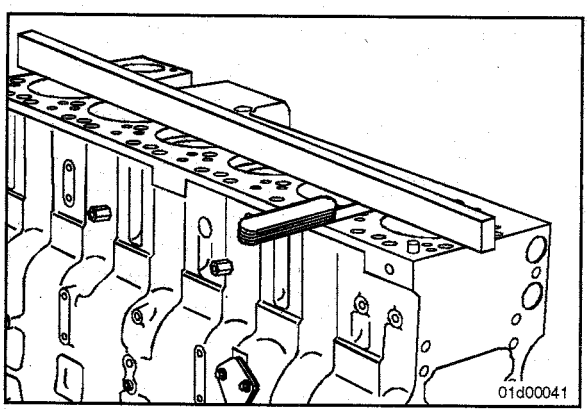
Clean the cylinder head combustion deck with a Scotch-Brite™, or equivalent, and diesel fuel or solvent.

Clean carbon deposits from the valve pockets with a high quality steel wire wheel installed in a drill or a die grinder.

NOTE: An inferior quality wire wheel will lose steel bristles during operation, thus causing additional contamination.

Wash the cylinder head in hot soapy water solution.

Dry with compressed air.



Use a straight edge and feeler gauge to measure the overall flatness of the cylinder block.

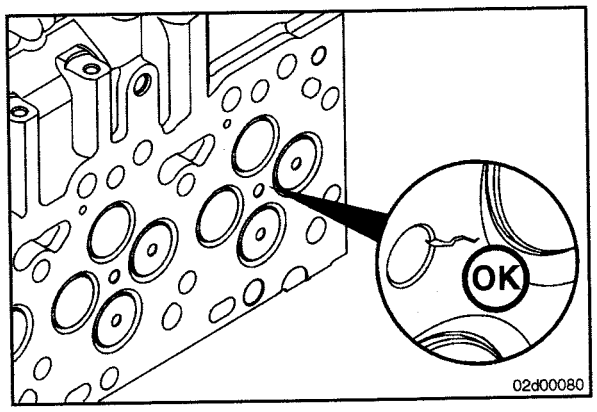
The overall flatness, end to end and side to side, **must not** exceed 0.075 mm [0.003 in].

Use a 2-inch straight edge and a 0.001-inch feeler gauge to measure local cylinder block combustion surfaces flatness. Check between the cylinder bores and also between the coolant passages. If the 0.001-inch feeler gauge fits under the 2-inch straight edge, or if the cylinder block is pitted, has grooves or other damage, the cylinder block **must** be replaced.

Cylinder Head Cracks - Reuse Guidelines

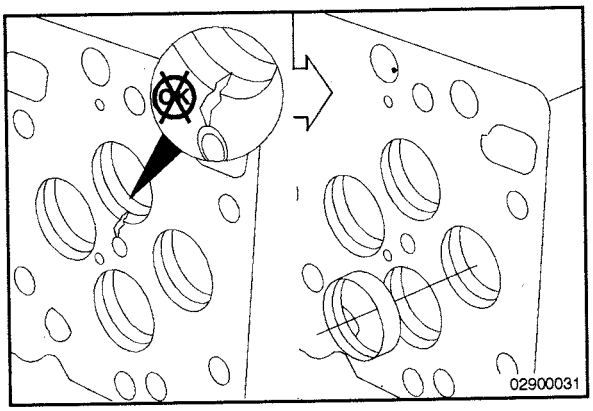
The reuse guidelines for a cylinder head with a crack extending from the injector bore to the intake valve seat are as follows:

- If the crack does **not** extend into the valve seat, the cylinder head is reusable.



- If a crack extends into or through the valve seat bore, the cylinder head **must** be replaced.

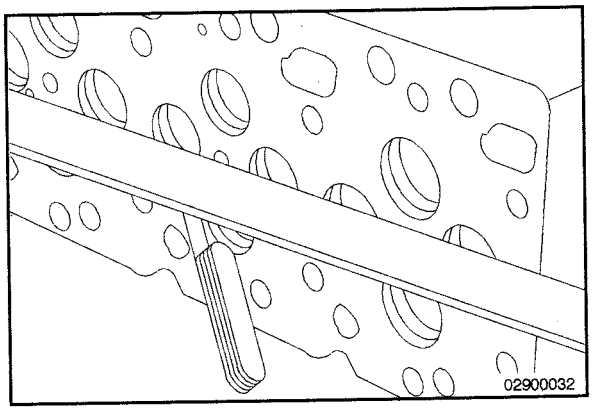
Use crack detection kit, Part Number 3375432, to help identify cylinder head cracks.



Use a straight edge and a feeler gauge to inspect the cylinder head combustion surface for flatness.

Cylinder Head Flatness

	mm		in
End to End	0.203	MAX	0.008
Side to Side	0.075	MAX	0.003



Use a 2-inch straight edge and a 0.001-inch feeler gauge to measure local cylinder head combustion surface flatness. Check between the cylinder bores and also between the coolant passages. If the 0.001-inch feeler gauge fits under the 2-inch straight edge or if the cylinder head is pitted, has grooves or other damage, the cylinder head **must** be replaced.

⚠WARNING⚠

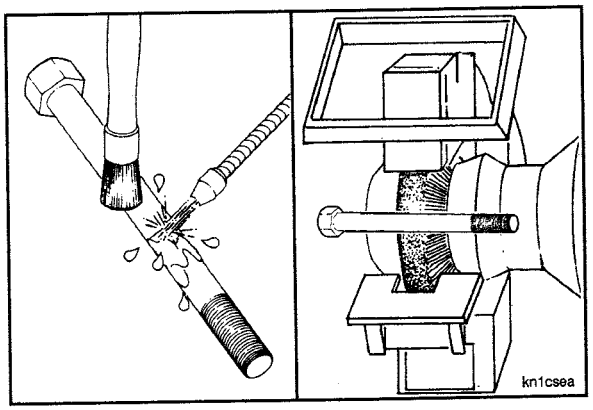
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

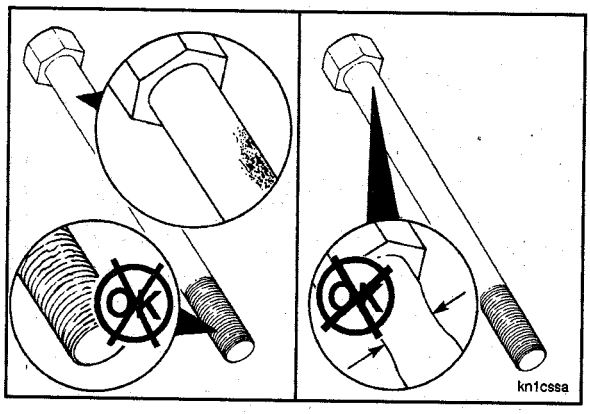
⚠WARNING⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

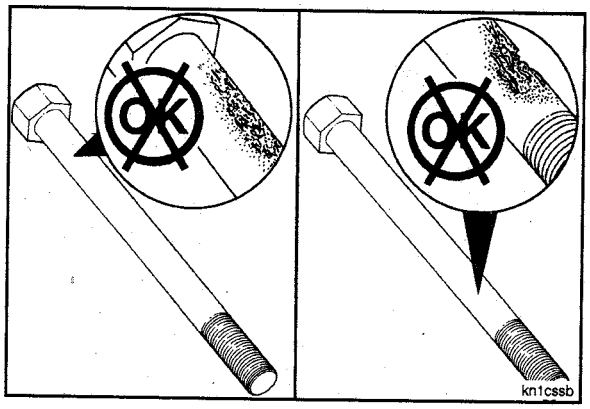
Use a petroleum-based solvent to clean the capscrews.

Clean the capscrew thoroughly with a wire brush, a soft wire wheel, or use a non-abrasive bead blast to remove deposits from the shank and the threads.



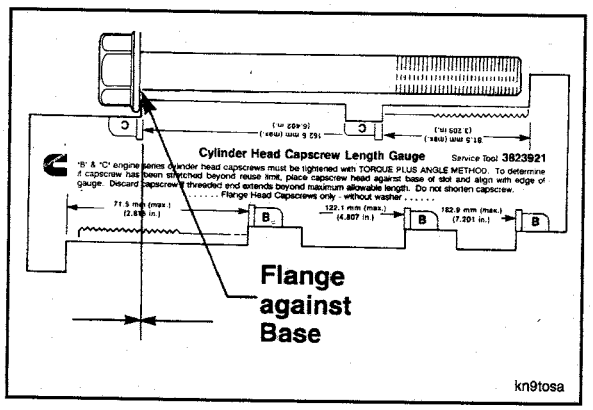


Inspect the cylinder head capscrews for damaged threads, corroded surfaces, or a reduced diameter (due to capscrew stretching).



Do **not** reuse cylinder head capscrews under the following conditions:

- Visible corrosion or pitting exceeds 1 sq cm [0.155 sq in] in area. Example:
  - acceptable is 9.525 x 9.525 mm [3/8 x 3/8 in]
  - unacceptable is 12.700 x 12.700 mm [1/2 x 1/2 in]
- visible corrosion or pitting exceeds 0.12 mm [0.005 in] in depth
- visible corrosion or pitting is located within 3.2 mm [1/8 in] of the fillet or threads
- stretched beyond "free length" maximum. Refer to the measurement procedure below.

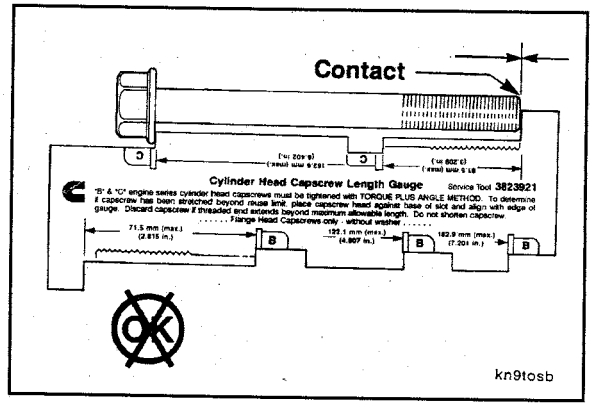


Capscrew Length Gauge, Part Number 3823921

Free Length Measurement

NOTE: If the capscrews are **not** damaged, they can be reused throughout the life of the engine unless the specified "free length" is exceeded.

To check the capscrew free length, place the head of the capscrew in the appropriate slot with the flange against the base of the slot.



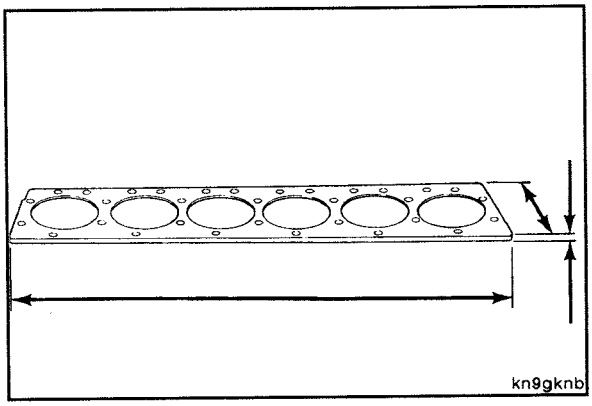
If the end of the capscrew touches the foot of the gauge, the capscrew is too long and **must** be discarded. The maximum capscrew free length is 162.6 mm [6.4 in].

Cylinder Head Capscrew Free Length		
mm		in
162.6	MAX	6.4

Pressure Test

A cylinder head test fixture can be fabricated from a flat piece of steel or aluminum. Refer to the following table for test fixture dimensions.

Test Fixture Dimensions		
mm		**in**
16	Thickness	0.630
749	Length	29.5
193	Width	7.6

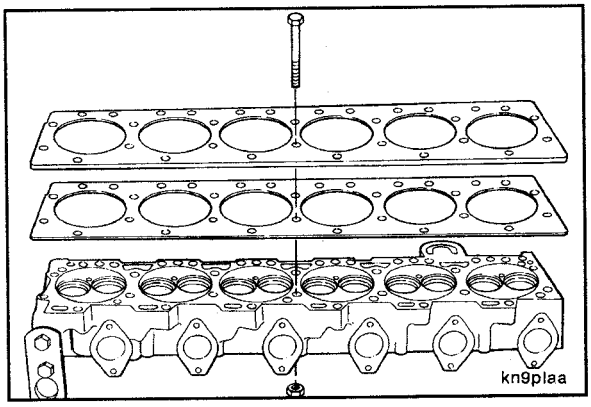


Use the cylinder head gasket as a pattern for drilling the capscrew holes.

Install the cylinder head water test fixture.

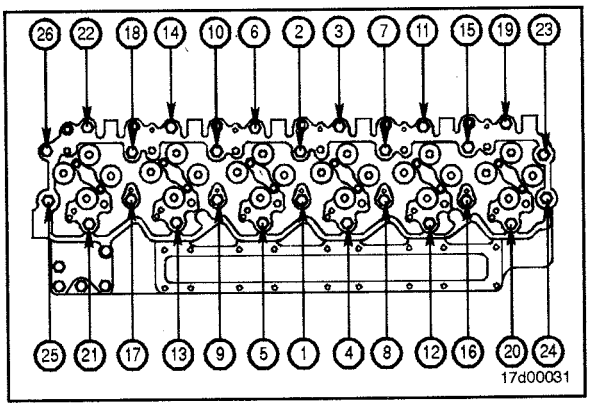
- Install a new head gasket
- Install the test plate
- Install the following
  - 26 - 180-mm long head capscrews, Part Number 3920781
  - 26 - M12 x 1.75 hex flange nuts
  - 52 - 12-mm washers, Part Number 3900269.

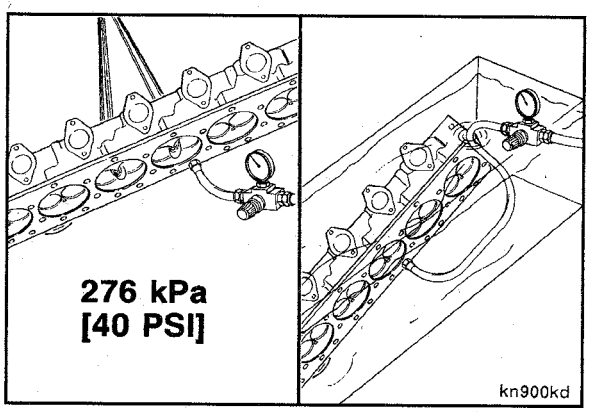
NOTE: Place a washer between each capscrew and the head, and between each nut and test plate. This will prevent mutilation on the surface of the cylinder head.



Use the illustrated sequence to tighten the 26 nuts.

Torque Value: 80 N•m [59 ft-lb]





⚠WARNING⚠

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

Connect a regulated air supply hose, Part Number 3164231, to the test fixture plate.

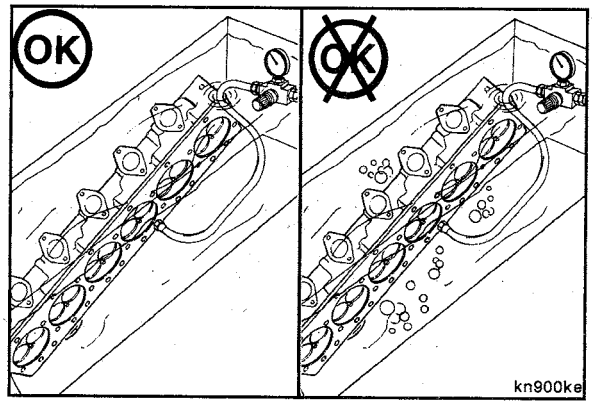
Apply air pressure.

Air Pressure 276 kPa [40 psi]

Use a nylon lifting strap and hoist to place the cylinder head in a tank of heated water.

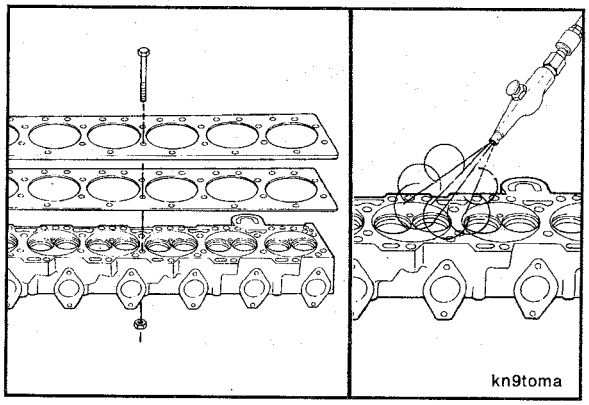
Water Temperature 60 °C [140 °F]

NOTE: The cylinder head **must** be completely submerged in the water.



Inspect the cylinder head. Bubbles indicate an air leak.

If the cylinder head leaks, it **must** be replaced.

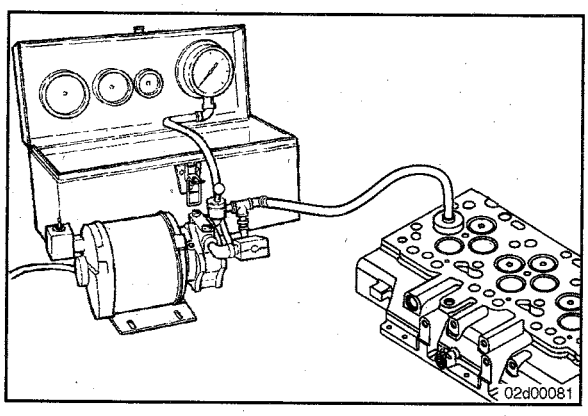


⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Remove the test fixture.

Use compressed air to dry the cylinder head.



NOTE: If a leaking valve is suspected, vacuum test the valves and valve seats, after the cylinder head has been assembled, using valve vacuum tester, Part Number 3824277, and cup, Part Number ST-1257-6. The vacuum **must not** drop more than 25.4 mm Hg [1.0 in Hg] in five (5) seconds.

Valve to Valve Seat Vacuum		
mm Hg		**in Hg**
457	Used	18
635	New	25

⚠WARNING⚠

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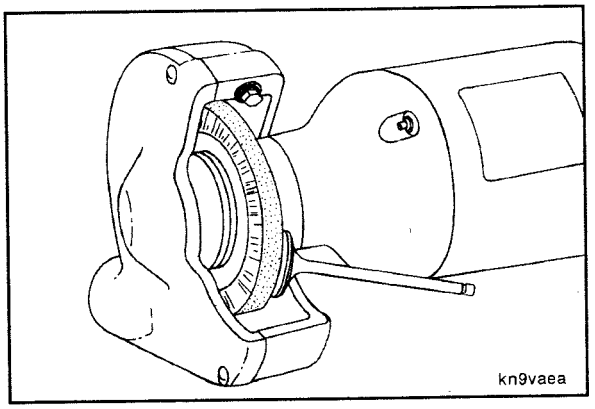
⚠WARNING⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean the valve heads with a soft wire wheel.

NOTE: Keep the valve in a labeled rack to prevent mixing prior to making measurements.

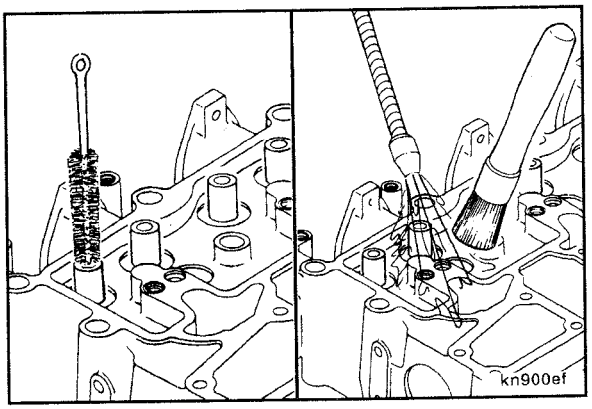
Polish the valve stem with a Scotch-Brite™ pad, or equivalent, and diesel fuel or solvent.



⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use a bristle brush to clean the inside diameter of the valve guide bore and blow out with compressed air.

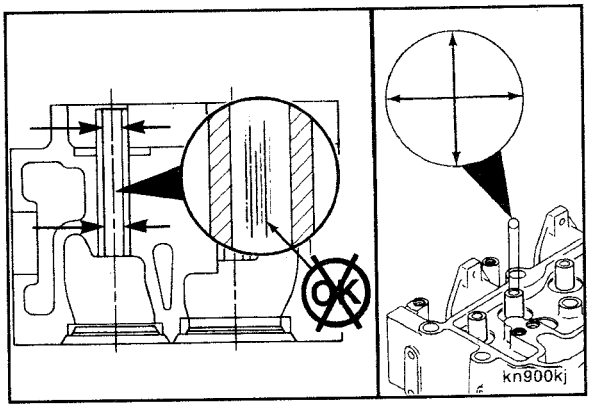


Inspect the valve guides for scuffing or scoring.

Measure the valve guide inner diameter (I.D.)

Valve Guide Inner Diameter (I.D.)		
mm		in
8.019	MIN	0.3157
8.071	MAX	0.3178

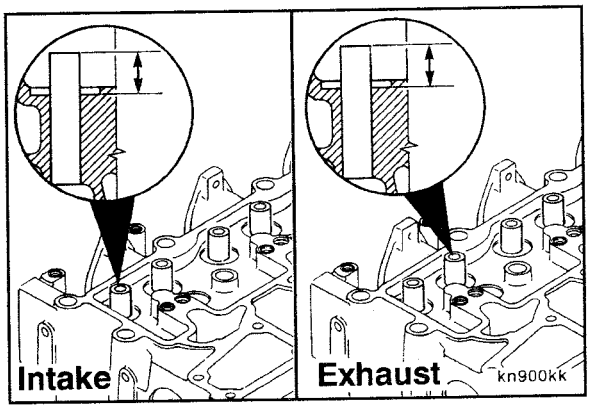
If the valve guide bore is worn larger than the maximum specified, the cylinder head **must** be replaced.

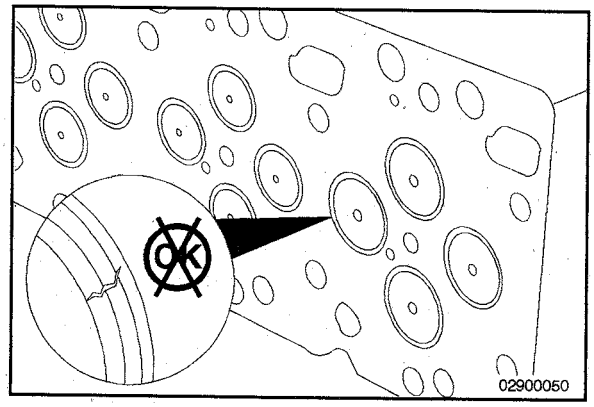


Use a depth micrometer to measure the valve guide installed height. Measure from the top of the valve guide to the bottom of the recess area.

Valve Guide Height (Installed)		
mm		in
13.15	MIN	0.518
13.65	MAX	0.537

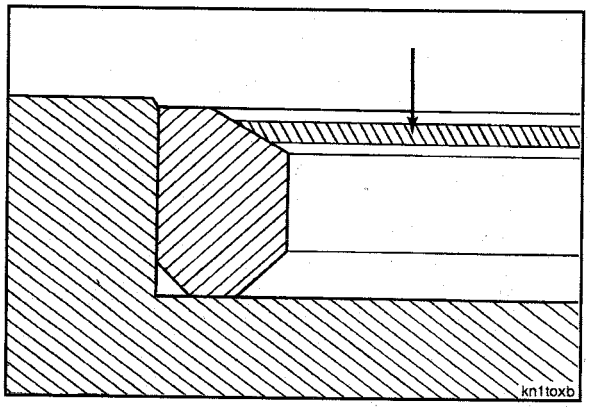
If the valve guide height is outside of the specification, the cylinder head **must** be replaced.





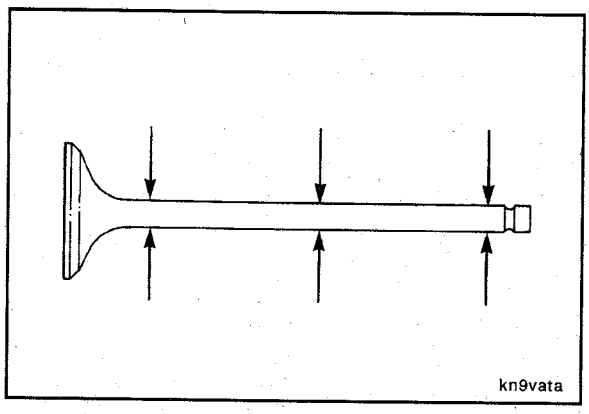
Inspect the valve seats for cracks or burnt spots.

The 4-valve cylinder head can **not** be rebuilt at this time. Replace the cylinder head if damage is found on the valve seats.



Visually verify that the valve sealing area is in the center of the valve seat insert. If the sealing area extends to the top or bottom of the valve seat insert, the valve should be replaced.

After replacing the valve, recheck the valve sealing area. If the sealing area still extends to the top or bottom of the valve seat insert, the cylinder head **must** be replaced.

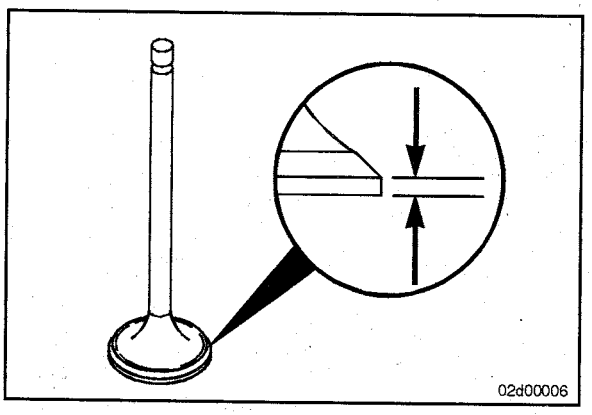


Inspect for abnormal wear on the heads and stems.

Measure the valve stem diameter.

Valve Stem Diameter		
mm		in
7.96	MIN	0.313
7.98	MAX	0.314

Replace any valve found outside of these dimensions.



Check the valve stem tip for flatness.

Inspect for bent valves.

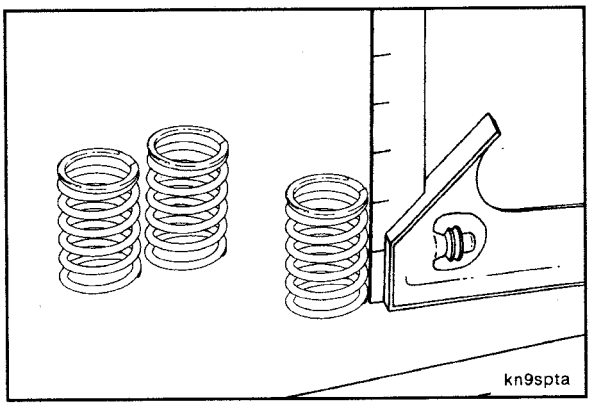
Measure the rim thickness. If the valve thickness is **not** within the limits, a new valve **must** be used.

Valve Rim Thickness Limit			
	mm		in
Exhaust	1.83	MIN	0.072
Intake	2.20	MIN	0.087

Inspect the valve springs.

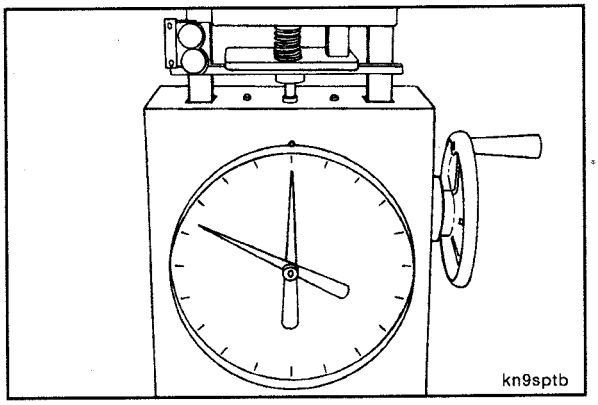
Measure the valve spring.

Approximate Free Length 59.18 mm [2.330 in]



A load of 906 to 1007 N [204 to 226 lb] is required to compress the spring to a height of 30.6 mm [1.20 in]. Use spring compressor tool, Part Number 3944711, to measure spring force.

Replace the valve spring if the load required to compress the spring is outside of the specification.

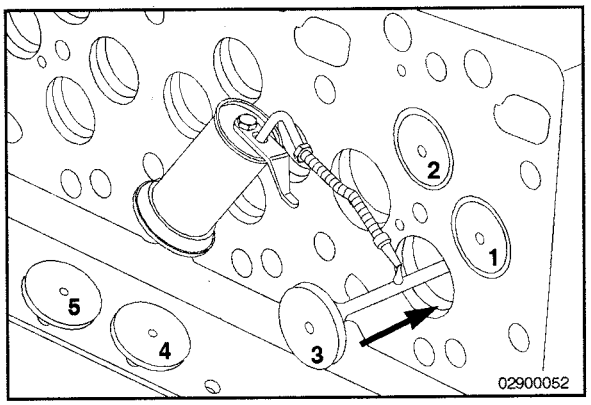


Assemble

Lubricate the stems with SAE 90W or 15W-40 engine oil before installing the valves.

Install the valves.

NOTE: If reusing the valves, they **must** be installed in the same location they came out of. Any numbering system can be used as long as the valves are put back in the same location.



Engines With Black and Blue Valve Seals

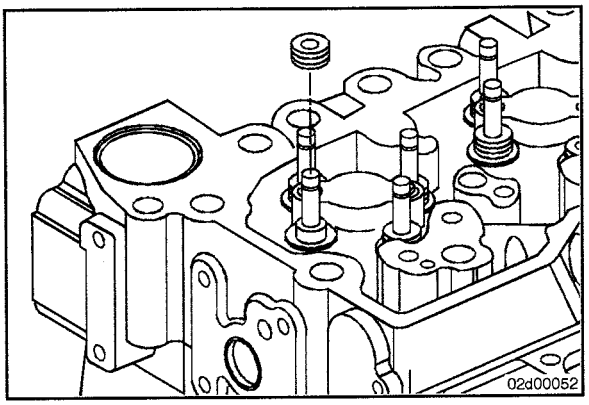
Install the black valve seals over the exhaust valve guides.
Install the blue valve seals over the intake valve guides.

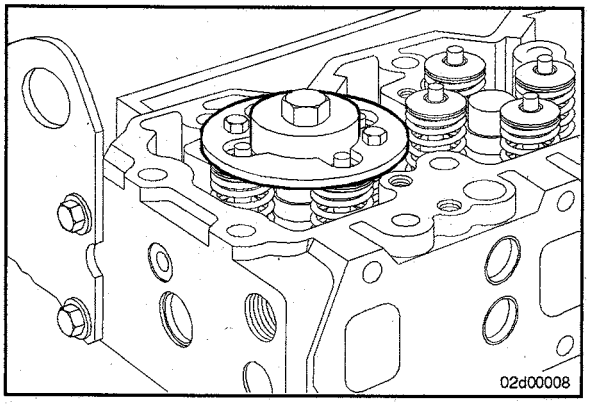
Engines With Yellow and Green Valve Seals

Install the yellow valve seals over the intake valve guides.
Install the green valve seals over the exhaust valve guides.

Use a valve stem seal installation tool, Part Number 3164055.

NOTE: A 13-mm deep-well socket and extension can be used to press the new valve stem seal in place.

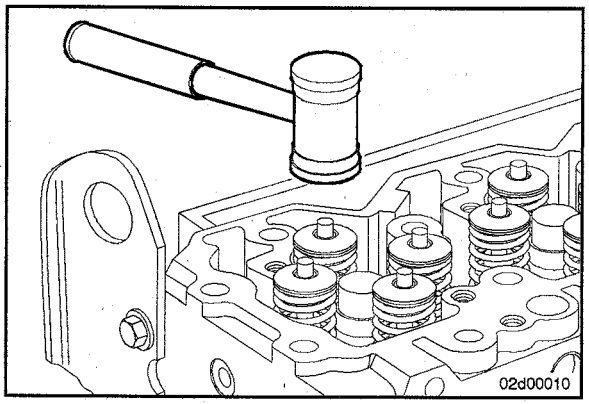




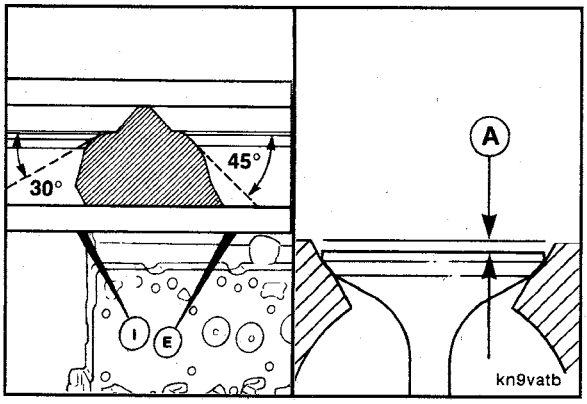
Install the valve spring retainers and valve springs.

Compress the valve springs using valve spring compressor, Part Number 3164239.

Install new valve collets and release the spring tension.



After assembly, hit the valve stems with a plastic hammer to make sure that the collets are seated.



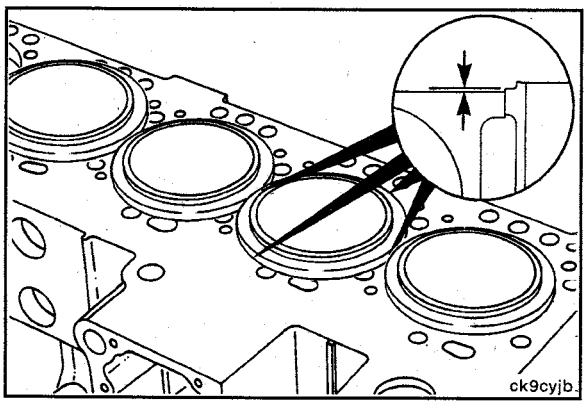
Valve Seat Angle

- Intake is 30-degrees
- Exhaust is 45-degrees

Measure the valve recess.

Valve Recess in Cylinder Head		
mm		in
0.84	MIN	0.033
1.32	MAX	0.052

NOTE: If the valve recess is outside the specifications, replace the valve. If the valve recess is still outside the specifications, the cylinder head **must** be replaced.

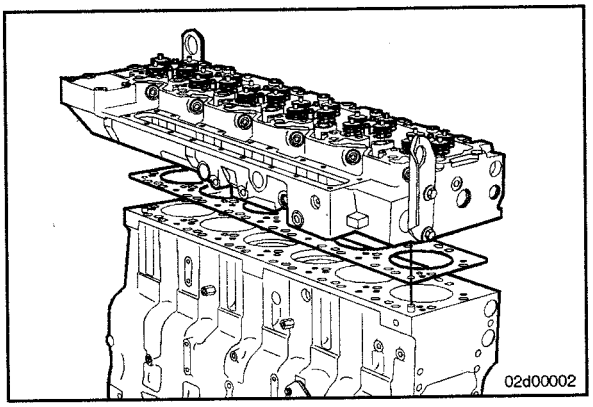


Before installing the cylinder head, check the cylinder liner protrusion. Refer to Procedure 001-028.

Install

Position the new cylinder head gasket over the dowels.

NOTE: Do **not** attempt to reuse cylinder head gasket.

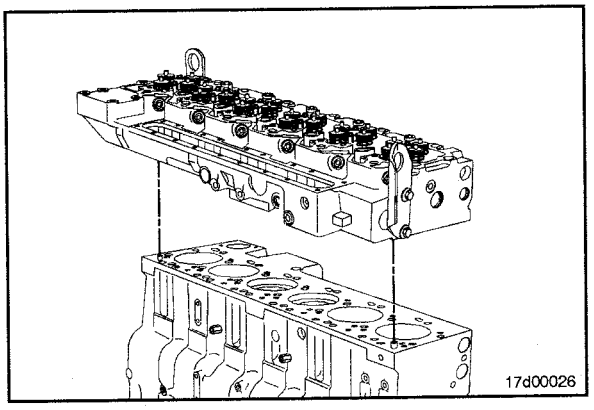


⚠WARNING⚠

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

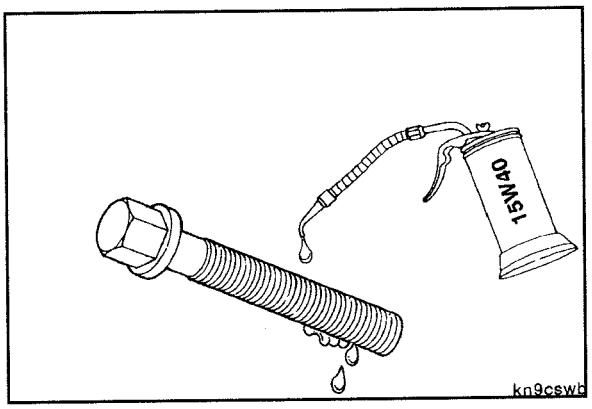
Carefully put the cylinder head on the cylinder block and seat it onto the dowels.

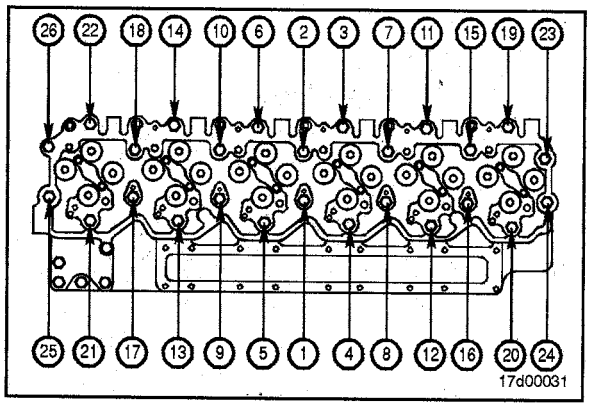
Cylinder Head Weight 75 kg [157 lb]



Lubricate the threads and under the heads on the head capscrews with clean 15W-40 engine lubricating oil.

NOTE: If new capscrews are used, capscrews threads are to be burnished. To burnish new capscrews, tighten the capscrews as described below. Loosen the capscrews and repeat the tightening sequence.





Use the illustrated sequence to tighten the cylinder head capscrews.

Engines with CM554 Control Module

148 N•m [109 ft-lb]
148 N•m [109 ft-lb]
Advance 90-degrees

Engines with CM850 Control Module

150 N•m [111 ft-lb]
Loosen all capscrews
110 N•m [81 ft-lb]
110 N•m [81 ft-lb]
Advance 120-degrees

Finishing Steps

Install the fan hub assembly. Refer to 008-036.

Install the drive belt. Refer to Procedure 008-002.

Install the exhaust manifold. Refer to Procedure 011-007.

Install the turbocharger. Refer to Procedure 010-033.

Install the turbocharger control valve, if equipped. Refer to Procedure 019-388 in the Troubleshooting and Repair Manual, ISC and ISL Electronic Control System, Bulletin 4021416.

Install the fuel return lines. Refer to Procedure 006-013.

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

Install the injectors. Refer to Procedure 006-026.

Install the crossheads. Refer to Procedure 002-001.

Install the rocker lever assembly. Refer to Procedure 003-008.

Install the rocker lever housing, if equipped. Refer to Procedure 003-011.

Install the engine brake assembly, if equipped. Refer to Procedure 020-004.

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

Install the fuel connection tubes. Refer to Procedure 006-052.

Install the fuel rail from the cylinder head, if equipped. Refer to Procedure 006-060.

Install the injector supply lines. Refer to Procedure 006-051.

Install the turbocharger actuator air line, if equipped. Refer to Procedure 010-118.

Install all water and heater hoses. Refer to Procedure 008-045.

Install the intake manifold cover and intake heater. Refer to Procedures 010-023, 010-080, and 010-108.

Install the crankcase breather tube. Refer to Procedure 003-018.

Install the air crossover tube. Refer to Procedure 010-019.

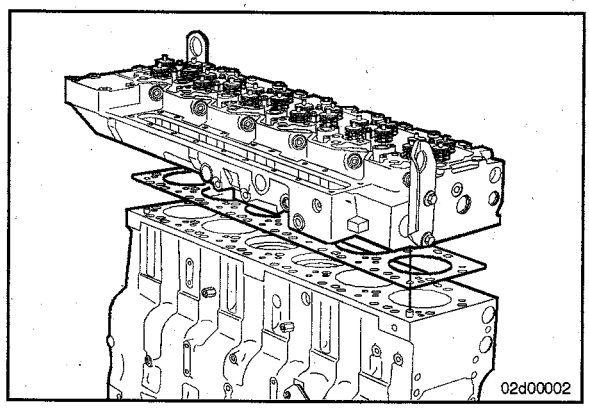
Fill the engine with coolant. Refer to Procedure 008-018.

Operate the engine and check for leaks.

Cylinder Head Gasket (002-021)

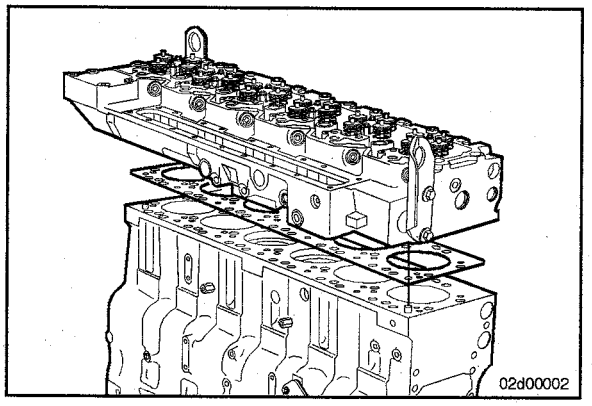
Preparatory Steps

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



Remove

Remove the cylinder head gasket.



Install

NOTE: A new gasket **must** be installed. Do **not** reuse an old gasket.

Install a new cylinder head gasket.

Finishing Steps

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

Section 3 - Rocker Levers - Group 03

Section Contents

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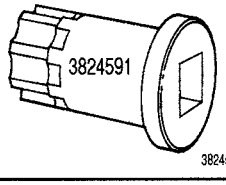
Service Tools

Rocker Levers

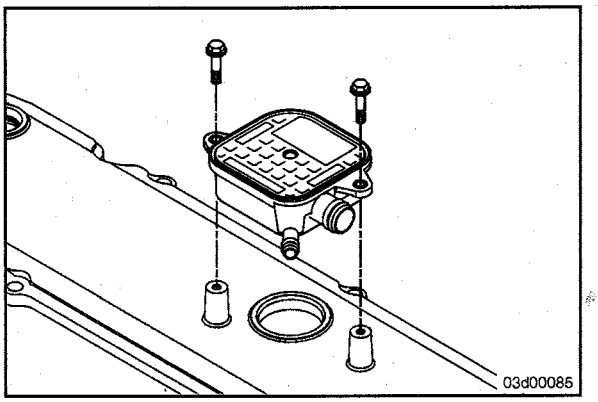
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3824591	**Engine Barring Gear** Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591

Crankcase Breather (External) (003-001)

Preparatory Steps

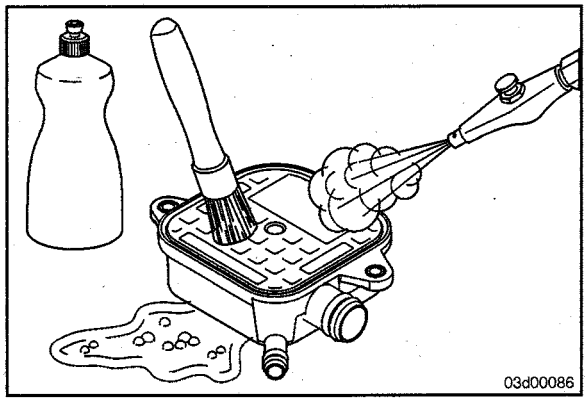
Remove the crankcase breather tube and drain tube. Refer to Procedure 003-018.



Remove

Remove the two mounting capscrews.

Remove the breather from the rocker lever cover by pulling straight up on the breather assembly.



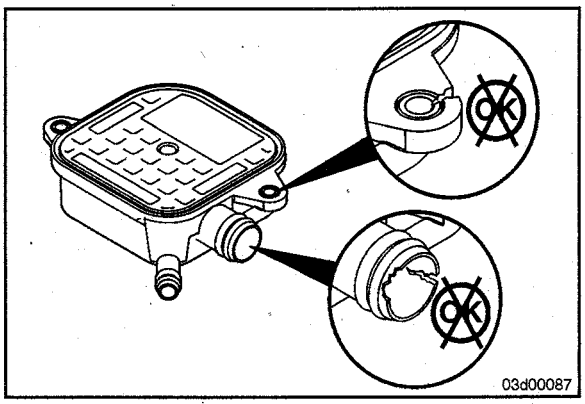
Clean and Inspect for Reuse

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use hot soapy water and a soft brush to clean the crankcase breather.

Dry with compressed air.



Inspect the breather for cracks or other damage.

Install

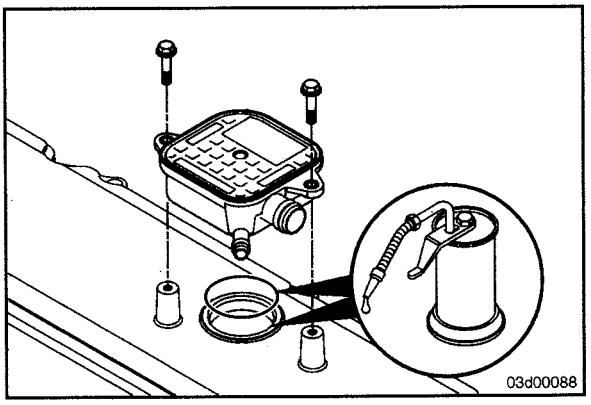
Place a new o-ring on the breather.

Lubricate the o-ring and the valve cover with lubricating oil.

Install the breather into the rocker lever cover.

Tighten the capscrews.

Torque Value: 7 N•m [62 in-lb]



Finishing Steps

Install the crankcase breather tube and drain tube. Refer to Procedure 003-018.

Crankcase Breather (Internal) (003-002)

Preparatory Steps

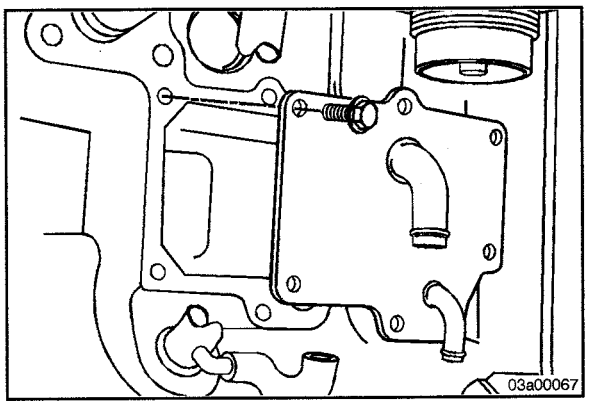
Remove the oil filter. Refer to Procedure 007-013.

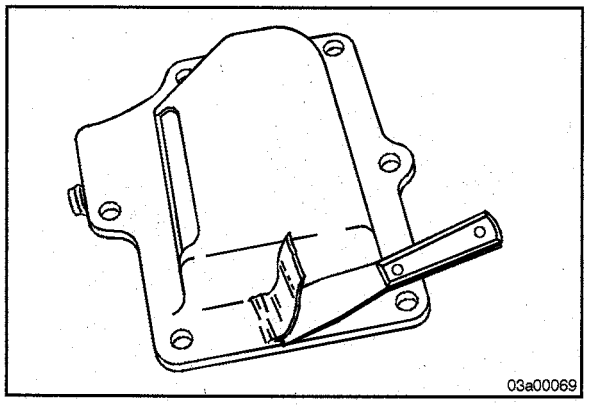
Disconnect the breather tube from the breather.

Disconnect the drain tube from the breather and the turbocharger drain tube.

Remove

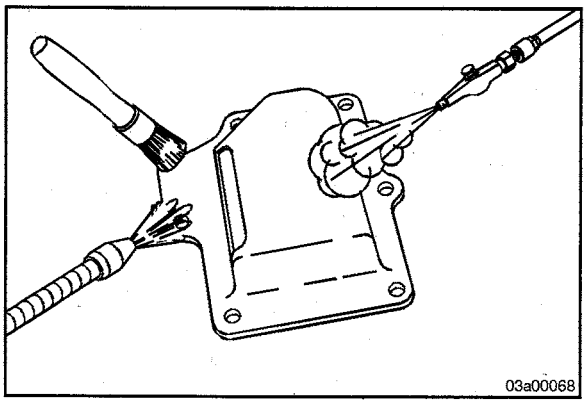
Remove the breather.





Clean and Inspect for Reuse

Remove any gasket material from the breather and breather mounting surface on the block.



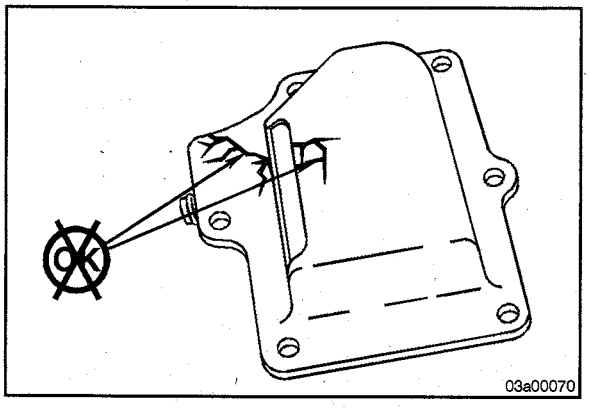
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use a solvent to clean the crankcase breather.

Dry with compressed air.



Inspect the breather for cracks or other damage.

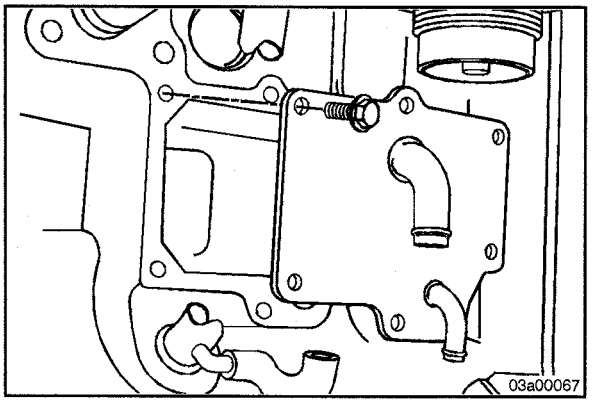
Install

Place a new breather gasket on the breather.

Install the breather into the block.

Tighten the capscrews in a crisscross pattern.

Torque Value: 10 N•m [89 in-lb]



Finishing Steps

Connect the breather drain tube to the breather and the turbo oil drain tube.

Connect the breather tube to the breather.

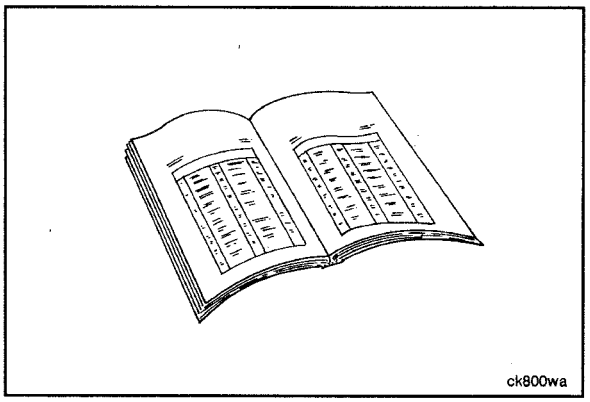
Install the oil filter. Refer to Procedure 007-013.

Overhead Set (003-004)

Preparatory Steps

Remove the following:

- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018.
- Plastic fuel pump drive cover located on the front of the engine.
- Rocker lever cover and gasket. Refer to Procedure 003-011.
- Engine brake assembly, if equipped. Refer to Procedure 020-004.

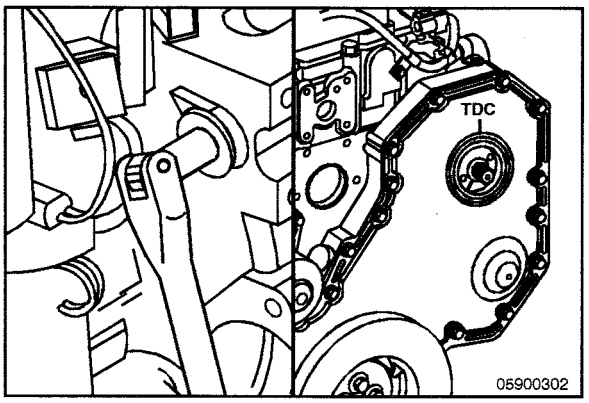


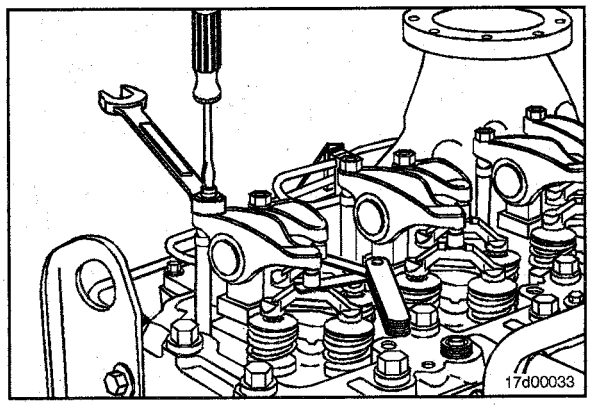
Adjust

⚠CAUTION⚠

Engine coolant temperature should be less than 60°C [140°F].

Using the barring tool, Part Number 3824591, rotate the crankshaft to align the top dead center marks on the gear cover and the fuel pump gear.

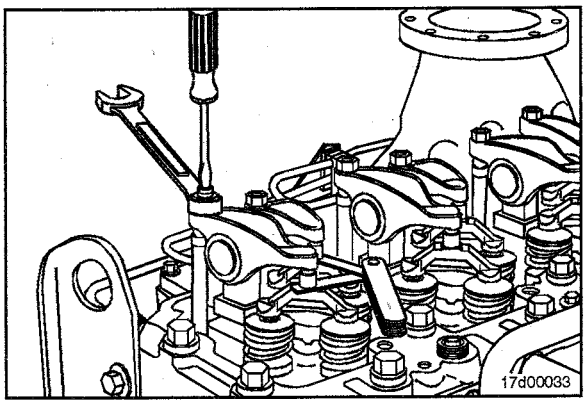




With the engine in this position, lash can be checked on the following rocker arms: 1I, 1E, 2I, 3E, 4I, and 5E.

Lash Check Limits			
	mm		in
Intake	0.152	MIN	0.006
	0.559	MAX	0.022
Exhaust	0.381	MIN	0.015
	0.813	MAX	0.032

NOTE: Lash checks are performed as part of a troubleshooting procedure, and resetting is **not** required during checks as long as the lash measurements are within the above limits.



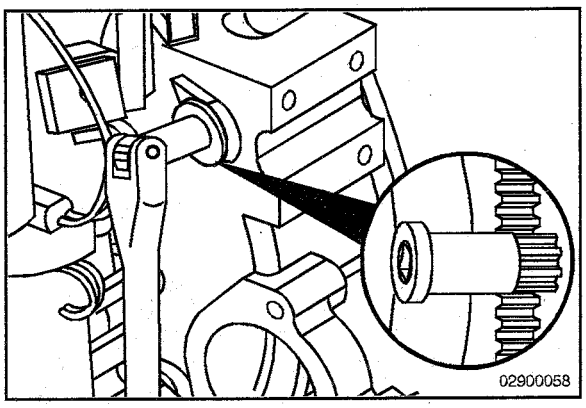
Measure lash by inserting a feeler gauge between the crosshead and the rocker lever ball insert and socket while lifting up on the end of the rocker arm. If the lash measurement is out of specifications, loosen the locknut and adjust the lash to nominal specifications.

Lash Reset Specifications			
	mm		in
Intake	0.305	NOM	0.012
Exhaust	0.559	NOM	0.022

NOTE: Lash resets are **only** required at the interval specified in the Operation and Maintenance Manual, ISC and ISL Engines, Bulletin 4021428, when lash is measured and found out of specification, or when engine repairs cause removal of the rocker arms and/or loosening of the adjusting screws.

Tighten the locknut and measure again.

Torque Value: 24 N•m [18 ft-lb]



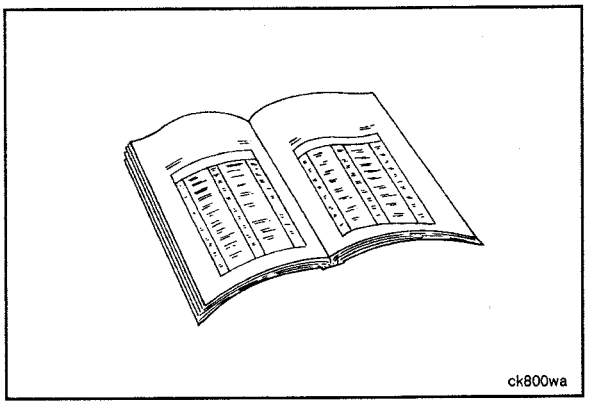
Using the barring tool, Part Number 3824591, rotate the crankshaft 360 degrees and measure lash for rocker arms 2E, 3I, 4E, 5I, 6I, and 6E. Reset the lash if out of specification.

Finishing Steps

Install the following:

- Engine brake assembly, if equipped. Refer to Procedure 020-004.
- Gasket and rocker lever cover. Refer to Procedure 003-011.
- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018.
- Plastic fuel pump drive cover located on the front of the engine.

Operate the engine and check for leaks.

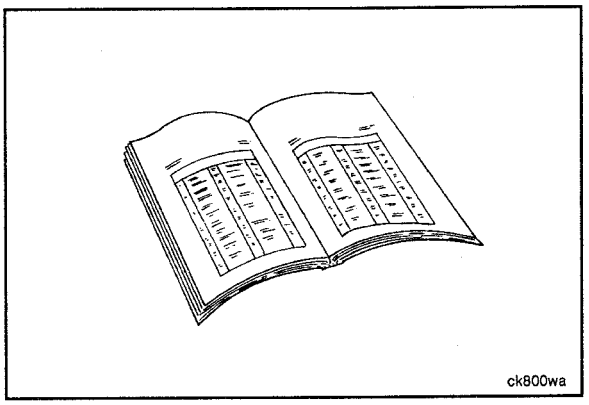


Rocker Lever (003-008)

Preparatory Steps

Remove the following:

- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018.
- Rocker lever cover and gasket. Refer to Procedure 003-011.
- Engine brake assembly, if equipped. Refer to Procedure 020-004.

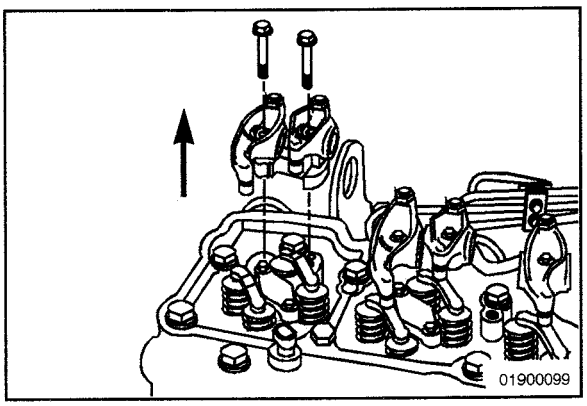


Remove

Remove the capscrews from the rocker lever pedestals.

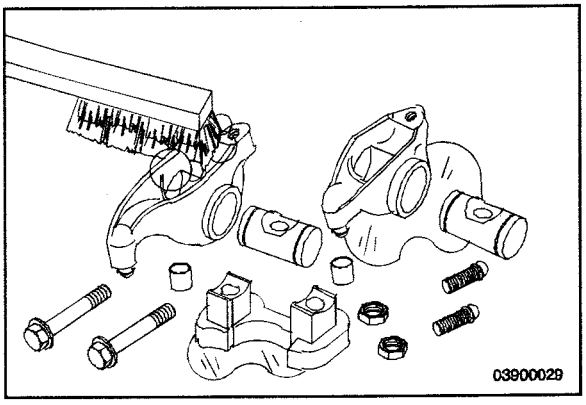
Remove and mark the pedestals and rocker lever assemblies one at a time as to their location and position.

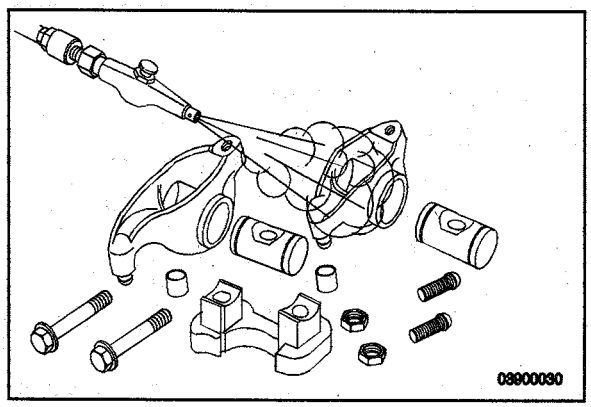
Remove and mark the crossheads one at a time as to their location and position. The crossheads and rocker assemblies **must** be installed in their original location and position.



Clean and Inspect for Reuse

Clean all parts in a strong solution of laundry detergent in hot water.





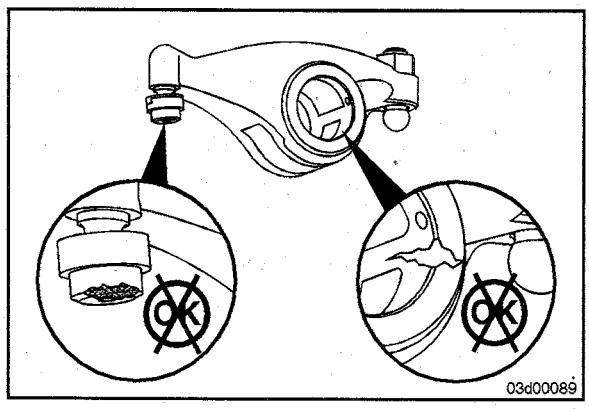
⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use compressed air to dry the parts after rinsing in clean hot water.

The pedestals are made from powdered metal and will continue to show wetness after they have been cleaned and dried.

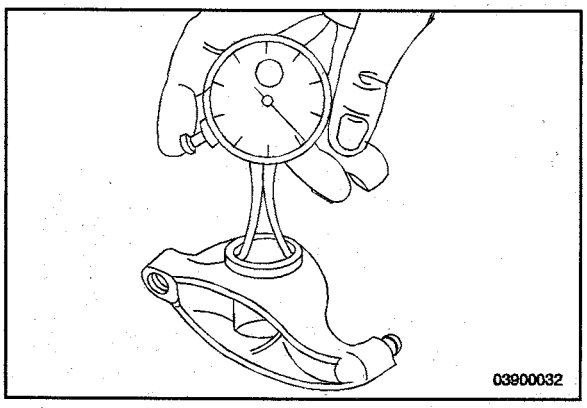
Be sure that oil drillings in the rocker arms and shafts are unobstructed.



Inspect for cracks and excessive wear in the bore.

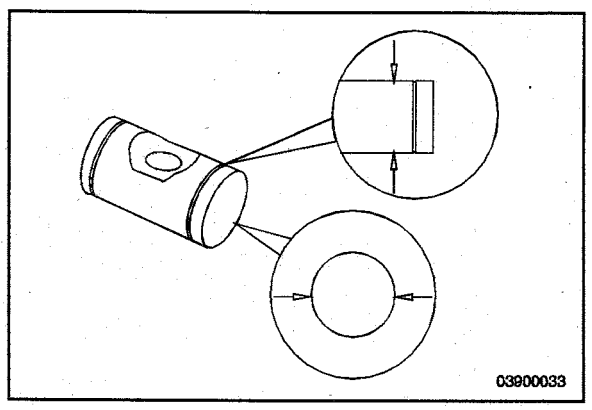
The socket should move freely on the rocker lever and the plastic socket retainer should be in place and **not** cracked.

Inspect for wear on the nose of the socket.



Measure the rocker lever bore.

Rocker Lever Bore		
mm		in
22.027	MIN	0.867



Inspect the rocker lever pedestal and rocker lever shaft.

Measure the rocker lever shaft diameter.

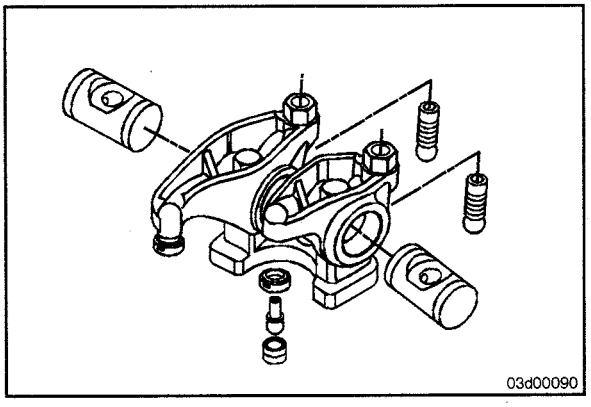
Rocker Lever Shaft		
mm		in
21.965	MIN	0.865

Install

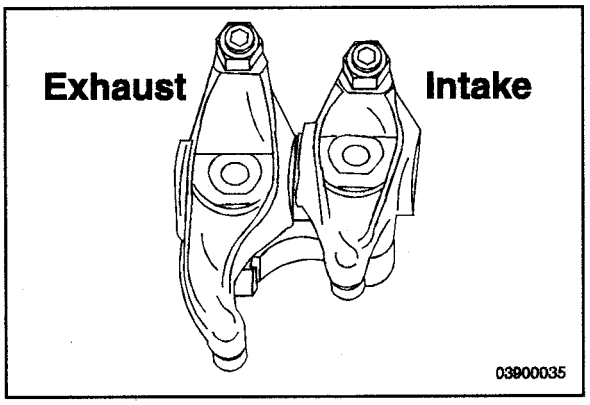
Without Engine Brakes

Different combinations of the adjusting screw, rocker lever shaft, rocker lever, and push rod can exist. Make sure when replacing rocker levers or adjusting screws that the correct part is being used.

Refer to Procedure 004-014 for the correct rocker lever, pushrod, and adjusting screw combinations.



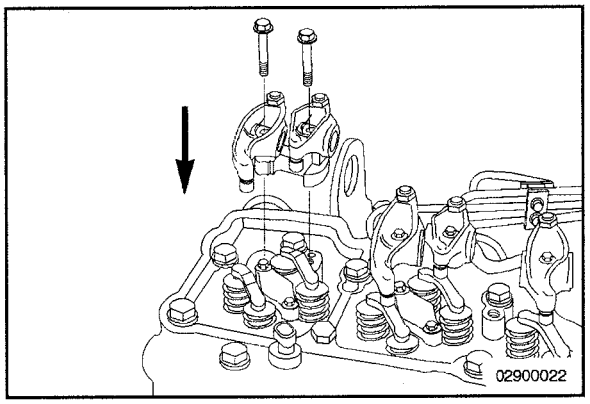
Position the rocker levers on the rocker pedestal.



Install the intake crossheads in their original location and position.

Install the exhaust crossheads in their original location and position.

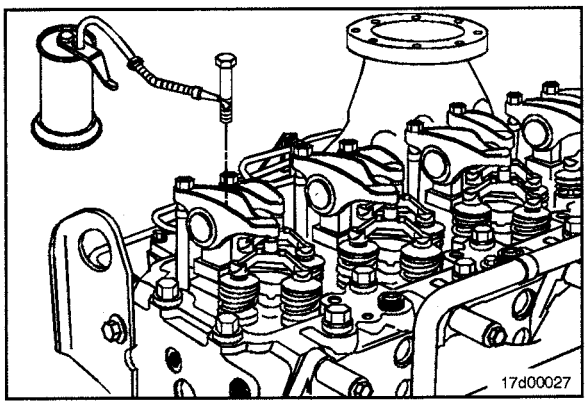
Install the rocker lever assemblies and pedestals in their original locations.

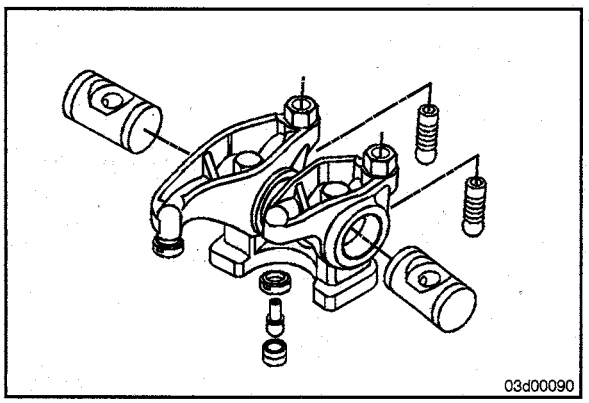


Lubricate the capscrew threads with clean engine oil.

Install and tighten the pedestal capscrews.

Torque Value: 65 N•m [48 ft-lb]

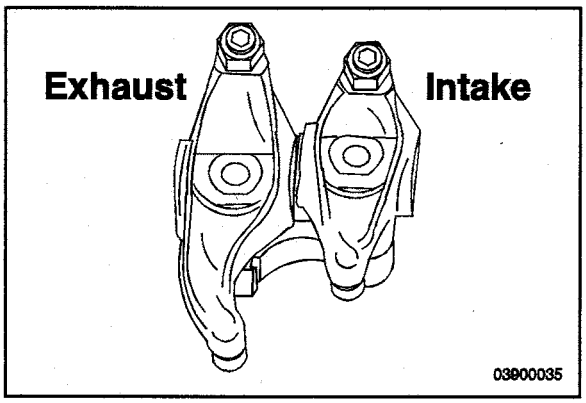




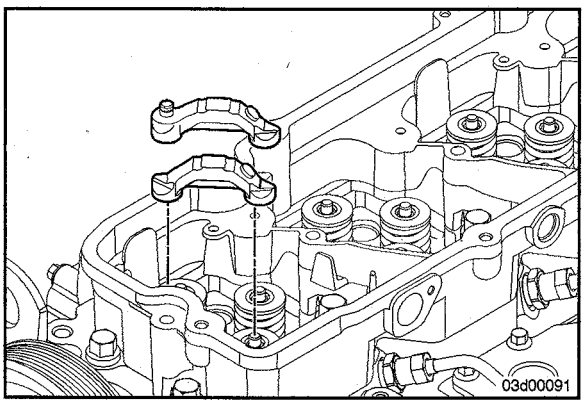
With Engine Brakes

Different combinations of the adjusting screw, rocker lever shaft, rocker lever, and push rod can exist. Make sure when replacing rocker levers or adjusting screws that the correct part is being used.

Refer to Procedure 004-014 for the correct rocker lever, pushrod, and adjusting screw combinations.

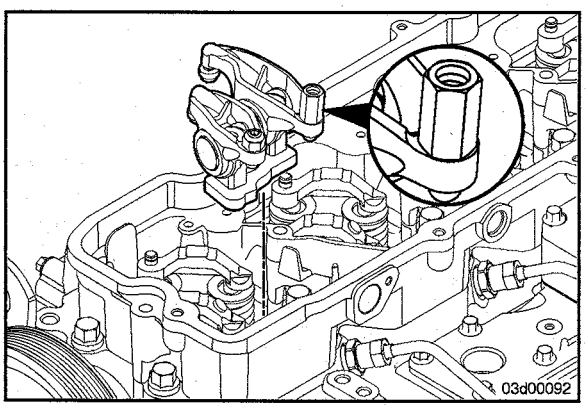


Position the rocker levers on the rocker pedestal.



Install the crossheads in their original location and position.

Install the engine brake compatible exhaust crossheads with the pin facing the exhaust manifold.



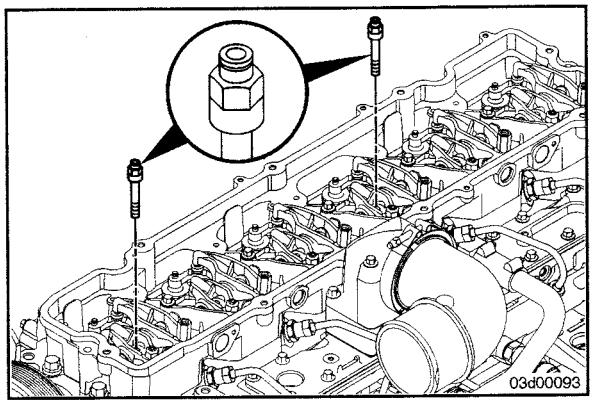
Install the rocker lever assemblies and pedestals in their original location.

Make sure the exhaust rocker levers have the longer adjusting screw locknut installed.

Lubricate the capscrew threads with clean engine oil.

Install the engine brake oil supply capscrews on intake rocker levers 1 and 4.

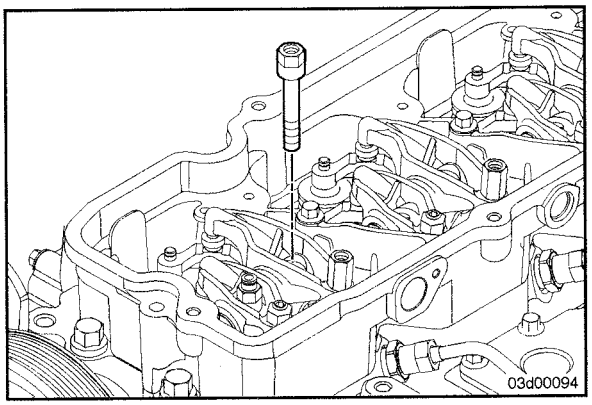
Torque Value: 65 N•m [48 ft-lb]



Lubricate the capscrew threads with clean engine oil.

Install the exhaust rocker lever capscrews into all exhaust levers.

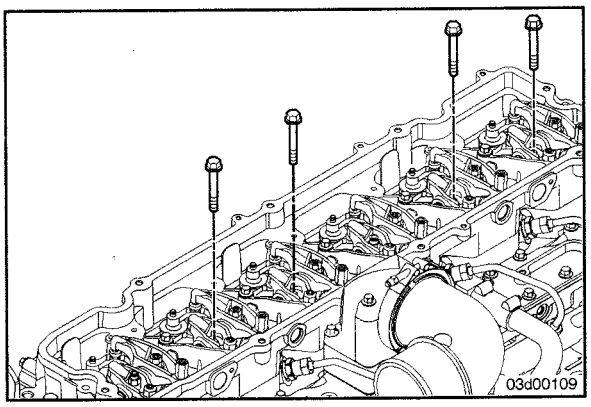
Torque Value: 65 N•m [48 ft-lb]



Lubricate the capscrew threads with clean engine oil.

Install the pedestal capscrews in cylinders 2, 3, 5, and 6 intake rocker pedestals.

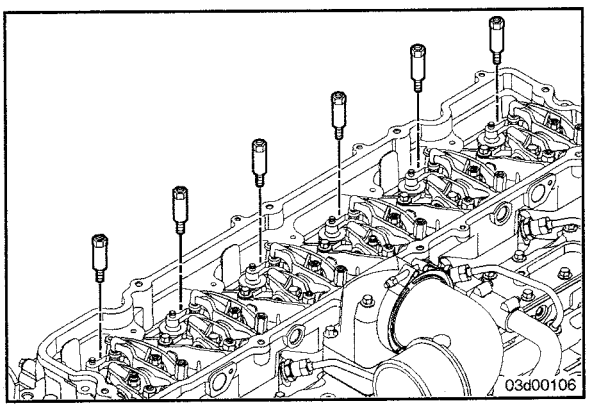
Torque Value: 65 N•m [48 ft-lb]

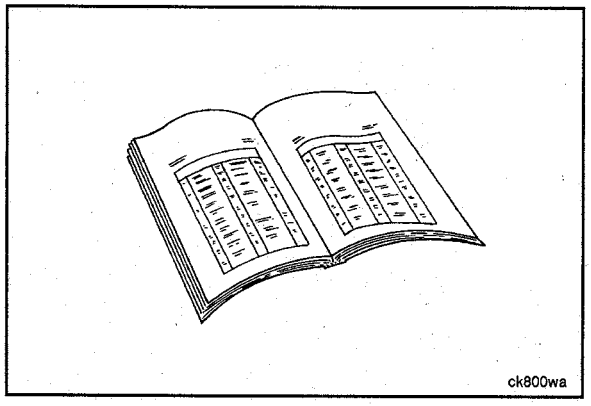


Lubricate the capscrew threads with clean engine oil.

Install the six threaded spacers into the cylinder head.

Torque Value: 24 N•m [18 ft-lb]





Finishing Steps

Adjust the overhead. Refer to Procedure 003-004.

Install the following:

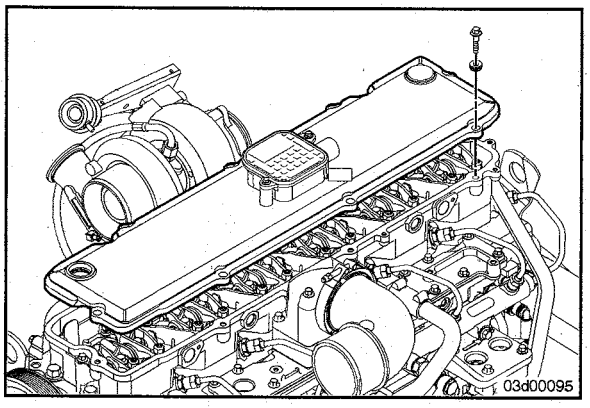
- Engine brake assemblies, if equipped. Refer to Procedure 020-004.
- Rocker lever cover and gasket. Refer to Procedure 003-011.
- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018.

Rocker Lever Cover (003-011)

Preparatory Steps

Remove the crankcase breather tube, rocker lever cover mounted breather **only**. Refer to Procedure 003-018.

Remove the variable geometry turbocharger actuator air supply line, if equipped. Refer to Procedure 010-118.

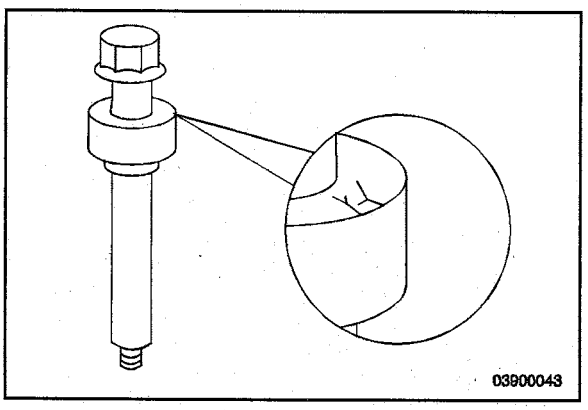


Remove

Remove the capscrews.

Remove the rocker lever cover and gasket.

NOTE: Rocker lever cover configurations will be different based upon if the cover is center bolted or perimeter bolted. The rocker lever cover can also be taller if the engine is equipped with engine brakes.



Clean and Inspect for Reuse

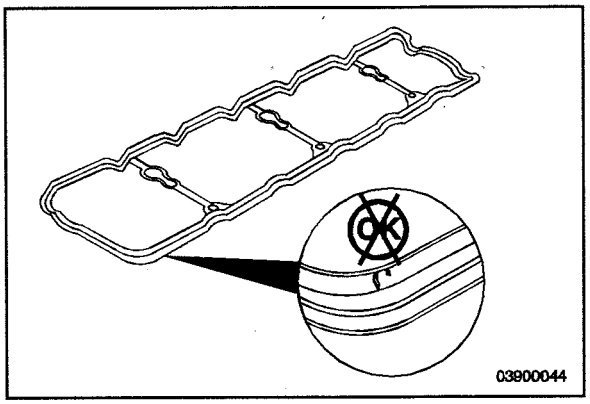
Center Bolted Rocker Lever Cover

Check the isolators for cracks, tears, or brittleness.

Replace the capscrew assembly if isolators are damaged.

Check the gasket for cracks in the silicone covering.

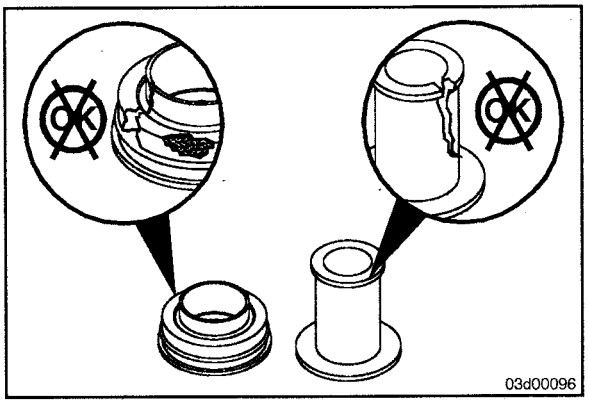
Replace the gasket if cracks are present.



Perimeter Bolted Rocker Lever Cover

Check the isolators for cracks, tears, or brittleness.

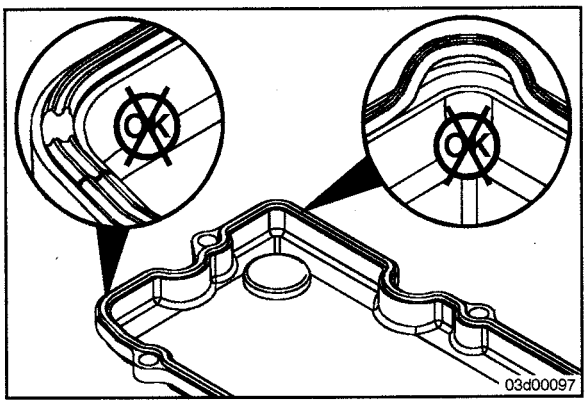
Replace the isolators if any damage is found.



Check the gasket for cracks on the sealing surface.

Replace the gasket if damage is present.

Replace the gasket if it is removed from the groove in the rocker lever cover.

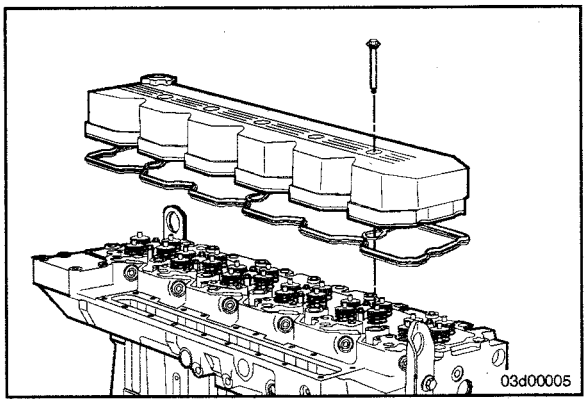


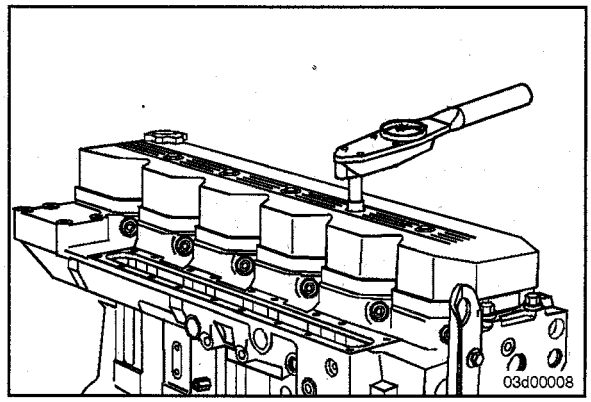
Install

Center Bolted Rocker Lever Cover

Place the gasket on the cylinder head. Be sure the gasket is properly aligned around the cylinder head capscrews.

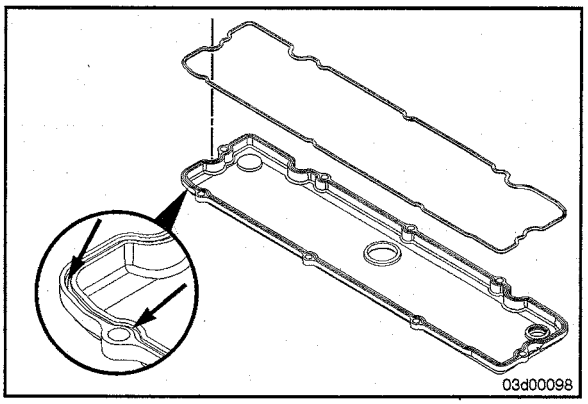
Install the rocker lever cover and capscrews.





Tighten the capscrews.

Torque Value: 12 N•m [106 in-lb]

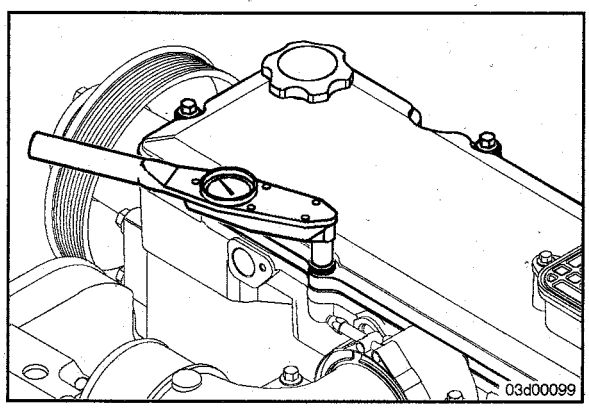


Perimeter Bolted Rocker Lever Cover

NOTE: If the gasket has been removed from the rocker lever cover, a new gasket **must** be used.

The following installation procedure **must** be used when installing the press-in gasket.

1. . Press the molded gasket into the corners of the rocker lever cover.
2. . Press the gasket around the capscrew mounting holes.
3. . Press the remaining gasket into the rocker lever cover.



Install the rocker lever cover and capscrews.

Torque Value: 12 N•m [106 in-lb]

Finishing Steps

Install the crankcase breather tube, rocker lever cover mounted breather **only**. Refer to Procedure 003-018.

Install the variable geometry turbocharger actuator air supply line, if equipped. Refer to Procedure 010-118.

Rocker Lever Housing (003-013)

Preparatory Steps

NOTE: This procedure is for engines with a perimeter bolted rocker lever cover. Refer to Procedure 020-007 for engines with a center bolted rocker lever cover.

Remove the crankcase breather tube. Refer to Procedure 003-018.

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

Disconnect the injector harness pass-through connectors.

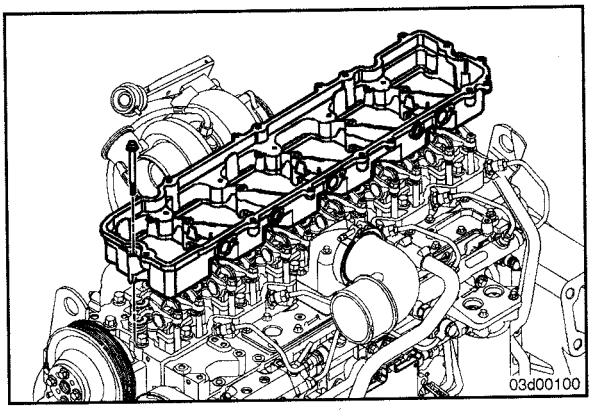
Remove the engine brake assembly, if equipped. Refer to Procedure 020-004.

Disconnect the injector wiring harness from the injector. Refer to Procedure 006-026.

Remove

Remove the rocker lever housing mounting capscrews.

Remove the rocker lever housing and gasket from the cylinder head.



Clean and Inspect for Reuse

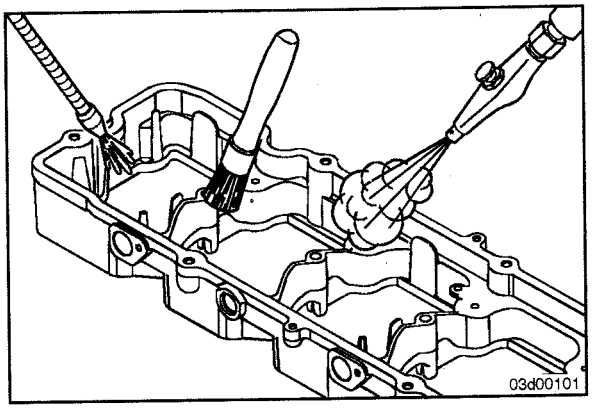
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

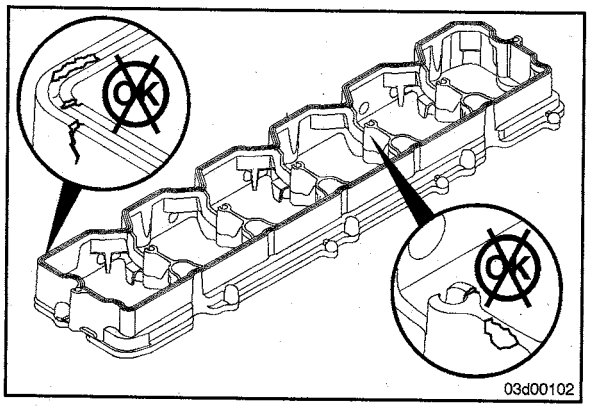
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the rocker lever housing with solvent.

Dry with compressed air.

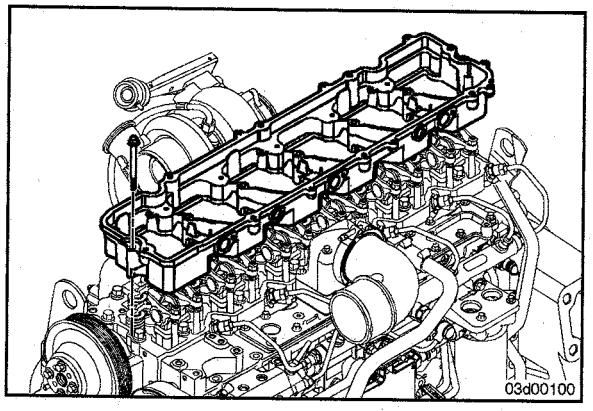




Inspect the rocker housing for cracks or any other damage, especially on the cylinder head mounting surface.

Inspect the bridge area in the center of the rocker housing for cracks.

Replace the rocker lever housing gasket.



Install

NOTE: A new rocker housing gasket **must** be used when the rocker housing is removed. Do **not** reuse the old gasket.

Install the rocker housing and a new rocker housing gasket. Start by pressing the molded gasket into the corners of the rocker lever housing then press the remaining gasket into the housing.

Start with the center bolt and work outward.

Torque Value: 24 N•m [212 in-lb]

Finishing Steps

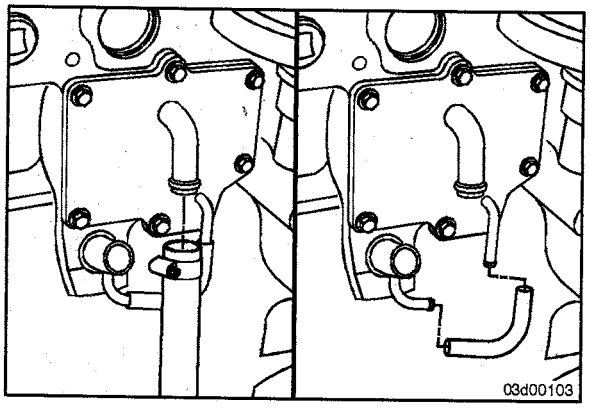
Connect the injector wiring harness to the injector. Refer to Procedure 006-026.

Connect the injector harness pass-through connectors.

Install the engine brake assembly, if equipped. Refer to Procedure 020-004.

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

Install the crankcase breather tube. Refer to Procedure 003-018.



Crankcase Breather Tube (003-018)

Remove

Block Mounted Crankcase Breather

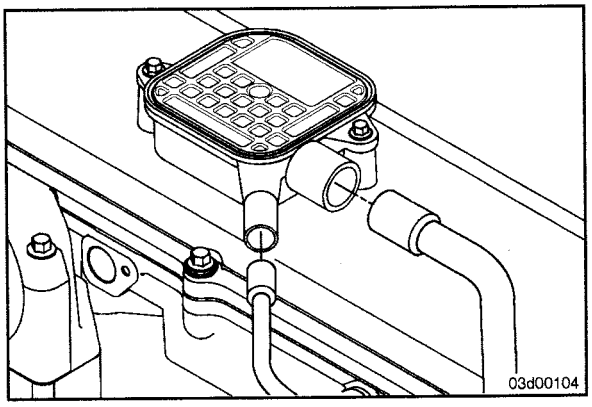
Remove the crankcase breather tube from the crankcase breather assembly.

Remove the crankcase drain tube form the crankcase breather assembly.

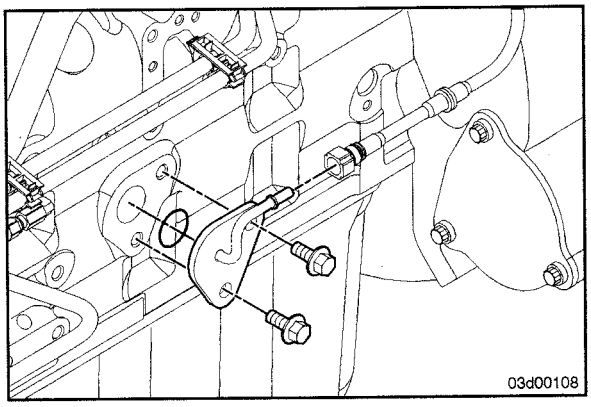
Rocker Lever Cover Mounted Crankcase Breather

Remove the crankcase breather tube from the crankcase breather assembly.

Remove the crankcase drain line from the crankcase breather assembly.



Remove the breather drain line, breather drain line cover and gasket from the cylinder block.



Clean and Inspect for Reuse

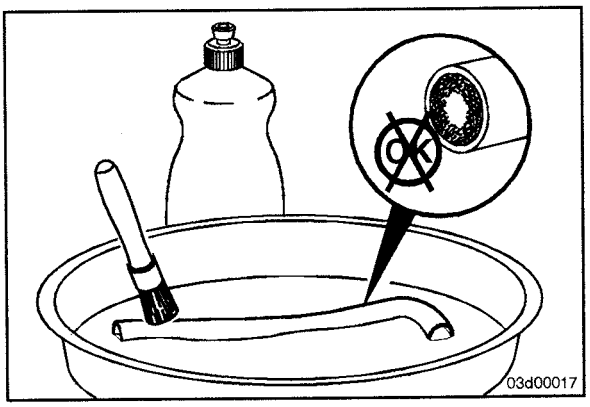
⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

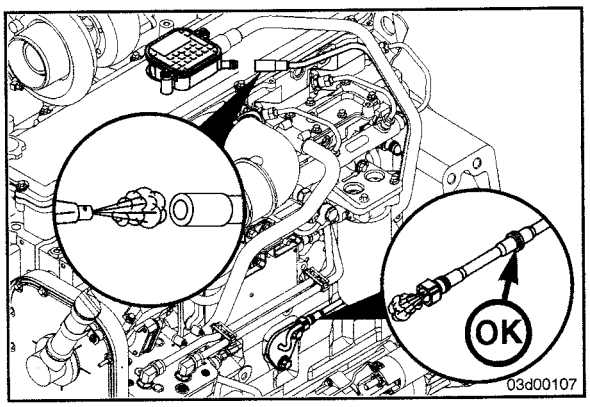
Check internally for obstructions or sludge buildup.

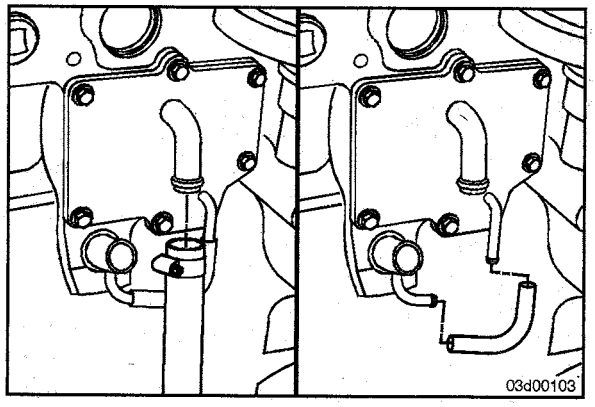
Clean with hot, soapy water and a soft brush.

Use compressed air to dry after rinsing in clean water.



Inspect the breather drain line check valve for correct operation. A small amount of air can be blown through the line (less than 34 kPa [5 psi]) to check the check valve operation.



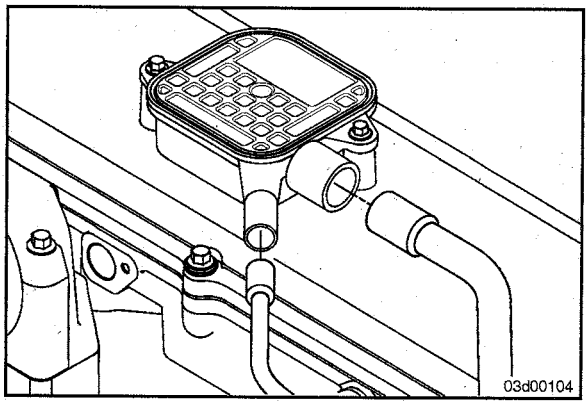


Install

Block Mounted Crankcase Breather

Install the crankcase breather tube to the crankcase breather assembly.

Install the crankcase drain line to the crankcase breather assembly.

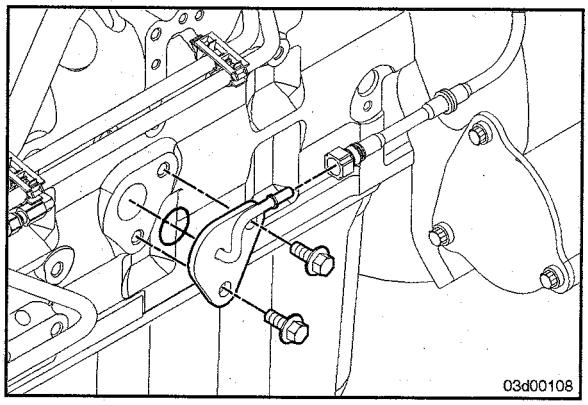


Rocker Lever Cover Mounted Crankcase Breather

NOTE: Make sure the crankcase breather tube or drain line does **not** contact any high pressure fuel lines.

Install the crankcase breather tube to the crankcase breather assembly.

Install the crankcase drain line to the crankcase breather assembly.



Install the breather drain line cover, gasket and tube to the cylinder block.

Torque Value: 45 N•m [33 ft-lb]

Section 4 - Cam Followers/Tappets - Group 04

Section Contents

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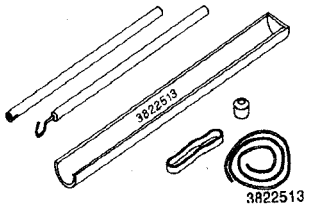
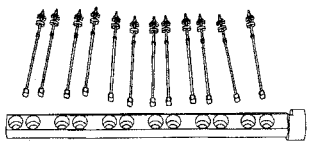
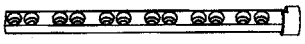
Service Tools

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.

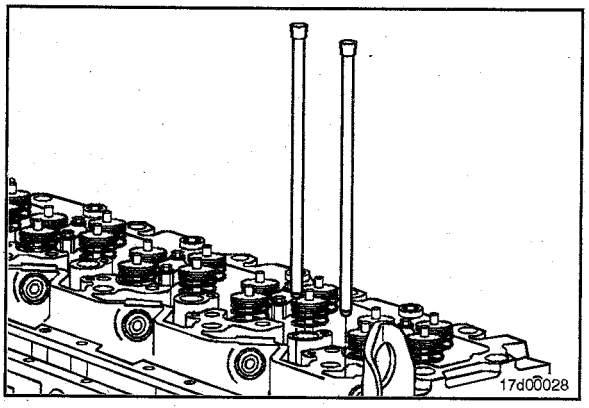
Tool No.	Tool Description	Tool Illustration
3822513	**Tappet Removal Tool Kit** Used to remove and install sliding valve tappets.	
3165088	**Tappet Removal Tool Kit** Used to remove and install tappets for all ISC and ISL engines equipped with roller tappets..	
3165086	**Tappet Removal Tool** Tappet trough for engines using the larger bore tappets. Used to update Tappet Removal Tool Kit, Part Number 3163468.	

Push Rods or Tubes (004-014)

Preparatory Steps

Remove the following:

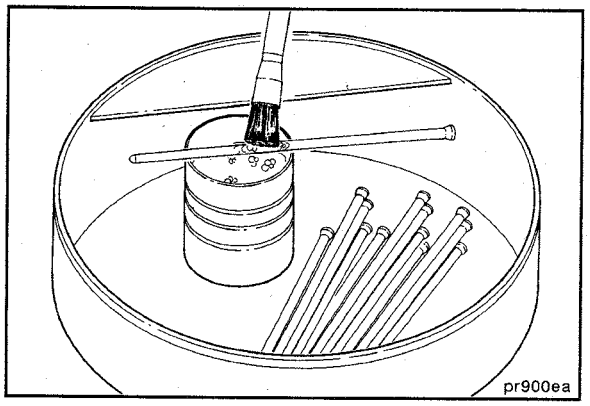
- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018.
- Rocker lever cover. Refer to Procedure 003-011.
- Engine brake assembly, if equipped. Refer to Procedure 020-004.
- Rocker levers. Refer to Procedure 003-008.



Remove

Mark the push tubes to identify their location.

Remove the push tubes.



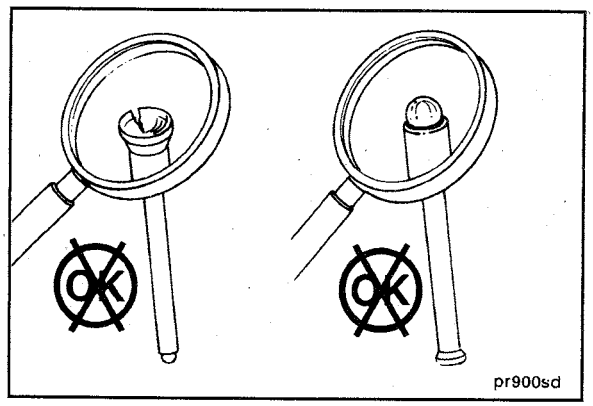
Clean and Inspect for Reuse

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

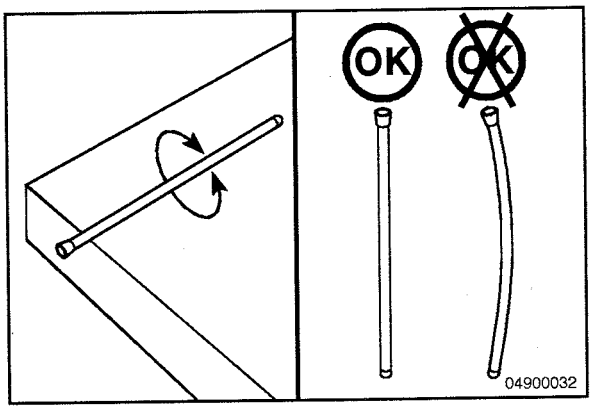
Clean the push tubes in hot soapy water.

Dry with compressed air.



Inspect the push tube ball and socket for signs of scoring. Check for cracks where the ball and the socket are welded into the tube.

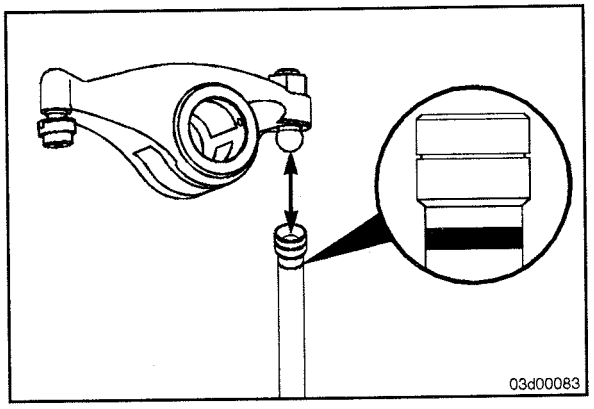
Check the push tubes for straightness.



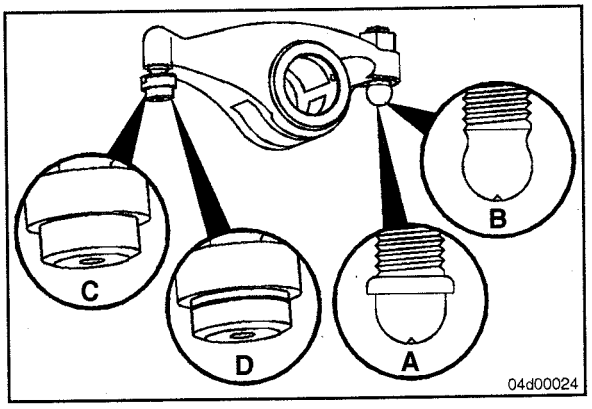
Install

⚠CAUTION⚠

Mismatching push tubes, rocker levers and rocker lever adjusting screws can lead to engine damage. These components are matched depending on the engine configuration. If components are being replaced, make sure the correct part numbers are being installed.



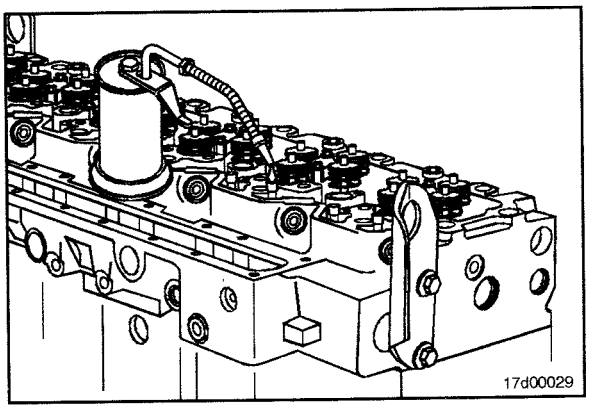
Different adjusting screws are used depending on the engine configuration. Older designs used a collar feature (A) between the adjusting screw threads and the ball. Newer designs (B) have eliminated the collar feature. These components are matched depending on the engine configuration. If components are being replaced, make sure the correct part numbers are being installed.



Install push tubes in their original location.

Install the push tubes into the sockets of the valve tappets.

Lubricate the push tube sockets with clean 15W-40 engine oil.



Finishing Steps

Install the following:

- Crossheads and rocker levers. Refer to Procedure 003-008.
- Adjust the valve lash. Refer to Procedure 003-004.
- Engine brake assembly, if equipped. Refer to Procedure 020-004.
- Rocker lever cover and associated gasket. Refer to Procedure 003-011.
- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018.

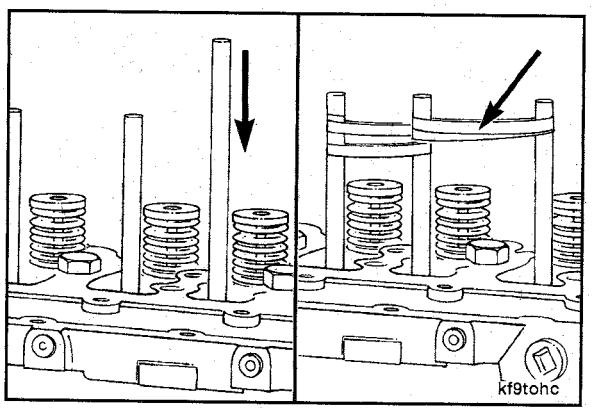
Operate the engine and check for leaks.

Tappet (004-015)

Preparatory Steps

Remove the following:

- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018.
- Rocker lever cover. Refer to Procedure 003-011.
- Engine brake assembly, if equipped. Refer to Procedure 020-004.
- Rocker levers. Refer to Procedure 003-008.
- Push tubes. Refer to Procedure 004-014.
- Vibration damper. Refer to Procedure 001-050.
- Gear cover. Refer to Procedure 001-031.



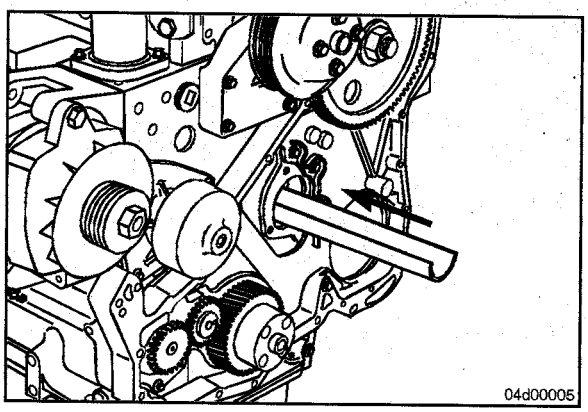
Remove

Sliding Tappets

Use tappet removal tool kit, Part Number 3822513, to remove the tappets.

Push a wooden dowel rod into each tappet. It will probably be necessary to push the dowel into the tappet with a soft-face hammer.

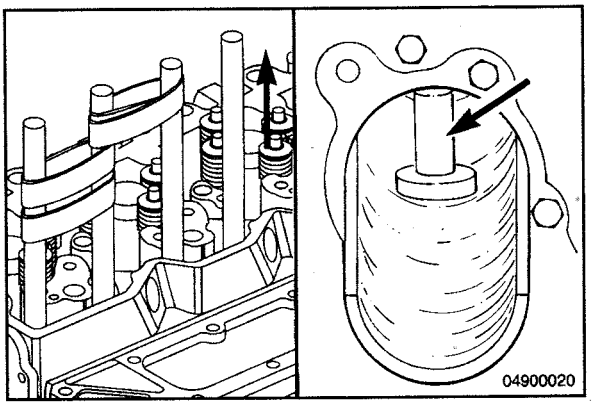
Pull each valve tappet up until it makes contact with the cylinder block. Put a rubber band around two dowels. This will hold the tappets up off the camshaft.



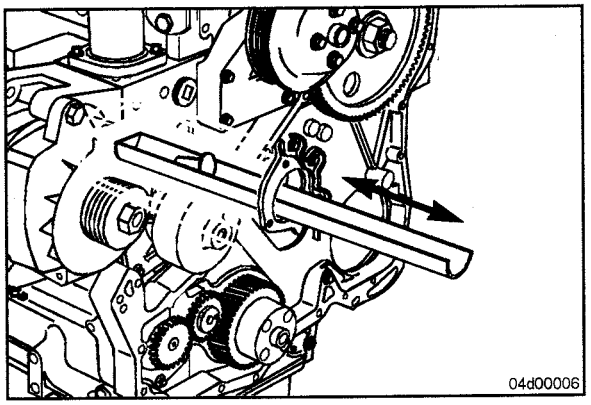
Remove the camshaft. Refer to Procedure 001-008.

Insert the trough to the full length of the cam bore.

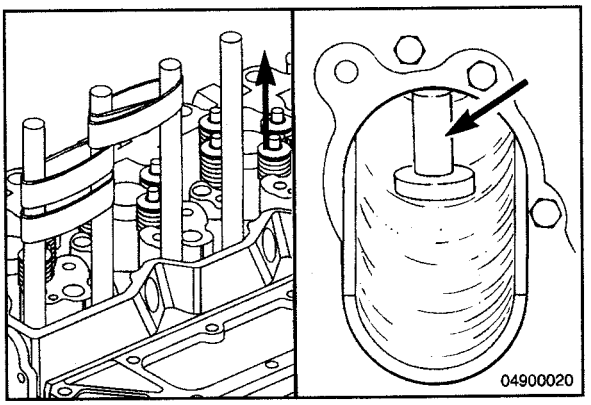
Make sure the trough is positioned so it will catch the tappet when the wooden dowel is removed.



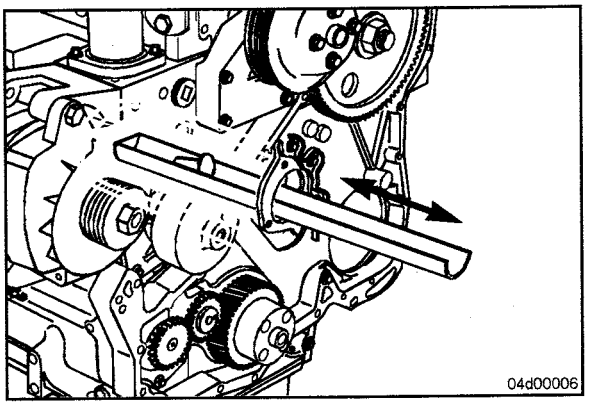
Only remove one (1) tappet at time. Remove the rubber band from the two (2) companion tappets, securing the tappet **not** to be removed with the rubber band.

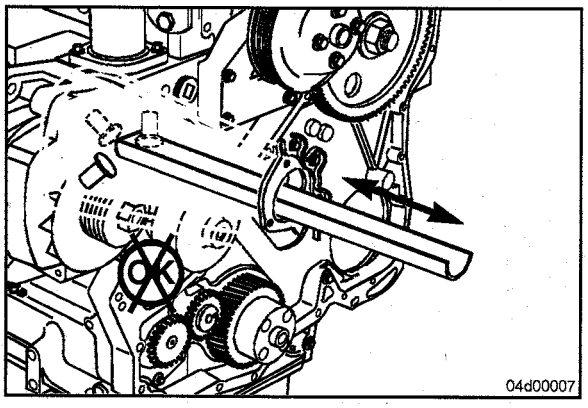


Pull the wooden dowel from the tappet bore allowing the tappet to fall into the trough.

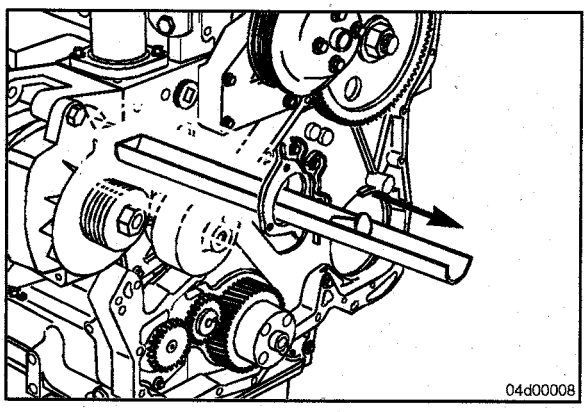


When the tappet is dropped into the trough, most of the time it will fall over. However, if it doesn't, gently shake the trough just enough to allow the tappet to fall over before removing.



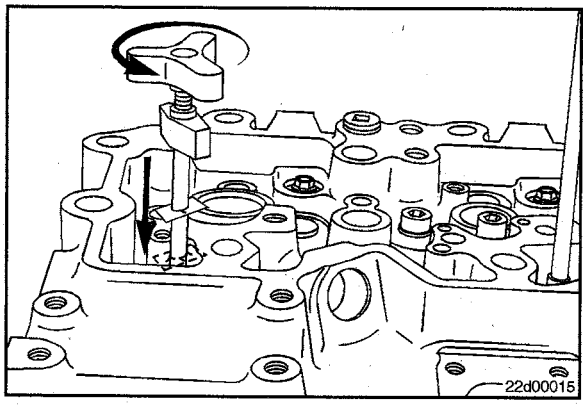


NOTE: When removing the Number 6 cylinder tappets, special care **must** be taken **not** to knock or shake the tappet over the end of the trough.



Carefully pull the trough and tappet from the cam bore and remove the tappet. Repeat the process until all tappets are removed.

Mark each tappet to indicate its location if the tappets are to be reused.



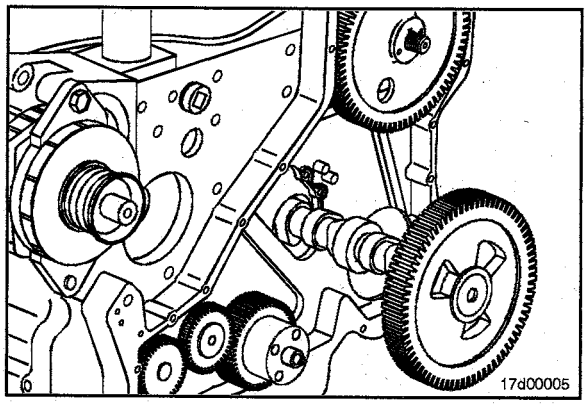
Roller Tappets

Use tappet removal tool kit, Part Number 3165088, to remove the tappets.

Insert the tappet extractor tool (2) into the tappet bore. Turn the top knob **counterclockwise** while holding the bottom knob to expand and secure the tool into the tappet.

Raise the tappet extractor (2) until it stops, and push the metal tab down against the head surface to secure the tool and captured tappet in the up position.

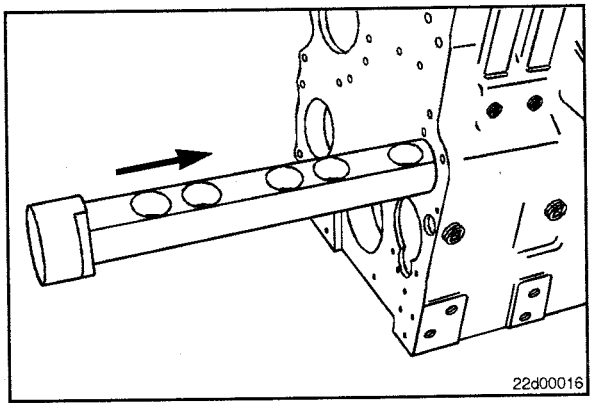
Repeat for the remaining tappets.



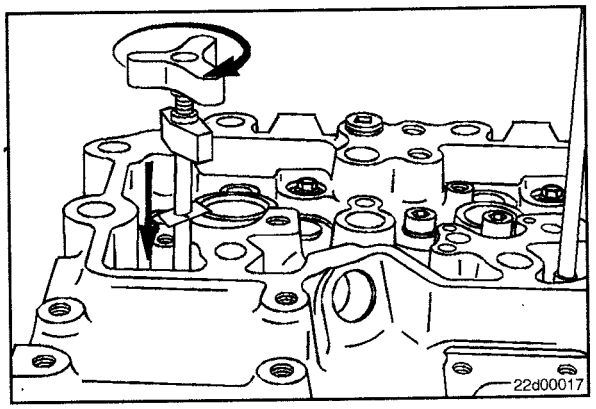
Remove the camshaft. Refer to Procedure 001-008.

NOTE: Make sure the holes are in the up position.

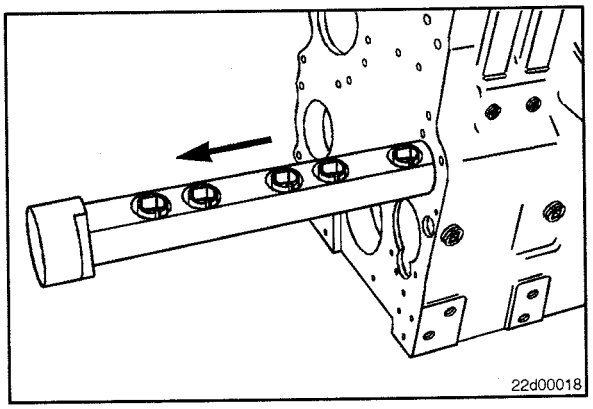
Insert the tappet holder to the full length of the cam bore.



Lower the tappet extractor, and seat the tappet into the tappet holder. Turn the top knob **clockwise** while holding the bottom knob to disengage the extractor from the tappet. Repeat the step for the remaining tappets.



Carefully pull the tappet holder and tappets from the cam bore. If the tappets will be reused, be sure to note their position. Do **not** reinstall a tappet in a different position.



Clean and Inspect for Reuse

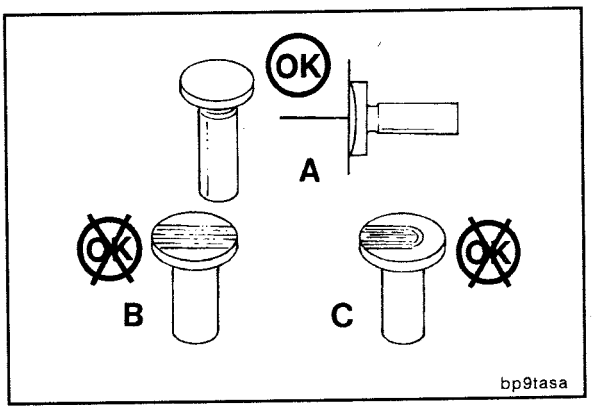
Sliding Tappets

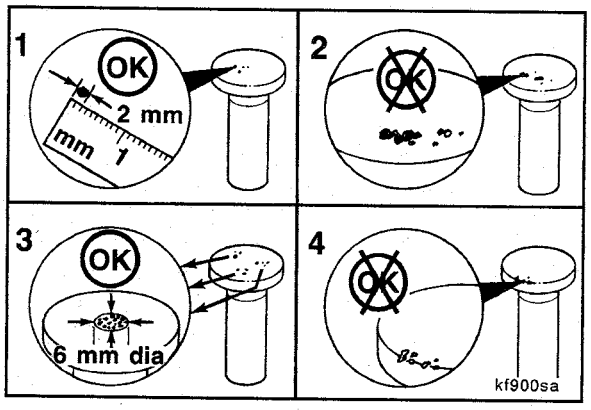
Inspect the socket, stem and face for excessive wear, cracks and other damage.

Visual Limits

(A) - Normal Contact (exaggerated)

(B) and (C) - Irregular Contact: Do **not** reuse.

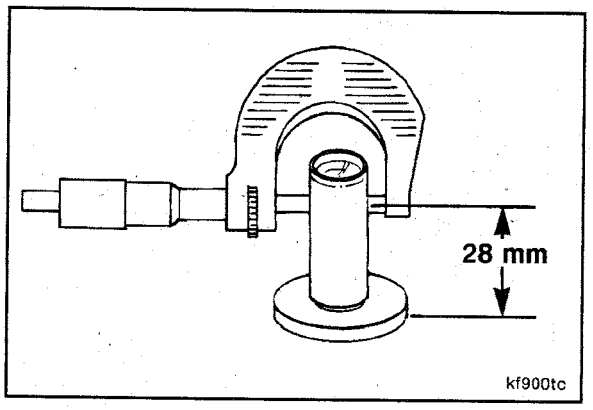




Pit marks on the tappet face are acceptable.

The following criteria defines the size of the pits allowed.

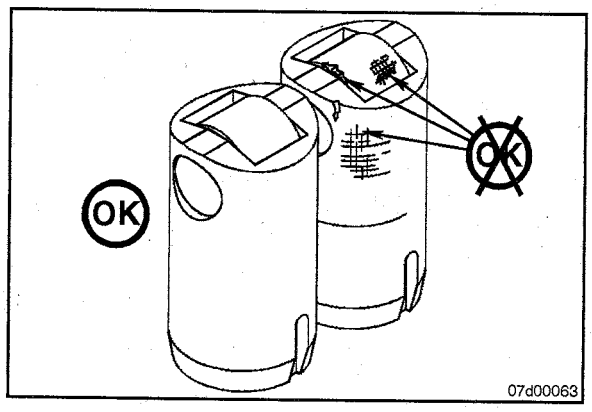
1. . A single pit **cannot** be greater than 2 mm [0.078 in].
2. . Interconnection of pits is **not** allowed.
3. . Total pits when added together **must not** exceed 6 mm [0.236 in] diameter or a total of 4 percent of the tappet face.
4. . No pitting is allowed on the edges of the wear face of the tappet.



Measure the valve tappet stem.

Valve Tappet Stem Diameter

mm		in
15.936	MIN	0.627
15.977	MAX	0.629

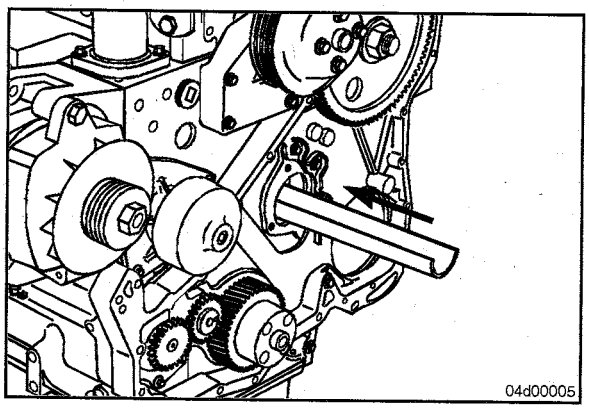


Roller Tappets

Inspect the tappet body for cracks or other damage.

Inspect the roller for flat spots or pitting. Refer to Camshaft Reuse Guidelines, Bulletin No. 3666052. If excessive wear is found, replace the tappet, and inspect the camshaft.

The roller **must** rotate freely. If it does **not**, replace the tappet.



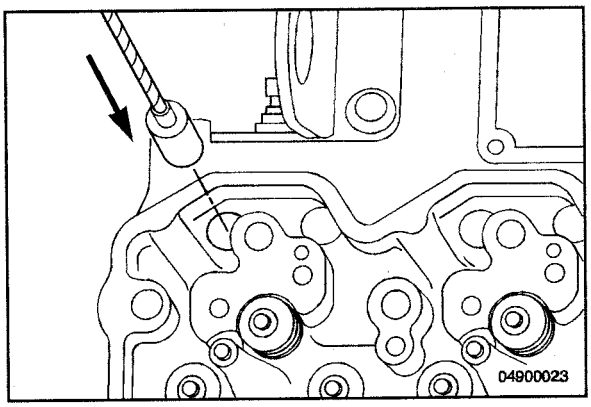
Install

Sliding Tappets

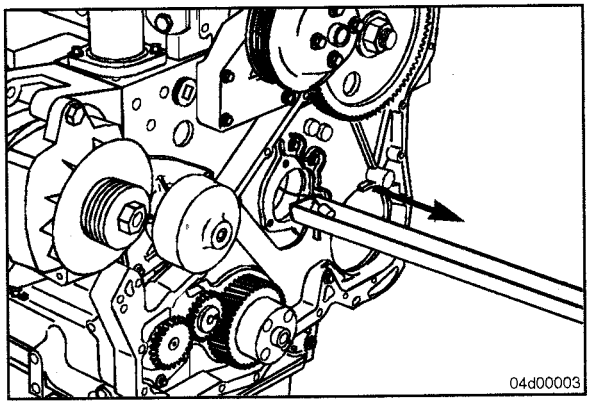
Insert the trough the full length of the cam bore.

NOTE: Do **not** use worn tappets with a new camshaft.

Lower the tappet installation tool down the push tube hole, through the tappet bore, and into the trough.



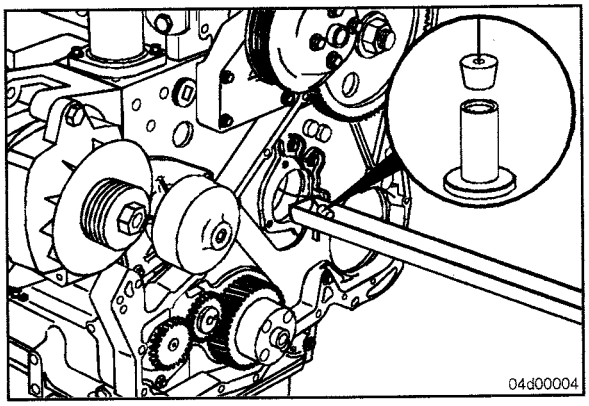
Feed the installation tool through the cam bores by carefully pulling the plastic trough or installation tool out the front. The barrier at the rear of the trough will pull the tool out most of the time.

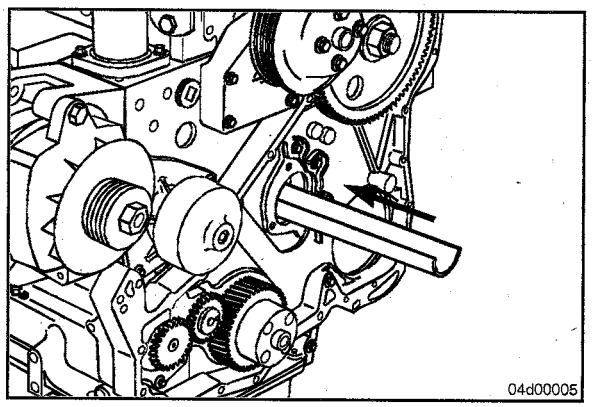


Lubricate the tappets with Lubriplate™ 105, Part Number 3163087, or equivalent.

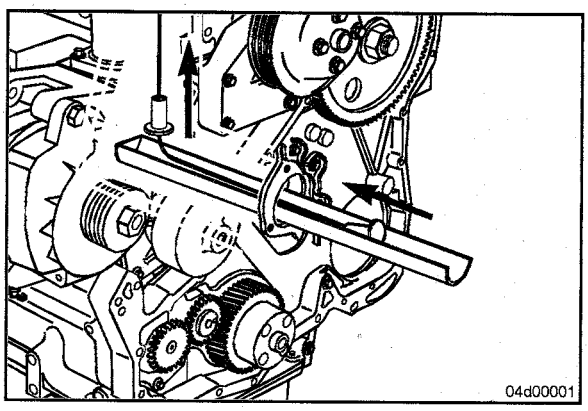
Insert the installation tool into the tappet.

NOTE: To aid in removing the installation tool after the tappet is installed, work the tool in and out of the tappet several times before installing the tappets.

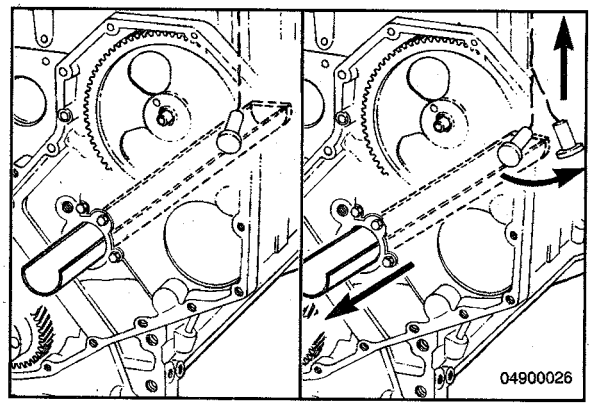




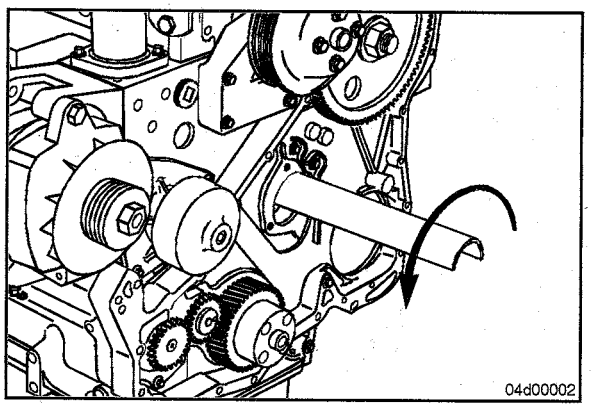
Slide the trough into the cam bore.



Pull the tool and tappet through the cam bore and up into the tappet bore.

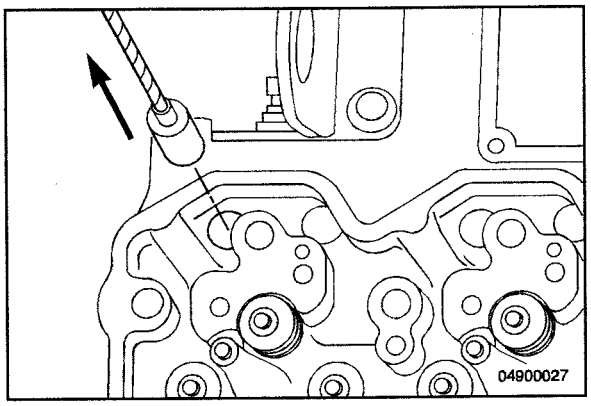


If difficulty is experienced in getting the tappet to make the bend from the trough up to the tappet bore, pull the trough out enough to allow the tappet to drop down and align itself, then pull the tappet up into the bore.



After the tappet has been pulled up into position, slide the trough back into the cam bore and rotate it one-half turn. This will position the round side of the trough up, and will hold the tappet in place.

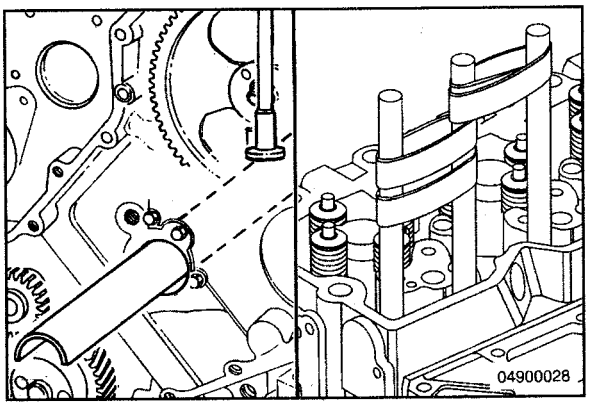
Remove the installation tool from the tappet.



Install a wooden dowel into the top of the tappet. Wrap rubber bands around the wooden dowels to secure the tappets.

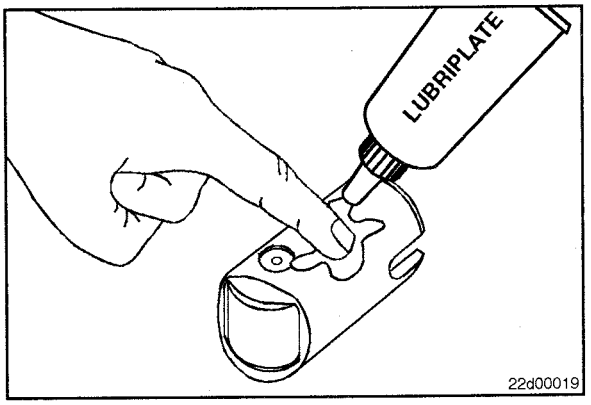
Repeat this process until all tappets have been installed.

Install the camshaft. Refer to Procedure 001-008.



Roller Tappets

Lubricate the tappets with Lubriplate™ 105, Part Number 3163087, or equivalent.

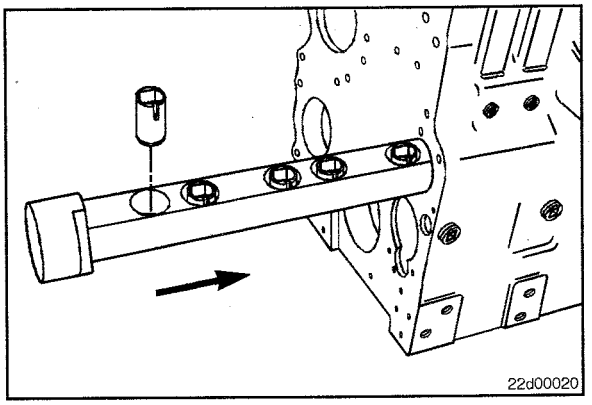


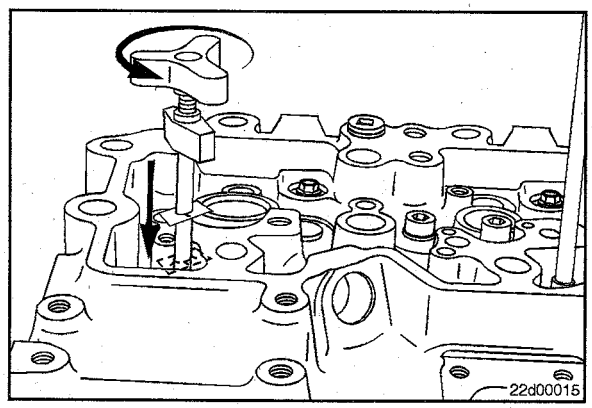
NOTE: Make sure the tappets are installed with the pin slots toward the outside of the block.

Insert the tappets into the tappet holder.

NOTE: If the tappets are being reused, be sure to reinstall them in their original position.

Insert the tappet holder the full length of the cam bore.



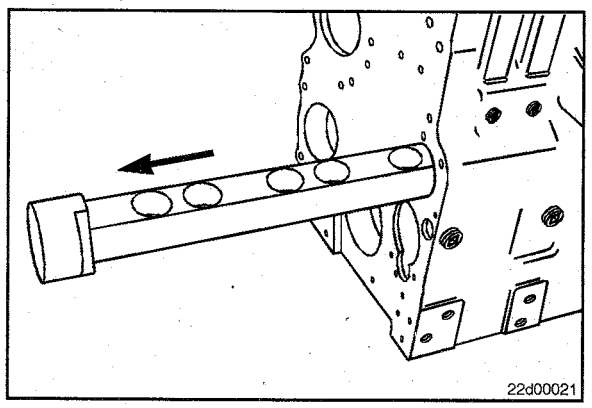


Insert the tappet extractor tool (2) into the tappet bore. Turn the top **counterclockwise** to expand and secure the tool into the tappet.

Raise the tappet extractor (2) until it stops, and push the metal tab down against the head surface to secure the tool in the up position.

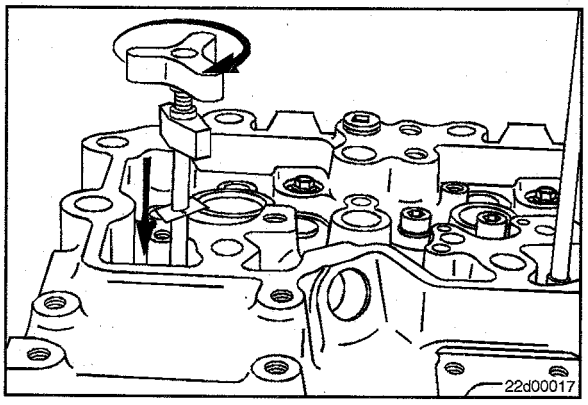
NOTE: Some manipulation may be necessary to get the tappet to enter the bore. When the tappet enters the bore, attempt to rotate the extractor while applying light upward pressure. If the tool will **not** rotate, the tappet has engaged the guide pin. If the tool does rotate, continue until the tappet engages the guide pin.

Repeat for the remaining tappets.



Remove the tappet holder.

Install the camshaft. Refer to Procedure 001-008.



Lower the tappet extractor, and seat the tappet into the camshaft. Turn the top knob **clockwise** while holding the bottom knob to disengage the extractor from the tappet. Repeat the step for the remaining tappets.

Finishing Steps

Install the following:

- Gear cover. Refer to Procedure 001-031.
- Vibration damper. Refer to Procedure 001-050.
- Push tubes. Refer to Procedure 004-014.
- Rocker levers. Refer to Procedure 003-008.
- Adjust the valves. Refer to Procedure 003-004.
- Engine brake assembly, if equipped. Refer to Procedure 020-004.
- Rocker lever cover. Refer to Procedure 003-011.
- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018.

Operate the engine and check for leaks.

Section 5 - Fuel System - Group 05

Section Contents

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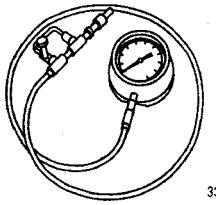
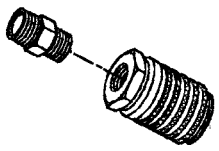
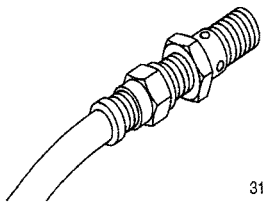
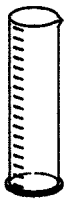
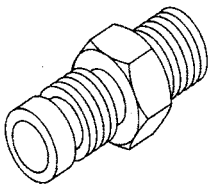
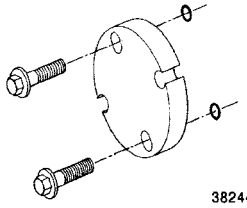
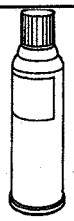
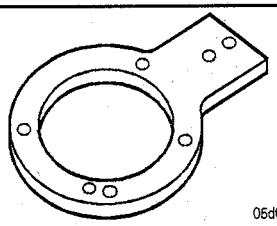
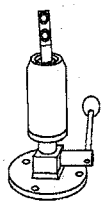
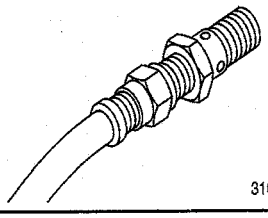
Service Tools

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
3375932	**Pressure Gauge** Used to measure gear pump pressure.	
3164621	**0.043-Inch Diagnostic Fuel Line** Used to create rated fuel flows through the low-pressure fuel system without loading the engine.	
3164614	**M14 Banjo Adapter Fitting (Leakage Flow Adapter)** Used to divert the drain flow (leakage) to an external measurement device. This tool can be installed at the fuel rail pressure relief valve to isolate return flow from this device.	
N/A	**1000 cc Graduated Cylinder** Used to measure high-pressure pump drain flow (leakage).	
3824842	**M10 Compucheck® Fitting** Used when measuring fuel system pressures at the fuel filter head.	
3824469	**Fuel Pump Gear Puller** Gear puller used to pull the fuel pump gear.	

Tool No.	Tool Description	Tool Illustration
3824510	**QD Contact Cleaner** Use this non-petroleum cleaner to clean electrical connections and fuel pump internal parts.	 oi8togt
3162897	**Fuel Pump Mounting Plate** The ring is used to hold the fuel pump in the ball joint vise during service.	 05d00150
ST 302	**Ball Joint Vise** Used with the fuel pump mounting plate for holding the fuel pump during service.	 05d00145
3164618	**12 mm Banjo Adapter Fitting (Leakage Flow Adapter)** Used to isolate drain flow from the fuel drain lines where they connect to the fuel drain manifold. Allows fuel leakage measurement from the fuel pump, injector, or fuel rail pressure relief valve drain lines.	 3164614

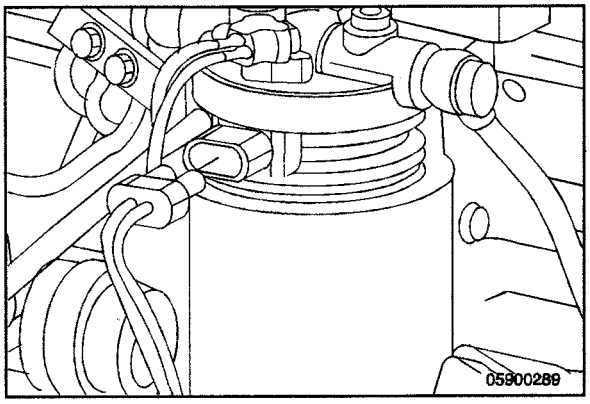
Engine Fuel Heater, Electric (005-008)

Initial Check

The fuel heater is an optional device installed on the fuel filter head. It is held on the filter head by the threaded filter spud.

NOTE: The fuel heater is **not** controlled by the electronic control module (ECM). A bimetallic switch on the filter head acts as a thermostat. The fuel heater will turn on at approximately 1°C [34°F] and turn off at approximately 18°C [65°F].

The switch should register as an open circuit above 18°C [65°F] and register as a closed circuit below 1°C [34°F].

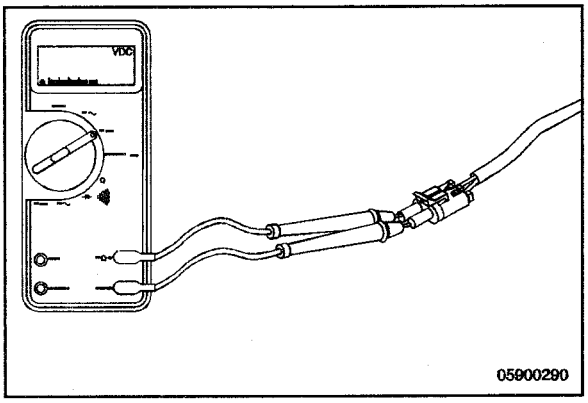


Remove the 2-pin connector from the fuel heater.

Check for proper voltage to the fuel heater.

NOTE: Minimum voltage is 12 VDC with keyswitch ON (separate 24 volt heaters are used on vehicles with 24 volts charging systems).

If the voltage is **not** within specifications, refer to the OEM troubleshooting and repair manual.



Preparatory Steps

⚠WARNING⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

⚠WARNING⚠

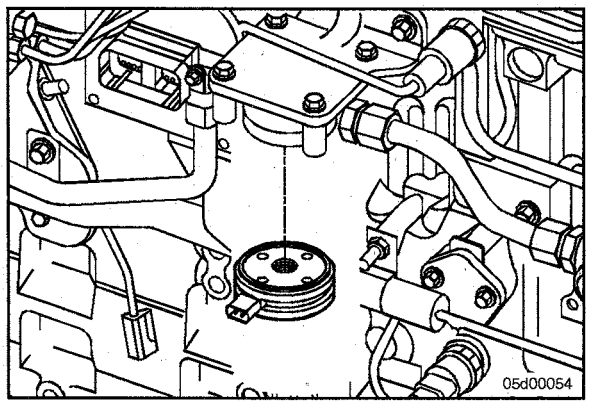
Drain the fuel-water separator into a container, and dispose of contents in accordance with local environmental regulations.

Disconnect the OEM power supply connector from the fuel heater.

Disconnect the engine harness connector from the water-in-fuel sensor.

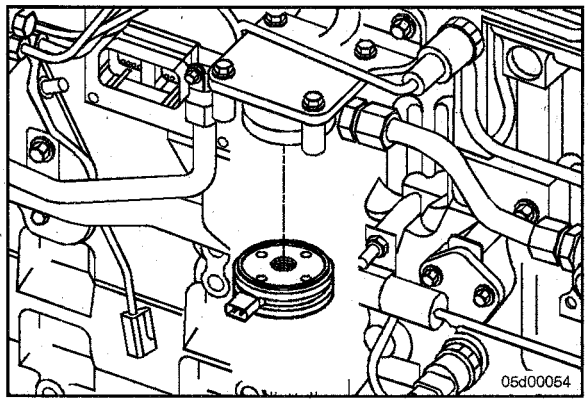
Drain a small quantity of fuel from the filter water drain to reduce fuel spillage during filter removal.

Remove the spin-on fuel filter. Refer to Procedure 006-015.



Remove

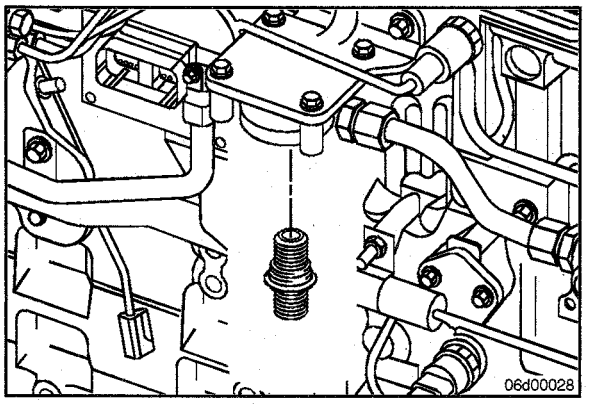
Remove the threaded filter spud and fuel heater.



Install

Install a new gasket onto the fuel heater.

Place the fuel heater, gasket side facing up, against the filter head with the electrical connector facing away from the engine block.



Apply Loctite® 271 (a thread-locker, Cummins Part Number 3375068) to the filter spud threads where they will engage the filter head.

Install the fuel filter spud.

Torque Value: 30 N•m [20 ft-lb]

Finishing Steps

Install the fuel filter. Refer to Procedure 006-015.

Connect the fuel heater.

Connect the water-in-fuel sensor.

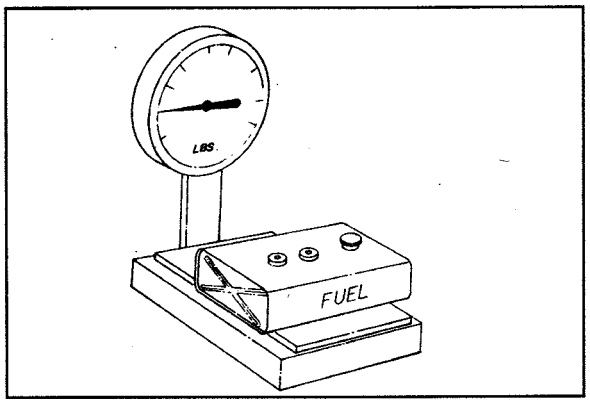
Fuel Consumption (005-010)

Measure

Refer to the fuel consumption checklist sheets in the back of Section TS.

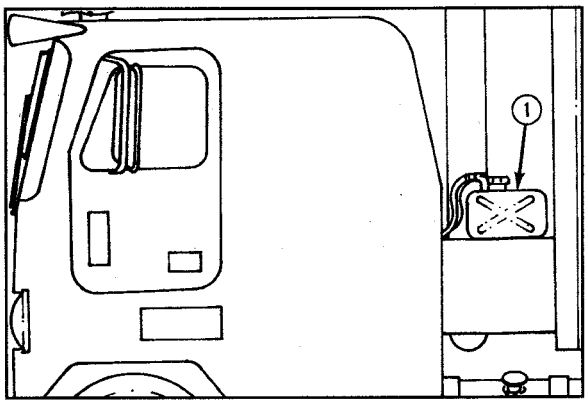
NOTE: The most accurate method to check the fuel consumption is to weigh the fuel used. Use a scale capable of measuring within 0.045 kg [0.1 lb] to weigh the fuel tank. Use a remote mount tank with enough capacity to run 80 km [50 mi].

Fill the fuel tank. Weigh the tank with the fuel. The weight of No. 2 diesel fuel is nominally 0.844 kg per liter [7.03 pounds per gal].

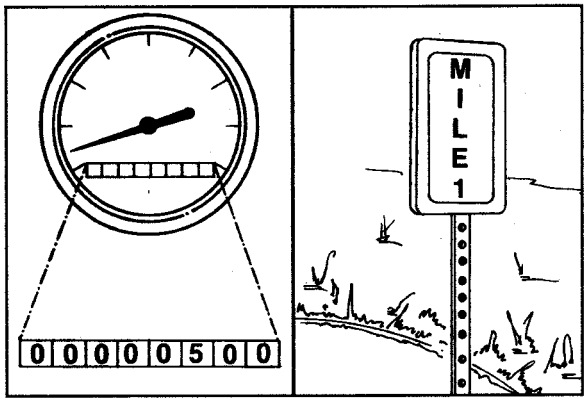


Install the remote tank (1).

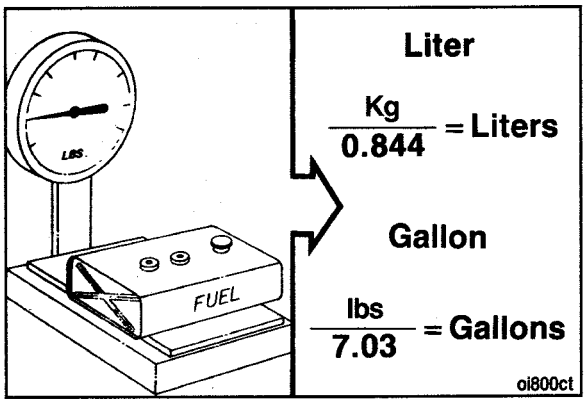
Install the return fuel line to the test tank or the results will **not** be accurate.



Measure the distance traveled with an accurate odometer. The odometer accuracy can be checked by using measured kilometers [miles].



After traveling the route, remove the tanks and weigh the fuel remaining. Compute the fuel used in liters [gal] as required.



Compute the kilometers per liter or miles per gallon:

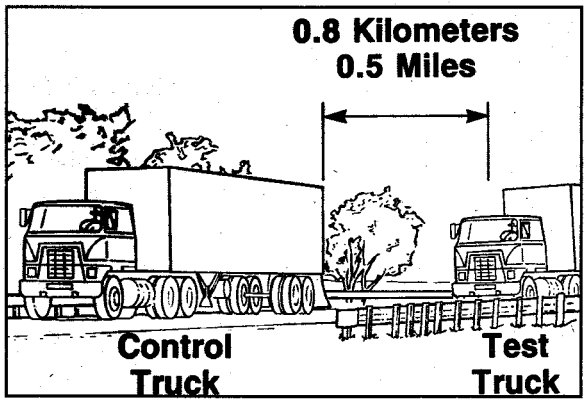
Miles (÷) Gallons (=) MPG
Kilometers (÷) Liters (=) KPL

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.

Type II Fuel Test

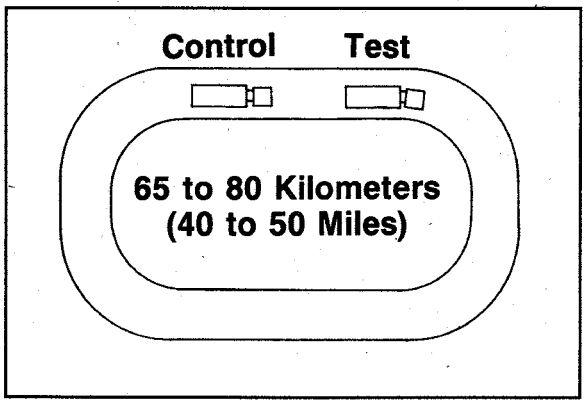
- SAE
- RCCC
- ATA

These procedures are helpful to determine differences in fuel consumption between two vehicles under the same environmental, road, and test conditions.

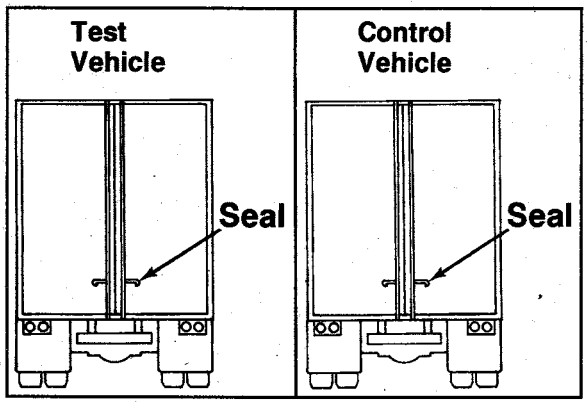


Perform the test with the test vehicle and a control vehicle. The control vehicle compensates for changes in traffic conditions.

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.

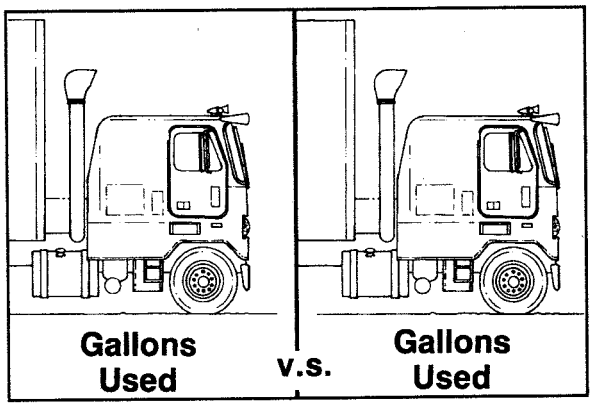


The test course **must** be 65 to 80 km [40 to 50 mi] long.



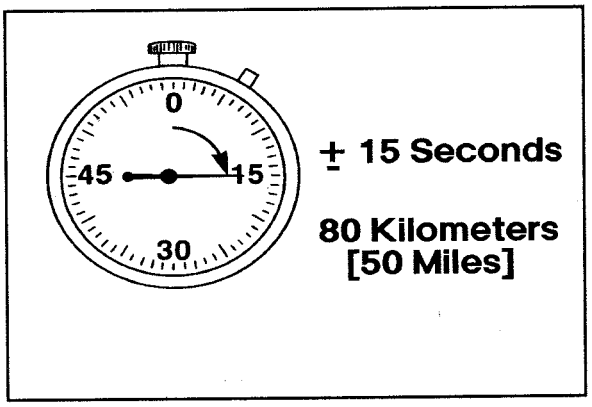
The test route and truck weights **must not** change during the test.

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 ±0.5 percent. This will be ±15 seconds on 80 km [50 mi] at 60 miles per hour.

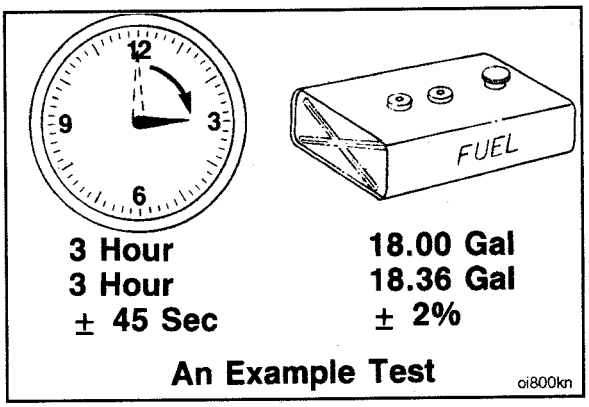


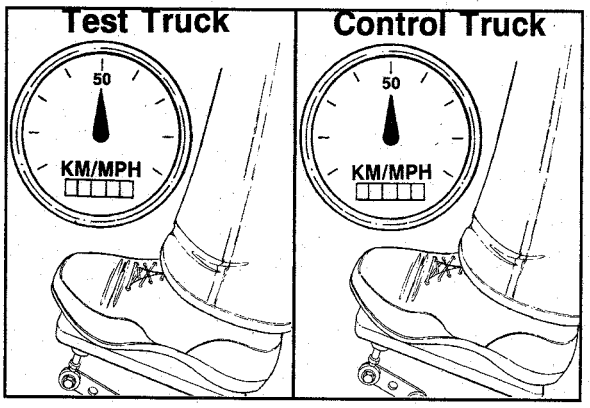
The fuel usage of the test truck between test drives **must** fall within a 2-percent range, e.g., 2.55 vs. 2.60 km/l [6.00 vs. 6.12 mpg].

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.

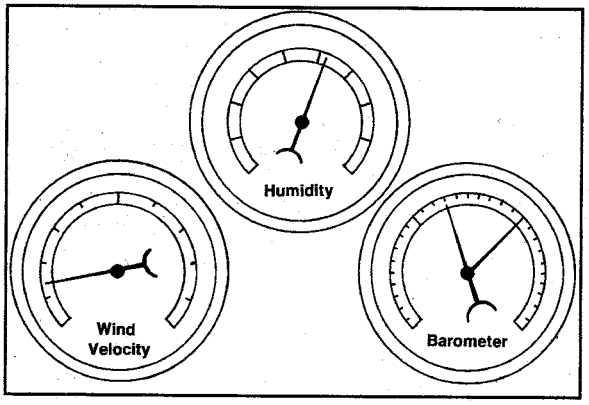
A minimum of three test drives that meet these conditions make a valid test. A single test drive is unreliable.





Use the same experienced drivers for all of the tests.

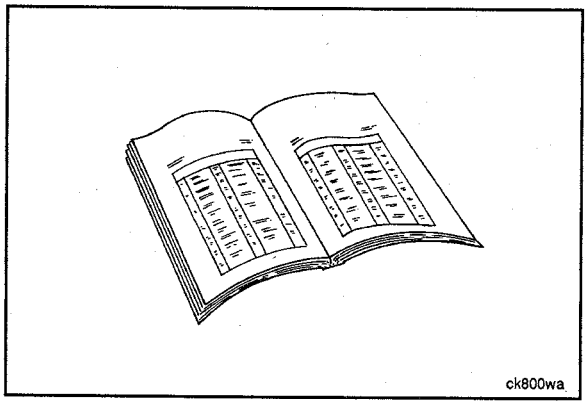
NOTE: The vehicle speeds **must** be representative of a typical operation.



During the test, record the following:

- Ambient temperature
- Humidity
- Barometric pressure
- Wind velocity
- Wind direction.

NOTE: Avoid testing under any extreme conditions.



Fuel Pump (005-016)

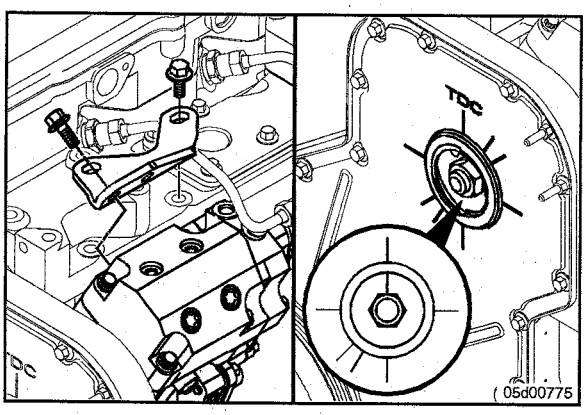
Preparatory Steps

Remove the fuel supply lines from the fuel pump. Refer to Procedure 006-024.

Remove the fuel drain line from the fuel pump. Refer to Procedure 006-013.

Disconnect the engine harness from the fuel pump actuator.

Remove the fuel pump gear access cover.



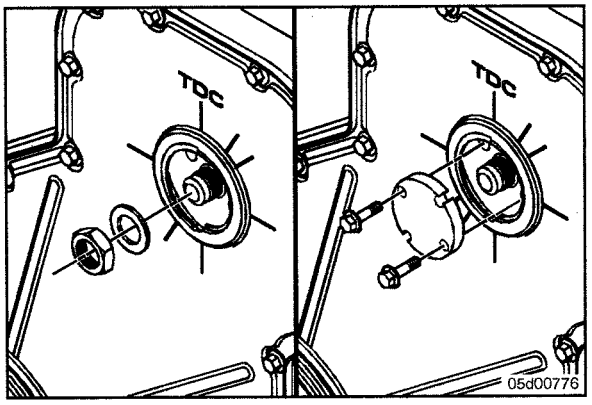
Remove

Remove the fuel pump upper support bracket.

Locate top dead center for cylinder Number 1 by barring the engine until the line on the fuel pump gear aligns with the front cover mark for top dead center.

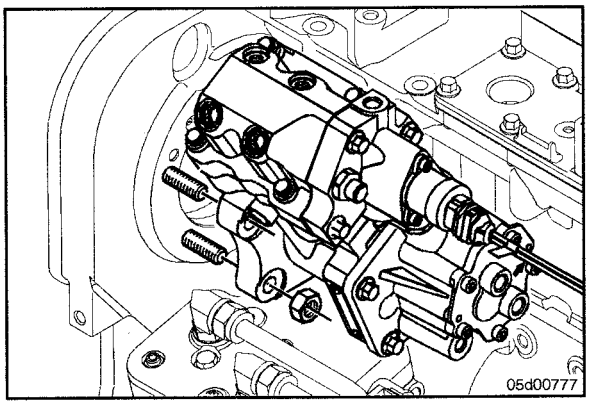
Remove the fuel pump gear nut and washer.

Pull the fuel injection pump drive gear loose from the pump drive shaft. This can be done using Cummins Gear Puller, Part Number 3824469.



Remove the four mounting nuts that hold the fuel pump to the gear housing.

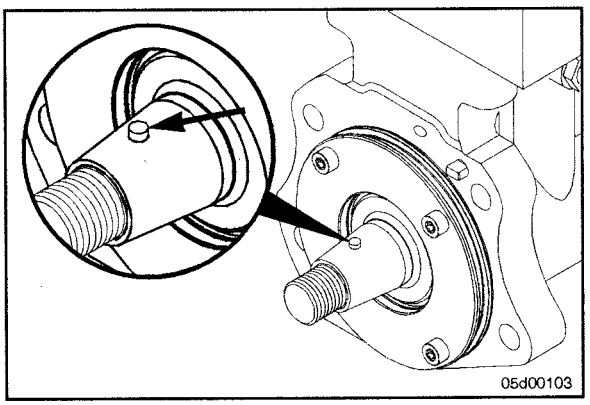
Remove the fuel pump.



Inspect for Reuse

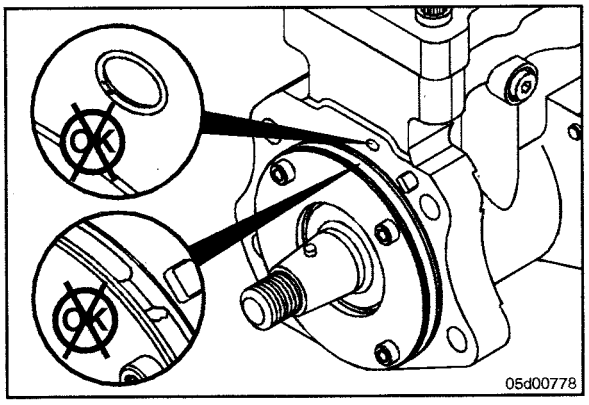
The dowel pin in the fuel pump driveshaft **must not** be sheared.

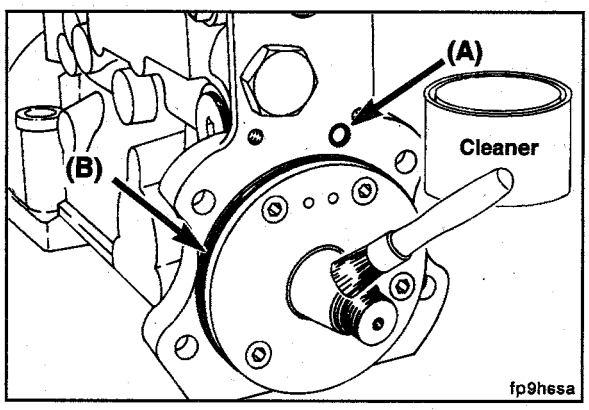
If the dowel is sheared, the cam housing or fuel pump **must** be replaced and the drive gear **must** be replaced.



Be sure that the pilot o-ring is **not** cut or damaged.

Be sure that the pump oil supply o-ring is **not** damaged.





Install

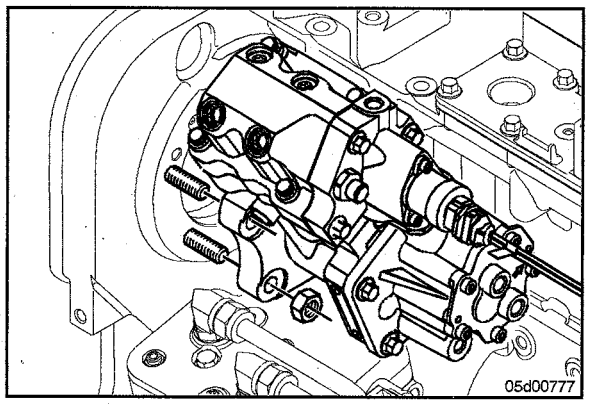
Be sure that the engine is at Number 1 cylinder top dead center. The fuel pump gear timing mark should align with the top dead center mark on the front cover.

Lubricate the pilot o-ring with clean engine oil.

Clean the nose of the camshaft with an evaporative cleaner.

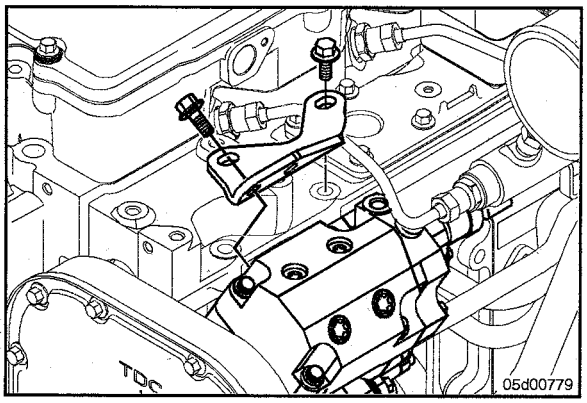
Clean the fuel pump gear inside diameter with an evaporative cleaner.

The fuel pump drive gear inside diameter and the drive shaft outside diameter **must** be clean and dry before installing the gear.



Slide the fuel injection pump shaft through the drive gear and position the fuel injection pump flange onto the mounting studs.

Make sure the dowel pin in the drive shaft lines up with the keyway in the fuel injection pump gear.



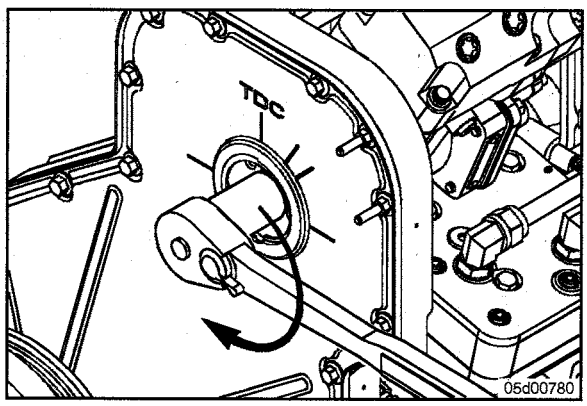
Installation Sequence:

1. . Install the pump mounting nuts (leave loose).
2. . Install the support bracket bolts (leave loose).
3. . Tighten the pump mounting nuts.

Torque Value: 44 N•m [32 ft-lb]

4. Tighten the support bracket bolts.

Torque Value: 65 N•m [48 ft-lb]



Tighten the fuel injection pump drive gear nut.

Torque Value: 180 N•m [132 ft-lb]

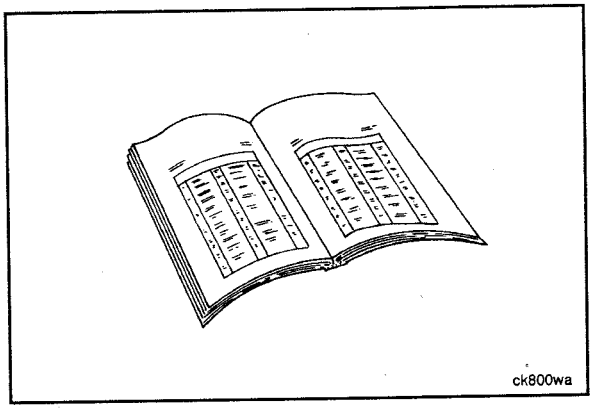
Finishing Steps

Install the access cover in the front cover.

Install the fuel supply lines to the fuel pump. Refer to Procedure 006-024.

Install the fuel drain line to the fuel pump. Refer to Procedure 006-013.

Connect the wire harness to the fuel pump actuator.



Fuel Pump Delivery Valve (005-020)

Preparatory Steps

⚠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.

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Thoroughly steam-clean the distributor outlet fitting and fuel pump area.

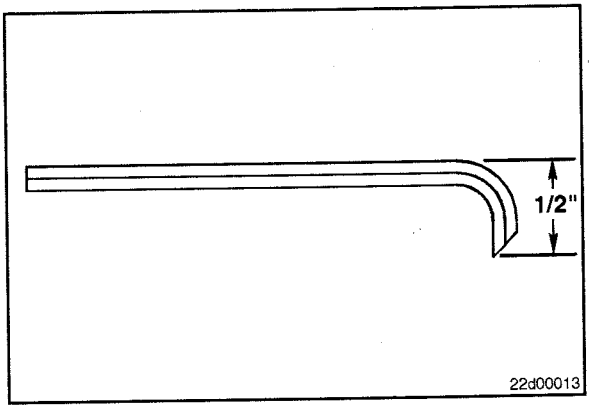
Dry with compressed air.

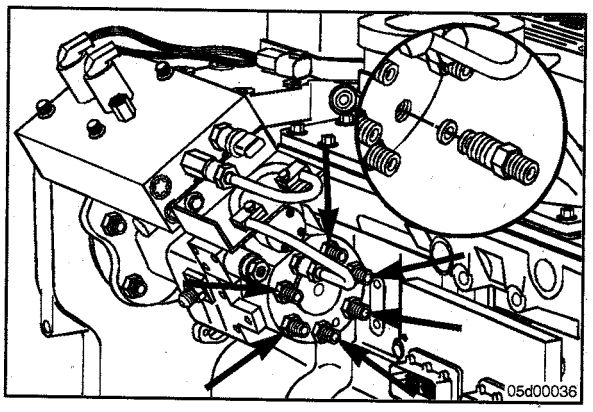
Remove the high-pressure fuel supply lines. Refer to Procedure 006-051.

Remove

Remove the distributor outlet fitting and the seal disk.

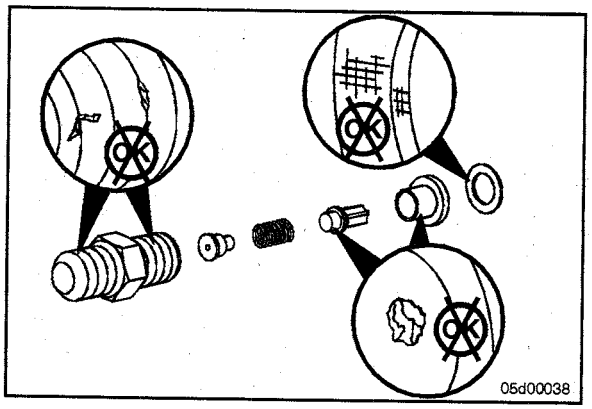
NOTE: A tool like the one shown here can be made from a 1/8 in or 3/16 in allen wrench. Use it to remove the seal disc. Refer to Procedure 005-084 for instruction on how to make the tool.





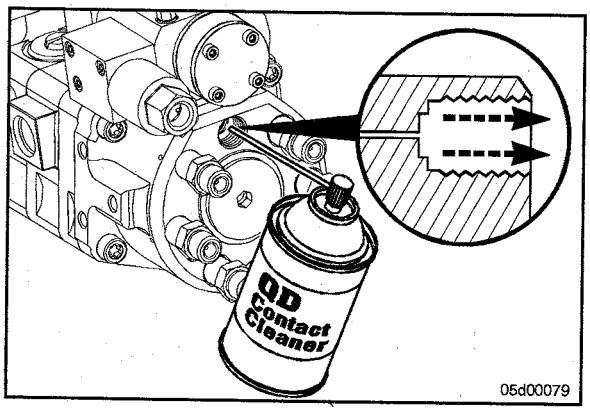
NOTE: The outlet fitting valve and seat are a matched set; do **not** "mix and match" valves and seats with other outlet fitting assemblies.

If either the outlet fitting valve or seat is damaged, the entire outlet fitting assembly **must** be replaced. Also, the seal washers **must always** be replaced.

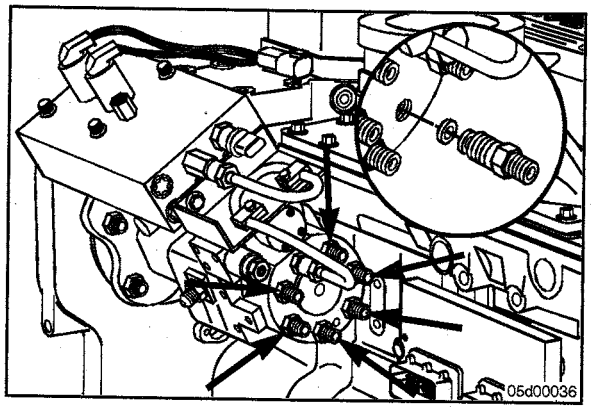


Clean and Inspect for Reuse

Check for broken parts, debris, or sticking of the outlet fitting valve. Replace the outlet fitting assembly if any parts are damaged. **Always** replace the seal washer.



Use QD contact cleaner, Part Number 3824510, to clean the delivery valve port in the distributor.



Install

Install a new seal washer into the distributor outlet fitting hole. Make sure the washer is fully seated in the bottom of the hole.

Install the outlet fitting assembly hand tight.

Tighten the outlet fitting assemblies.

Torque Value: 81 N•m [60 ft-lb]

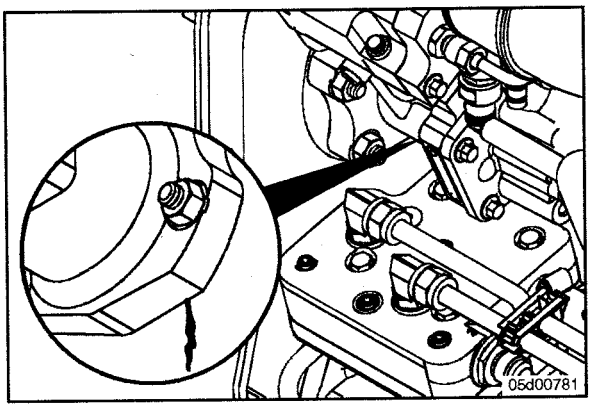
Finishing Steps

Install the high-pressure fuel supply lines. Refer to Procedure 006-051.

Operate the engine and inspect for fuel leaks.

Fuel Pump Gear Pump (005-025)

Initial Check

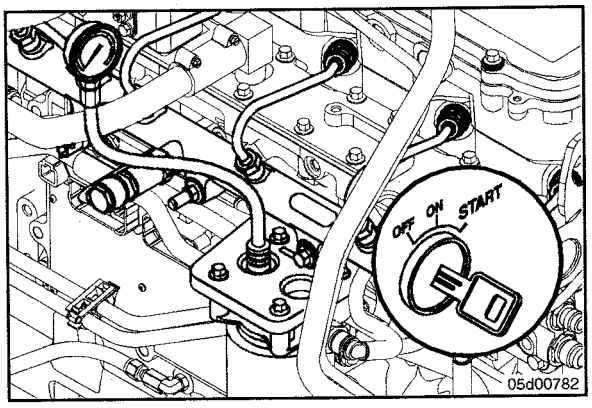


The gear pump shaft incorporates a double seal. The first seals oil in the fuel pump cam housing; the second seals fuel in the gear pump. If either seal fails, a leak will drip from the weep hole. The weep hole is located near the gear pump mounting flange on the inboard side (toward the engine block).

A gear pump gasket seals oil at the gear pump to cam housing interface.

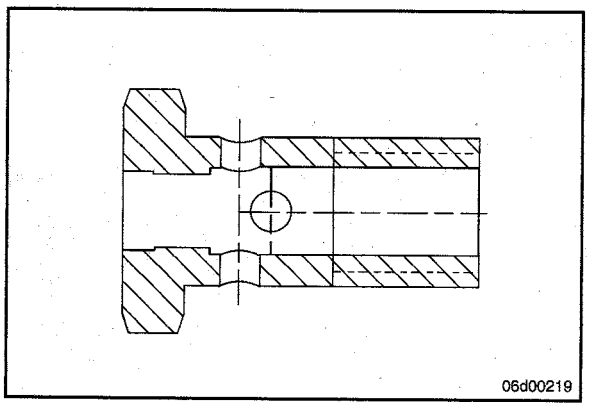
Measuring gear pump pressure with the engine cranking (useful if engine will **not** start).

1. . Install a pressure gauge at the on engine fuel filter head (M10 x 1.5 Compuchek® fitting, Part Number3824842).
2. . Monitor the gear pump pressure while the engine is cranking.



Gear Pump Pressure at Cranking (minimum) 69 kPa [10 psi]

If the gear pump pressure is lower than 69 kPa [10 psi] during cranking, make sure that the engine cranking speed is at least 150 rpm. Make sure that the lift pump pressure during cranking is at least 35 kPa [5 psi]. Refer to Procedure 005-045.



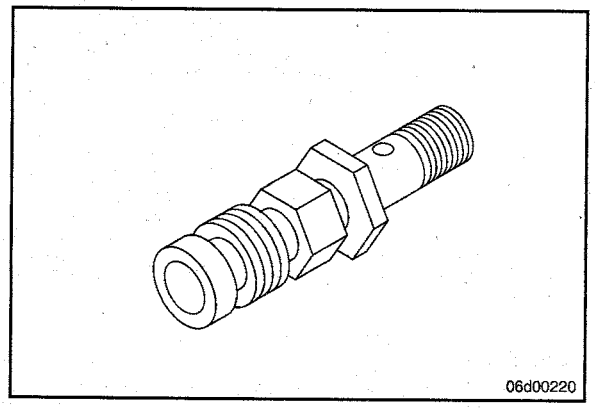
Construction of Banjo Pressure Gauge Adapter

A banjo-style pressure gauge adapter can be used to measure pressure or vacuum at any point in the low-pressure fuel system where a banjo bolt exists at a fuel line.

The ISC and ISL engines with high-pressure common rail fuel systems use M12 x 7/16-inch banjo bolt connection. This tool can be used for measurement of drain line restriction (pressure) at the fuel drain manifold.

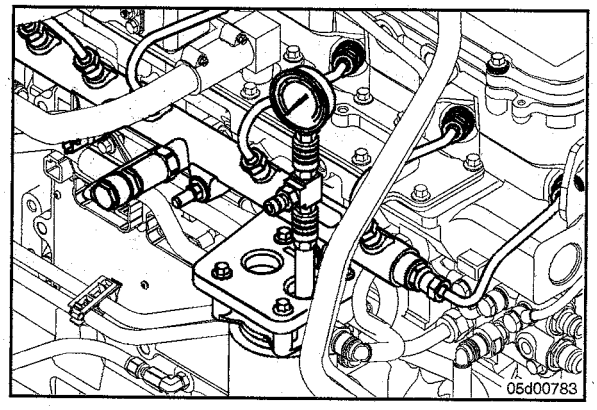
Make a banjo bolt flow adapter tool by drilling and tapping the hex face of an M12 x 7/16-inch banjo bolt, Part Number 3903035 or similar banjo bolt.

Drill and tap the banjo bolt to the size of Compuchek® fitting (or other hose union) being used (example 1/8-inch NPT Compuchek® fitting, Part Number 3377244, or M10 Compuchek® fitting, Part Number 3824842).



Assemble the banjo pressure gauge adapter as follows.

1. . Install the Compuchek® fitting, or other type fitting, in the hexagon face of the banjo bolt.
2. . Attach a hose or pressure gauge to the banjo pressure adapter.



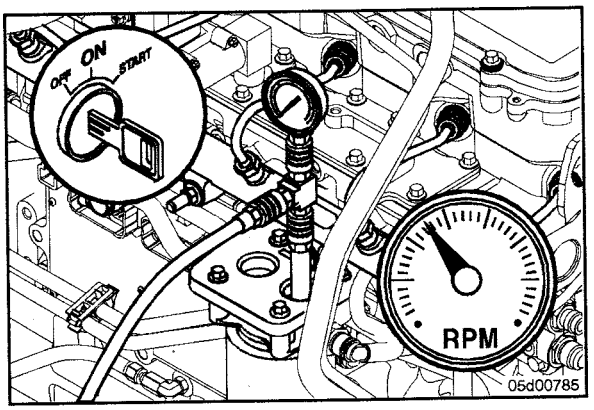
Measuring Gear Pump Pressure at Rated Condition

1. . Install a M10 x 1.5 Compuchek® fitting, Part Number 3824842, at the diagnostic port on the outlet of the fuel filter head.
2. . Construct a "T" adapter fitting using one quick-disconnects, Part Number 3376859, and two 1/8-inch NPT Compuchek® fitting, Part Number 3042618.
3. . Install a 0.043-inch orificed diagnostic fuel line (Part Number 3164621) at the outlet of the fuel filter head. Run the fuel hose back to the fuel tank.
4. . Install a 0 to 1034 kPa [0 to 150 psi] pressure gauge at the "T" adapter fitting.

Operate the engine at high idle and observe the gear pump pressure.

Minimum Gear Pump Pressure 483 kPa [70 psi]

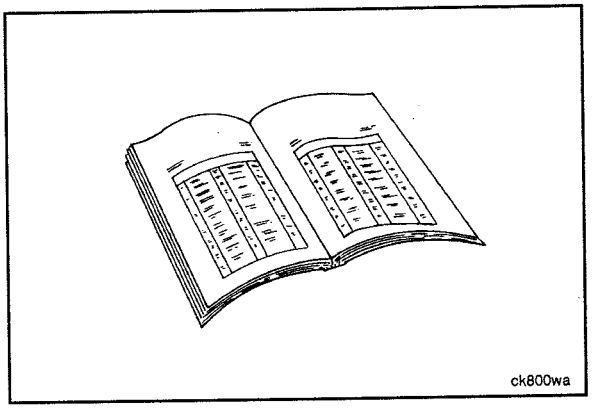
If the gear pump pressure is low, check for excessive inlet vaccum. Refer to Procedure 006-020.



Preparatory Steps

Clean the fuel, oil and debris from the gear pump.

Remove the fuel supply lines from the gear pump. Refer to Procedure 006-024.

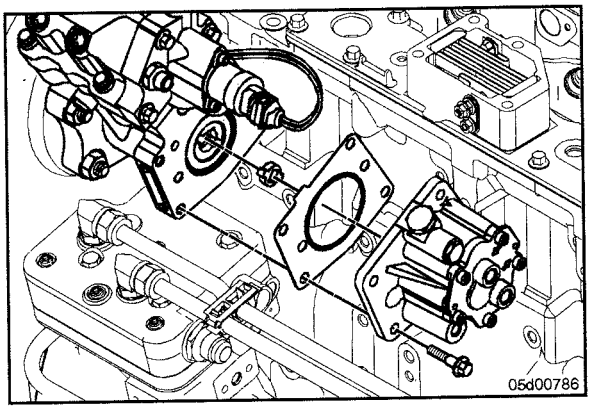


Remove

Remove the four bolts that hold the gear pump to the fuel pump.

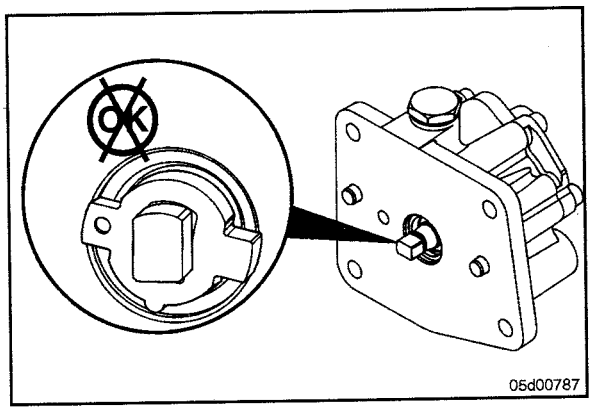
Remove the drive coupling if it remains attached to the rear of the fuel pump camshaft.

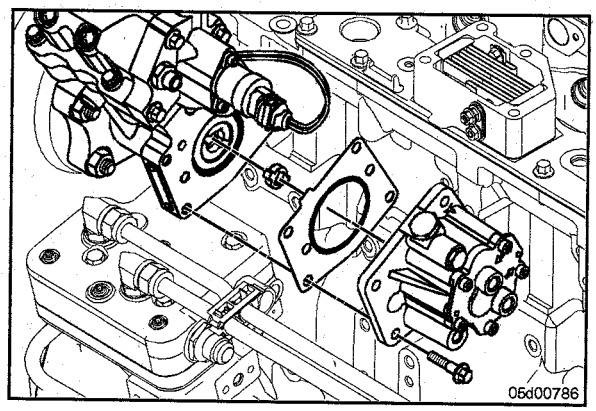
Remove the gear pump gasket.



Clean and Inspect for Reuse

Inspect the drive coupling for wear. If worn, the drive coupling **must** be replaced.





Install

Install the drive coupling into the back of the high-pressure pump camshaft.

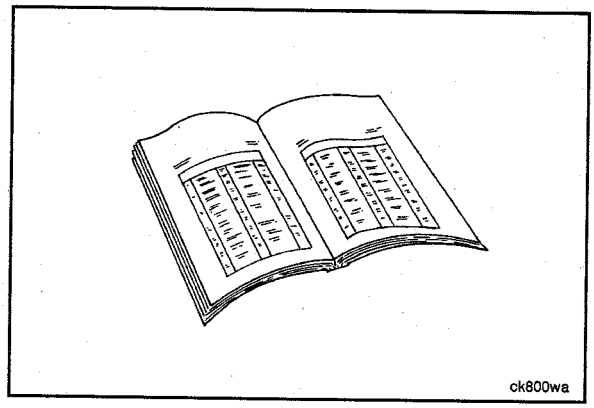
Insert the mounting bolts through the gear pump flange.

Install a new gasket onto the bolts.

Index the gear pump input shaft to engage the drive coupling and install the gear pump.

Install the four gear pump bolts and tighten.

Torque Value: 34 N•m [25 ft-lb]



Finishing Steps

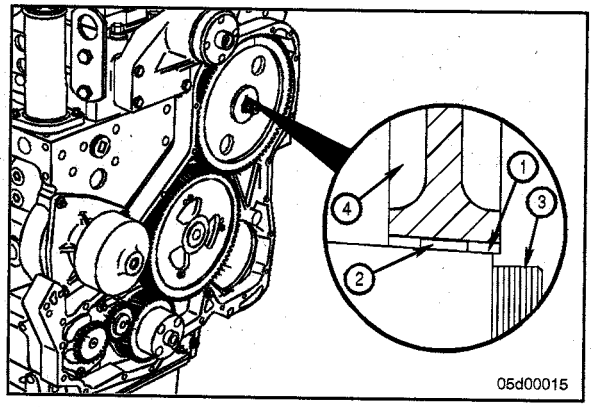
Install the fuel supply lines. Refer to Procedure 006-024.

Fuel Pump Timing (005-037)

Preparatory Steps

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

Remove the fuel pump camshaft nut. Refer to Procedure 005-016 or 005-229.



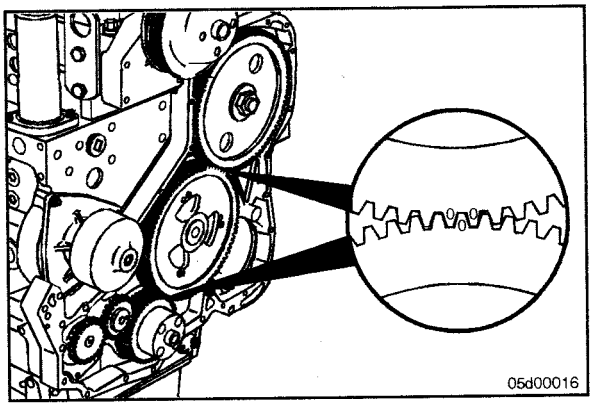
Inspect for Reuse

Check that the fuel pump camshaft alignment dowel is present in the fuel pump drive gear keyway. If the alignment dowel is **not** visible, remove the injection pump, determine the cause of misalignment, and repair or replace any damaged components.

1. . Fuel pump gear keyway
2. . Fuel pump timing dowel pin
3. . Fuel pump camshaft
4. . Fuel pump gear

If this inspection is being performed due to a performance complaint, and the problem first occurred after gear train removal and replacement then check the timing of the camshaft gear to the crankshaft gear and the camshaft gear to the fuel pump drive gear. Refer to Procedure 001-012.

If the engine camshaft gear is mistimed in relation to the crankshaft gear, intake and exhaust valve events will **not** be optimized. Also, for CAPS injection pump fuel systems, the primary speed sensor reads the tonewheel on the camshaft gear and fuel injection timing will be incorrect.



Finishing Steps

Install and tighten the injection pump camshaft nut. Refer to Procedure 005-016 or 005-229.

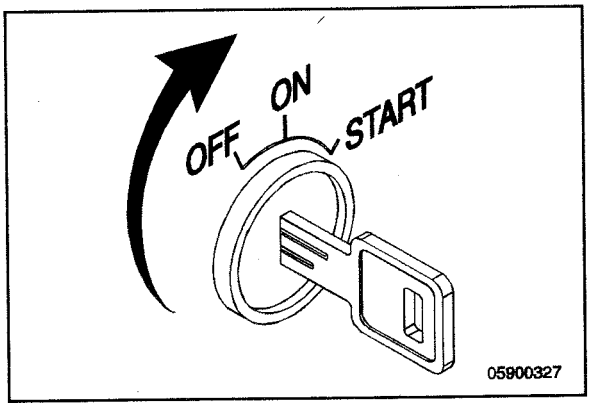
Install the front gear cover. Refer to Procedure 001-031.

Fuel Lift Pump (005-045)

Initial Check

A malfunctioning electric fuel lift pump can cause slow engine starts or may result in an engine failing to start. The fuel lift pump can be cleaned and repaired to a limited extent.

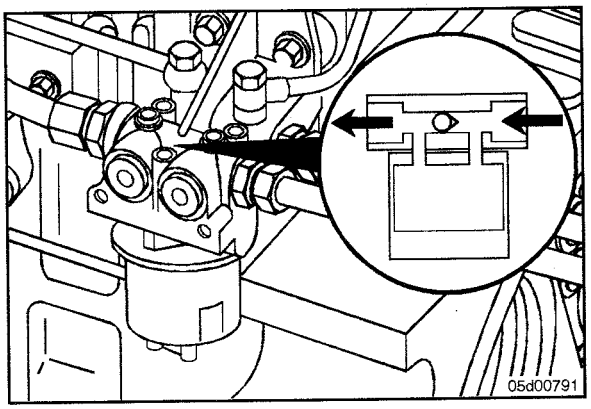
The lift pump will operate for 30 to 60 seconds when the key is switched ON. The lift pump will also operate while the engine is cranking.

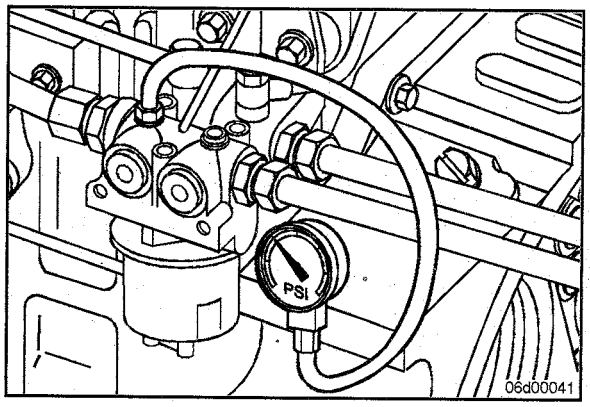


Block Mounted Lift Pump

The lift pump is contained in an assembly that includes fuel supply and drain manifolds. These manifolds provide for OEM connection of fuel supply and return hoses. The fuel supply manifold also contains M10 STORM fittings which allow for pressure and vacuum measurement of the fuel supply at the electric lift pump.

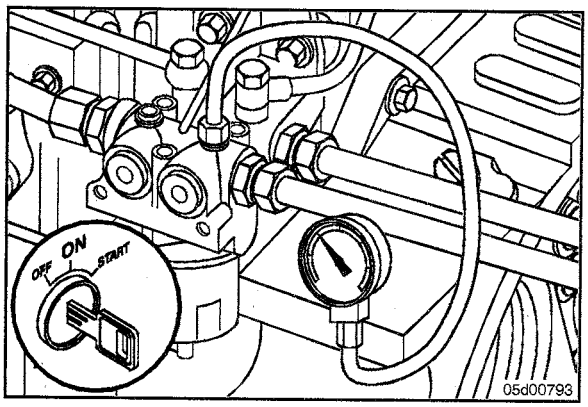
A bypass check valve in the fuel supply manifold ensures that the system is primed by the lift pump. This check valve opens under vacuum created by the fuel injection pump once the engine is started. High vacuum measured between the electric lift pump and the fuel filter may indicate that this check valve has become plugged.





The output of the fuel lift pump can be checked through the following test:

- Measure the output pressure using a pressure gauge at the lift pump outlet port.

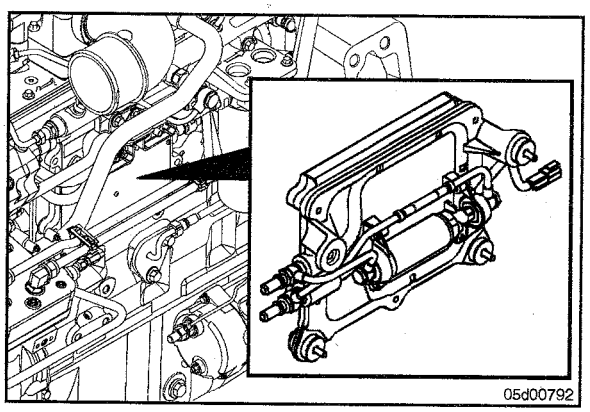


The lift pump check valve restriction can be determined using the following test:

1. . Install a 0 to 762 mm Hg [0 to 30 in Hg] vacuum gauge at the inlet and outlet M10 STORM ports on the electric lift pump head
2. . Operate the engine at rated power condition
3. . Record the inlet restriction at the inlet and outlet of the lift pump.

Refer to Procedure 006-020.

Fuel Lift Pump Inlet Restriction		
mm Hg		in Hg
102	MAX	4

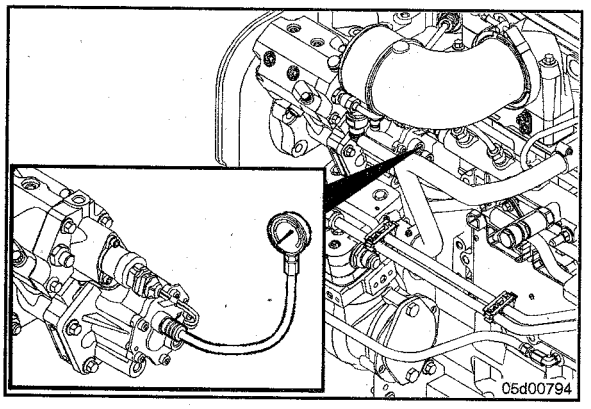


ECM Cooling Plate Mounted Lift Pump

A lift pump is mounted to the back of the ECM cooling plate.

A bypass check valve in the ECM cooling plate ensures that the system is primed by the lift pump. This check valve opens under vacuum created by the gear pump once the engine is started. High vacuum measured between the electric lift pump and the gear pump may indicate that this check valve has become plugged.

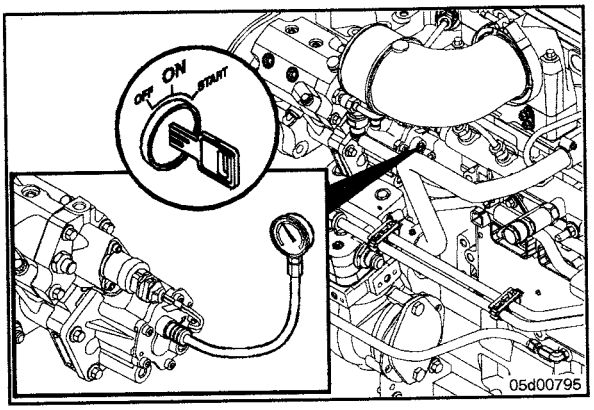
The ECM cooling plate check valve is integral with the lower (outlet) fitting of the ECM cooling plate.



The output of the fuel lift pump can be checked through the following test:

1. . Measure the output pressure using a pressure gauge at the inlet to the high-pressure pump gear pump assembly.
2. . Install a pressure gauge at the inlet port of the high-pressure pump gear pump.

Turn the keyswitch ON and measure the lift pump pressure using a pressure gauge at the gear pump inlet.



NOTE: At initial key-on, the lift pump will run for 30 seconds then stop.

Minimum Pressure 34 kPa [5 psi]

NOTE: If the lift pump pressure is low while the lift pump runs, make sure that the ECM cooling plate check valve is **not** blocked open.

NOTE: If the lift pump pressure is low while the lift pump runs, make sure that fuel is primed. For example, following fuel filter replacement it is necessary to cycle the fuel lift pump three or four times before air is purged.

Preparatory Steps

Block Mounted Lift Pump

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the negative (-) battery cable first.

NOTE: Thoroughly clean fittings and components before removal. Make sure that the debris, water, steam or cleaning solution does **not** reach inside the fuel system.

Remove the fuel lift pump inlet and outlet fuel lines. Refer to Procedure 006-024.

Disconnect the fuel pump power lead.

ECM Cooling Plate Mounted Lift Pump

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

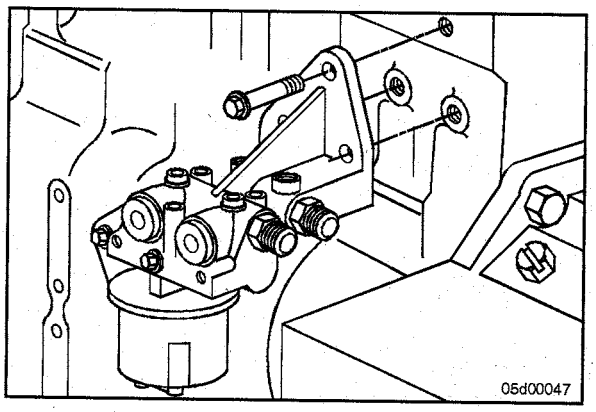
Disconnect the negative (-) battery cable first.

Disconnect the electric fuel priming pump from the engine wiring harness.

NOTE: Thoroughly clean fittings and components before removal. Make sure that the debris, water, steam or cleaning solution does **not** reach inside the fuel system.

Remove the fuel supply lines. Refer to Procedure 006-024.

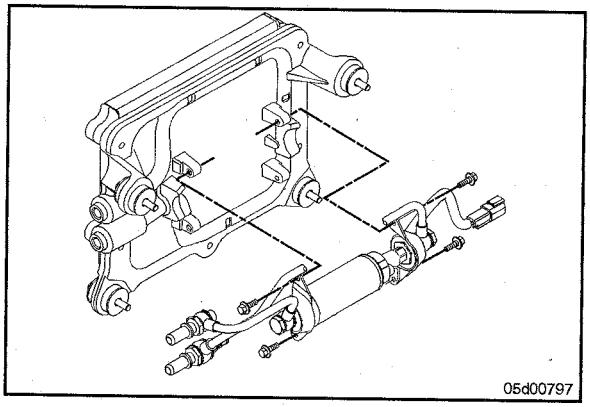
Remove the ECM cooling plate. Refer to Procedure 006-006.



Remove

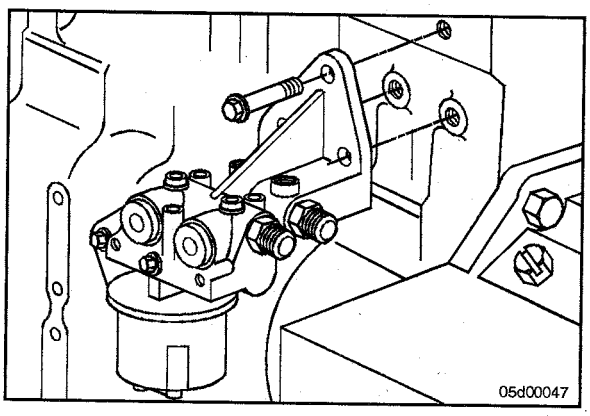
Block Mounted Lift Pump

Remove the three capscrews and the electric lift pump from the engine block.



ECM Cooling Plate Mounted Lift Pump

Remove the electric lift pump from the ECM cooling plate.



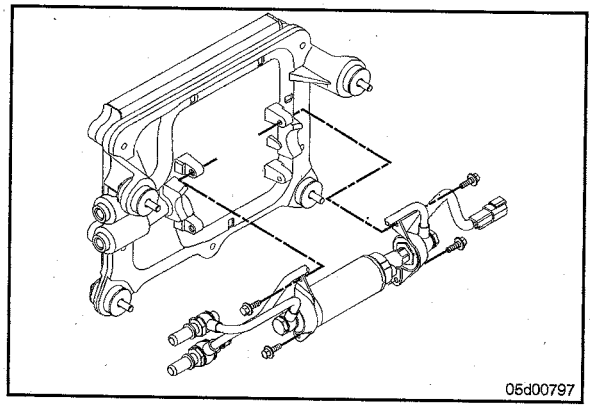
Install

Block Mounted Lift Pump

Install the fuel lift pump to block using the three mounting capscrews.

Tighten the capscrews.

Torque Value: 12 N•m [106 in-lb]



ECM Cooling Plate Mounted Lift Pump

Install the electric lift pump to the ECM cooling plate.

Tighten the mounting capscrews.

Torque Value: 10 N•m [89 in-lb]

NOTE: The ECM cooling plate check valve **must** be free of debris and installed into the lower ECM cooling plate port (outlet port).

NOTE: Hold the fuel lines as shown so that they can **not** come into contact with each other or the engine block.

Finishing Steps

Block Mounted Lift Pump

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Connect the power lead to the fuel lift pump.

Install all removed fuel lines. Refer to Procedure 006-024.

Connect the battery, negative (-) cable last.

ECM Cooling Plate Mounted Lift Pump

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Install the ECM cooling plate to the engine block. Refer to Procedure 006-006.

Install all fuel lines. Refer to Procedure 006-024.

Connect the battery, negative (-) cable last.

Rotor, CAPS Fuel Injection Pump (005-072)

Preparatory Steps

⚠WARNING⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturers recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠

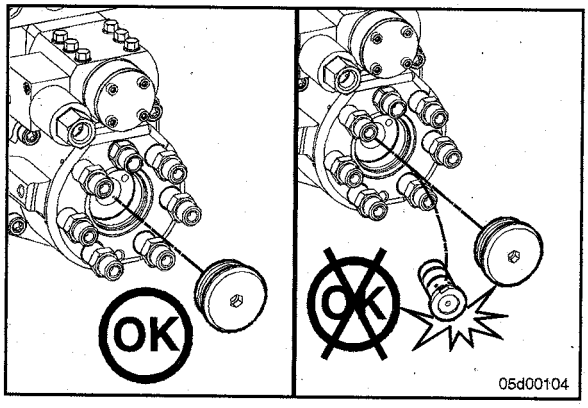
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Steam clean the fuel injection pump and the engine in the vicinity of the fuel pump.

Dry with compressed air. Pay special attention to the distributor area.



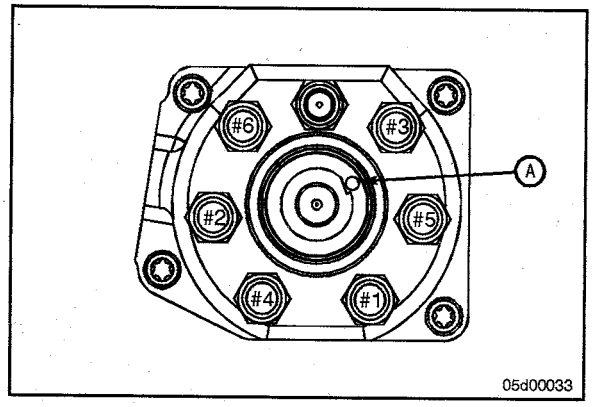
Remove

⚠CAUTION⚠

The rotor can slide out during the removal of the distributor plug. If the rotor is dropped, the entire distributor module must be replaced. Do not attempt to start the engine with the distributor plug removed. Doing so can cause the rotor to be ejected from the distributor, causing damage to the rotor.

ISL Only: Remove the air bleed line. Refer to Procedure 006-056.

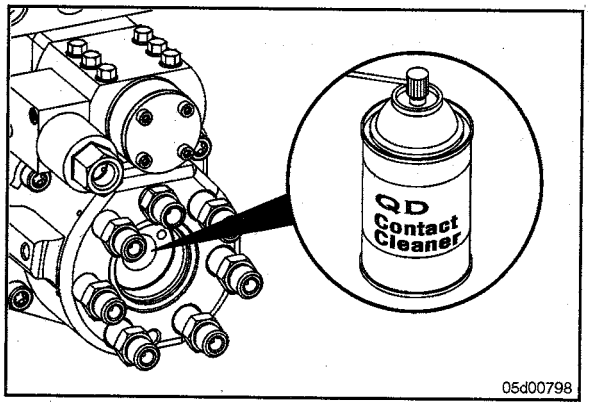
Remove the distributor plug, being sure the rotor does **not** fall out.



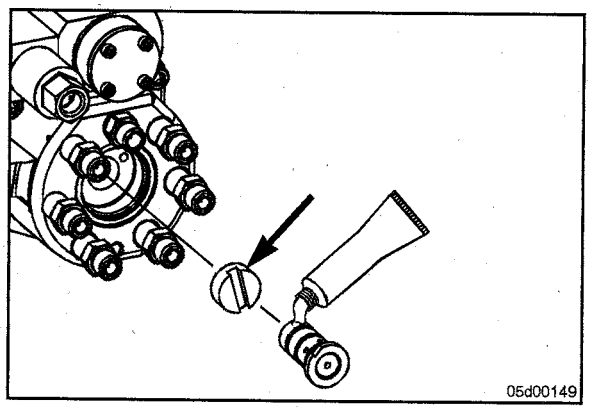
Clean and Inspect for Reuse

Check the position of the notch on the rotor. It **must** line up with the alignment mark (A) on the outside of the distributor (when the engine is barred to TDC for the number 1 cylinder). If the alignment is correct, the rotor is properly timed to the engine.

If a mechanical problem exists, indicated by misalignment of the rotor, the entire fuel pump will have to be replaced; refer to Procedure 005-016.



Clean the rotor bore with QD contact cleaner, Part Number 3824510.



Install

Use Lubriplate™ 105, or equivalent, between the drive coupling and the rotor to prevent it from falling off during assembly.

⚠CAUTION⚠

The rotor must be properly timed to the fuel pump camshaft. Improper assembly will cause the rotor to be 180 degrees out of time.

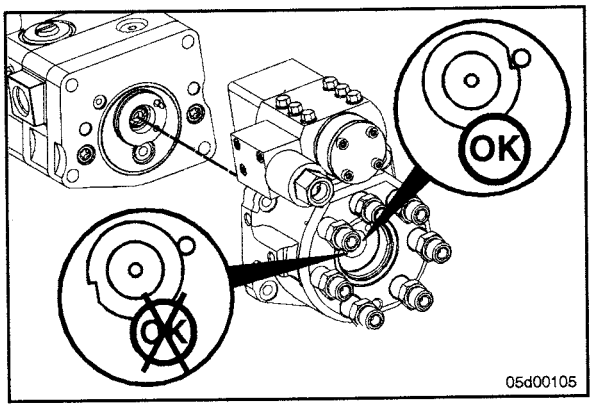
Insert the rotor and coupling into the distributor module completely.

Lightly rotate the rotor with finger-pressure until it drops into the slot in the drive coupling.

When properly engaged, the notch in the rotor will align with the hole in the distributor while the engine is at Number cylinder TDC.

If the rotor will **not** engage, remove the rotor and drive coupling and try again. Do **not** tighten the rotor cap if the coupling will **not** engage.

If **not** properly timed, remove the rotor and drive coupling and repeat the previous step. Make sure the fuel pump camshaft dowel pin is pointing toward the top of the fuel pump before installing.

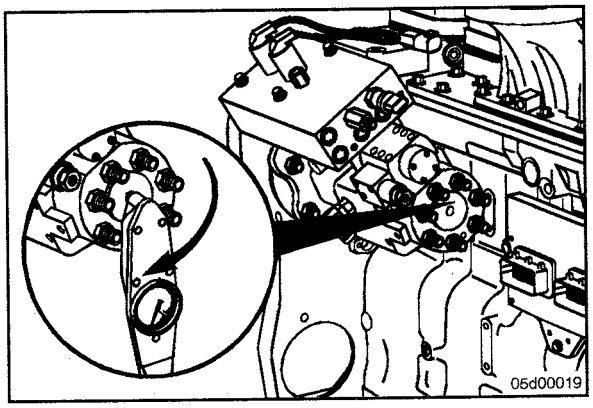


Install the distributor plug and torque.

Torque Value: 14 N•m [10 ft-lb]

NOTE: Be sure the rotor is fully engaged before replacing the plug.

ISL Only: Install the air bleed line. Refer to Procedure 006-056.



Injection Control Valve (005-078)

Preparatory Steps

⚠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.

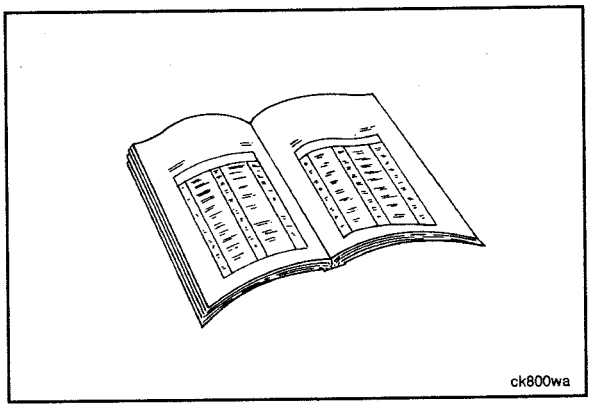
⚠WARNING⚠

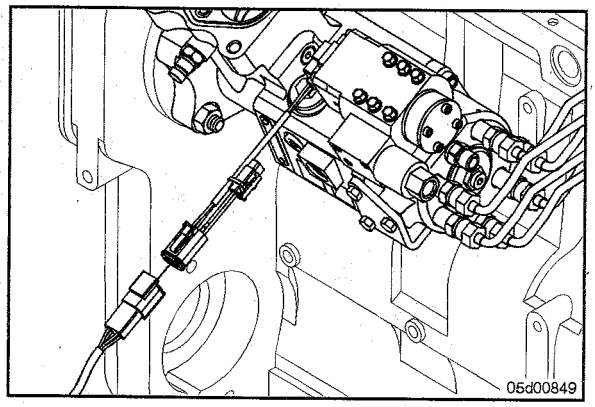
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠CAUTION⚠

Fault codes can occur if steam sprays directly on the electrical connections on top of the accumulator block.

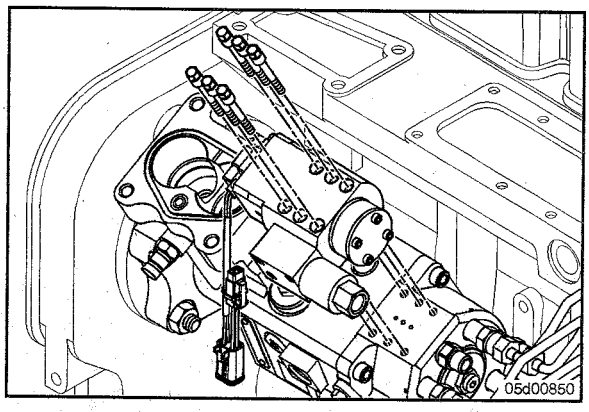
- Thoroughly steam-clean the entire fuel pump.
- Dry the fuel pump with compressed air.
- Remove the fuel injection pump accumulator. Refer to Procedure 005-085.





Remove

Unplug the engine wiring harness from the injection control valve connector.



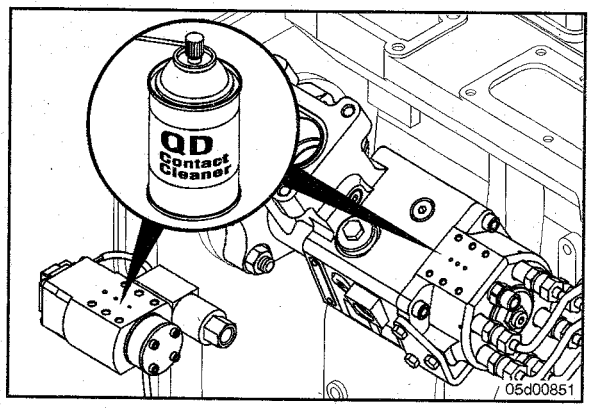
Remove the injection control valve drain line.

Remove the six injection control valve mounting screws.

Remove the injection control valve from the distributor module.

Do **not** misplace parts during disassembly.

Secure the six bolts, sealing plate, and both crush tubes into a parts bag. The parts are to be returned with the core.



Clean and Inspect for Reuse

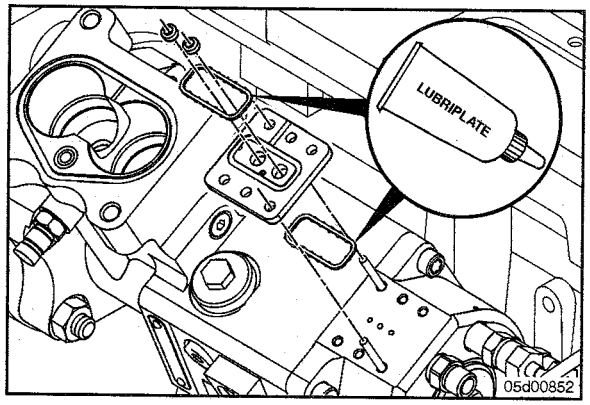
Clean the mounting surface of the distributor module and injection control valve.

Use QD contact cleaner, Part Number 3824510.

Spray or wipe debris away from the three distributor module drillings. Do **not** allow debris to enter the distributor module drillings.

Inspect the distributor module sealing face for cracks, indentations, and damage.

Replace the distributor module if damage is found.



Install

Install guide pins, Part Number 3165166, in the upper left and lower right corner of the distributor module.

Install the o-rings into the sealing plate using Lubriplate™ to hold them in place.

Slide the sealing plate down over the guide pins.

The o-rings **must** be securely seated in the sealing plate before proceeding.

Insert crush tubes into the sealing plate.

Check the position of the crush tubes. They **must** sit flush on the distributor module and **must not** be installed at an angle.

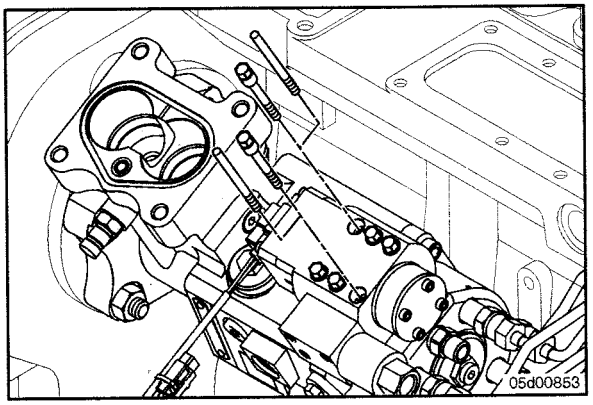
Install the injection control valve on top of the distributor module using guide pins.

Check that the o-rings are still in their grooves.

Install four bolts through the injection control valve and tighten finger tight.

Remove the two guide pins.

Install the two remaining bolts, finger tight, through the injection control valve.

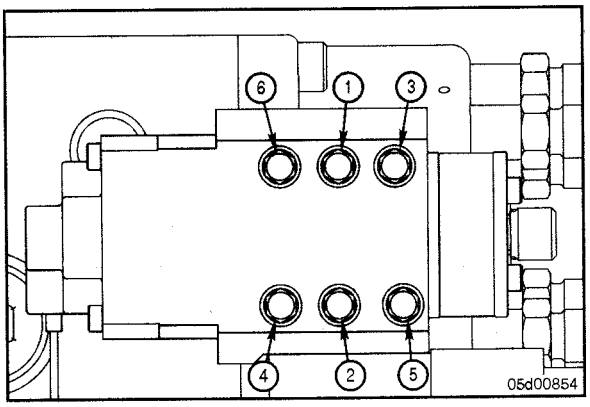


⚠CAUTION⚠

Bolts must be torqued as described or the injection control valve/distributor module will not function properly. Use a high-quality, calibrated torque wrench.

Torque bolts in sequence for each step. Refer to the accompanying illustration for the torque sequence.

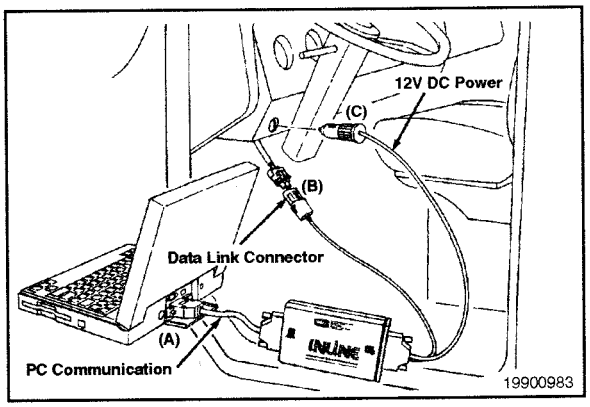
Torque Value:	Step1	1.8 N•m	[16 in-lb]
	Step2	3.6 N•m	[32 in-lb]
	Step3	5.6 N•m	[50 in-lb]
	Step4	Torque to 5.6 N•m [50 in-lb] three more times following the torque sequence	

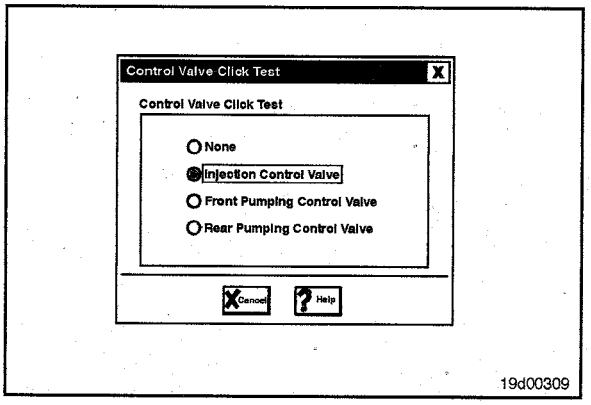


Install the injection control valve drain line.

Click Test

Use INSITE™, with the keyswitch in the ON position, to run the control valve click test.



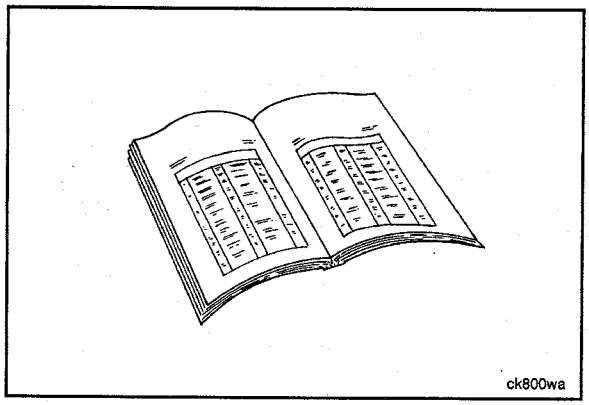


Select Injection Control Valve to initiate the test.

A click will be heard until None is selected on the Control Valve Click Test screen.

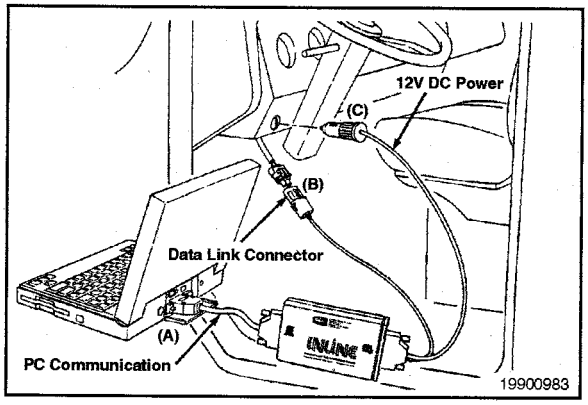
If no click is heard, troubleshoot any active fault codes.

The click test will need to be performed after any repairs are made to clear the fault codes.



Finishing Steps

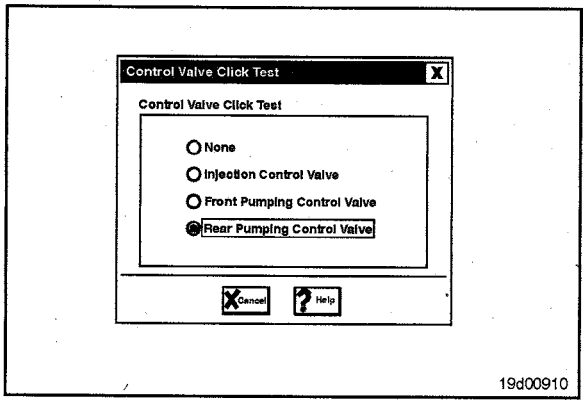
- Install the fuel injection pump accumulator. Refer to Procedure 005-085.
- Install the air bleed line. Refer to Procedure 006-056.
- Install the drive gear cover.
- Connect the fuel pressure sensor and the fuel temperature sensors to the engine harness.
- Connect the pumping control valve connector to the engine harness.
- Connect the stator connector to the engine harness.
- Click test the injection control valve stator to check for proper operation. Refer to Click Test in this procedure.
- Start the engine and check for fuel leaks or active fault codes.
- Recheck for fuel leaks or active fault codes.



Pumping Control Valve (005-079)

Click Test

Use INSITE™, with the keyswitch in the ON position, to run the control valve click test.



Select the Pumping Control Valve to be tested to initiate the test. Select either front control valve or rear control valve.

A "click" will be heard until the other pumping control valve is selected, or None is selected on the Control Valve Click Test screen.

If no "click" is heard, troubleshoot any active fault codes.

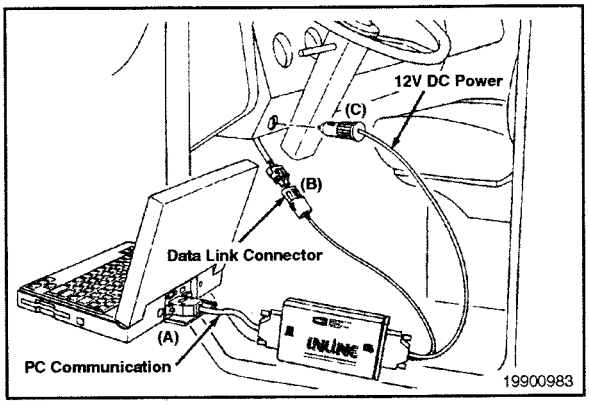
NOTE: The click test will need to be performed after any repairs are made to clear the fault codes.

Cutout Test

The plunger cutout test can be used to check performance of the front and rear pumping plungers.

NOTE: When performing this test, the engine load **must** be the same when each pumping plunger is cut out.

Use INSITE™, with the engine running at idle, to perform this test.



Select the pumping control valve to be cut out.

Select the monitor button and monitor valve close angle, engine speed, and accumulator pressure while the selected plunger is cut out.

Record valve close angle, engine speed, and accumulator pressure after the engine stabilizes.

After testing with one pumping control valve disabled, select "None" so that the engine will run with both valves enabled. Switching directly from "Front" to "Rear" or "Rear" to "Front" will cause the engine to misfire or hesitate.

Cut out the other pumping control valve, and record valve close angle, engine speed, and accumulator pressure after the engine stabilizes.

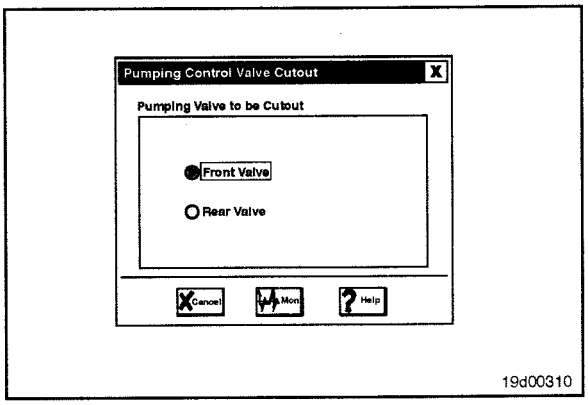
Compare the results when the rear pumping control valve is cut out, against the results when the front pumping control valve is cut out.

If the engine dies when one of the pumping control valves is cut out, replace the accumulator. Refer to procedure 005-085.

NOTE: The valve close angle **must not** vary more than 15 degrees crank angle.

If the valve close angle varies more than 15 degrees between the front and rear valves then replace the accumulator module. Refer to Procedure 005-085.

NOTE: Troubleshoot any active fault codes before replacing the pump.



Snubber, Rate Shape (005-081)

Preparatory Steps

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

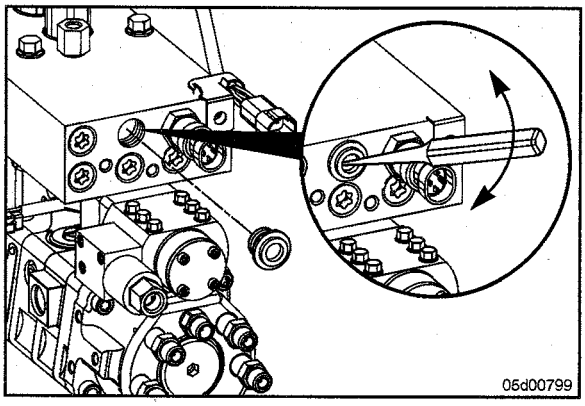
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Thoroughly steam-clean the rate shape tube and fuel pump area.

Dry with compressed air.

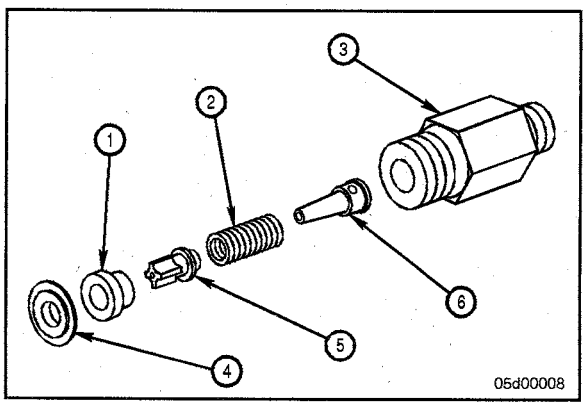
Remove the rate shape tube assembly. Refer to Procedure 005-090.



Remove

Remove the rate shape snubber assembly.

Use a center punch to pry the seal disc from the accumulator.



Inspect for Reuse

The parts in the assembly are as shown:

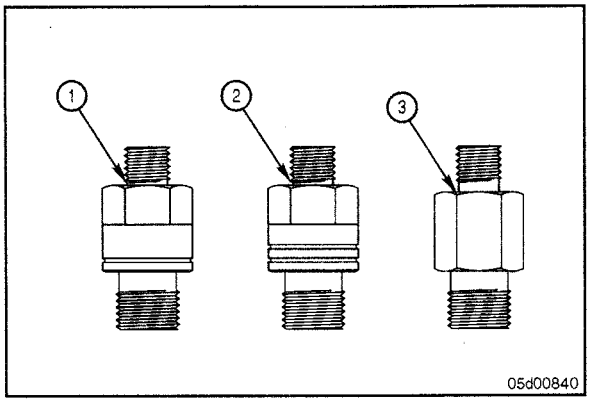
1. . Snubber valve seat
2. . Spring
3. . Rate shape snubber body
4. . Seal disc
5. . Snubber valve
6. . Spring post.

Replace the snubber assembly if the snubber spring is broken.

Do **not** reuse snubber seal discs.

Early design snubber valves are **not** reusable.

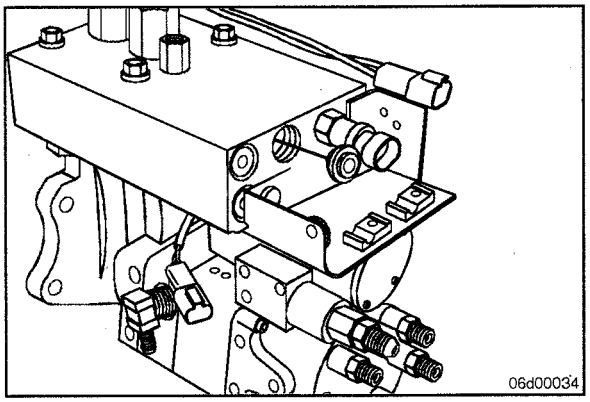
1. . Part Number 3800351, first snubber valve assembly released for CAPS (one groove, **not** reusable)
2. . Part Number 3800764, second snubber valve assembly released for CAPS (two grooves, **not** reusable)
3. . Part Number 4010544, current snubber valve assembly released for CAPS (no grooves, may be reused); always replace the seal disk.



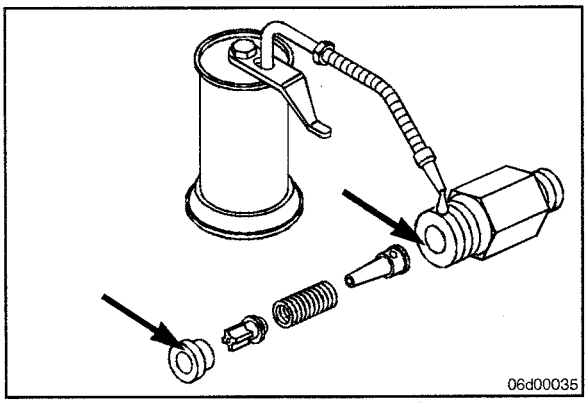
Install

Clean the bore for the distributor outlet fitting with QD cleaner prior to installation of the new snubber assembly.

Install a new seal disc into the accumulator.

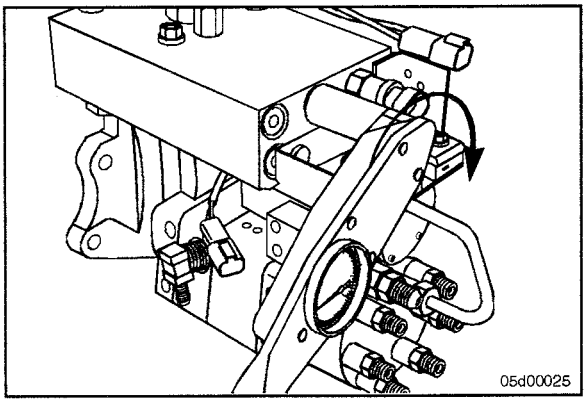


Apply lubricating oil to the face of the snubber seat and to the face and threads of the snubber fitting.



Install the snubber assembly.

Torque Value: Step1 14 N•m [124 in-lb]
Step2 Rotate 80 degrees



Finishing Steps

Install the rate shape tube assembly. Refer to Procedure 005-090.

Operate the engine and check for leaks.

Fuel Pump Distributor Inlet Fitting (005-084)

Preparatory Steps

⚠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.

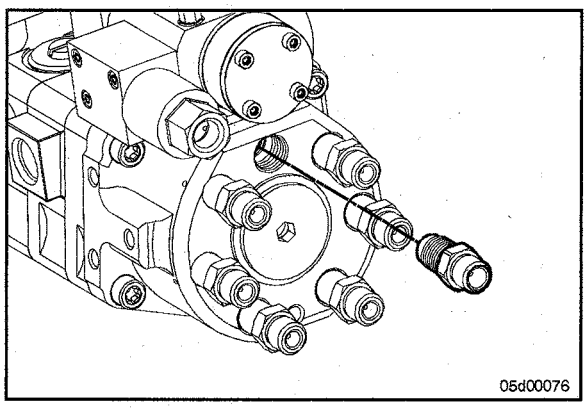
⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Thoroughly steam-clean the distributor outlet fitting and fuel pump area.

Dry with compressed air.

Remove the rate shape tube assembly. Refer to Procedure 005-090.



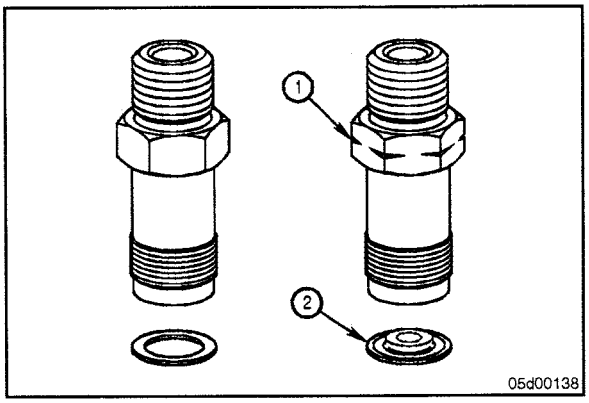
Remove

Remove the distributor inlet fitting and the seal disc.

NOTE: A tool like the one shown in this procedure can be made from a 1/8-inch or 3/16-inch Allen wrench. Use it to remove the seal disc.

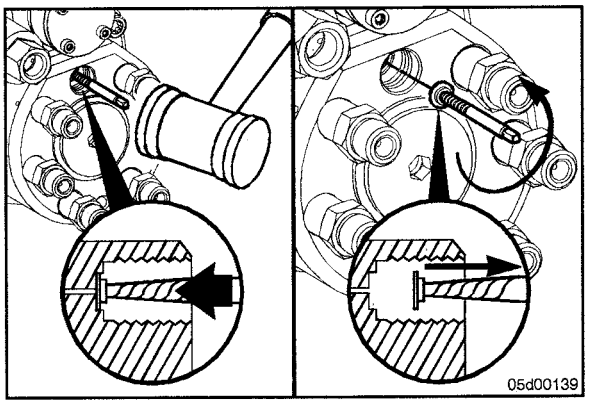
Two (2) types of inlet fittings and sealing washers may be in use. A flat washer will be installed in most new pumps and a piloted washer will be installed in some ReCon® pumps. The piloted washer is provided in service kits to aid installation.

Different removal techniques are necessary based on the type of sealing washer being removed.



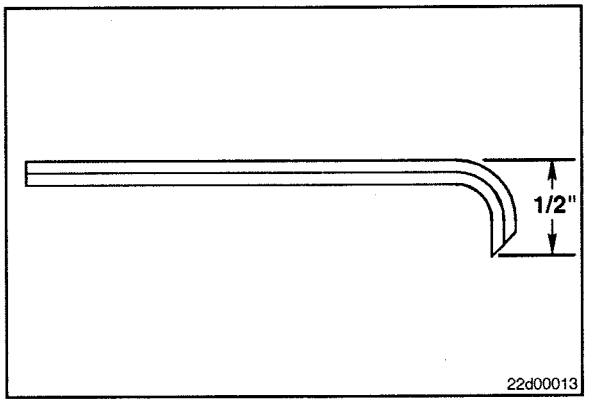
Removal of "piloted seal washer"

Using a plastic hammer, tap a spiral easy out into the center hole of the sealing washer. Turn the easy out **counterclockwise** to dislodge the washer.



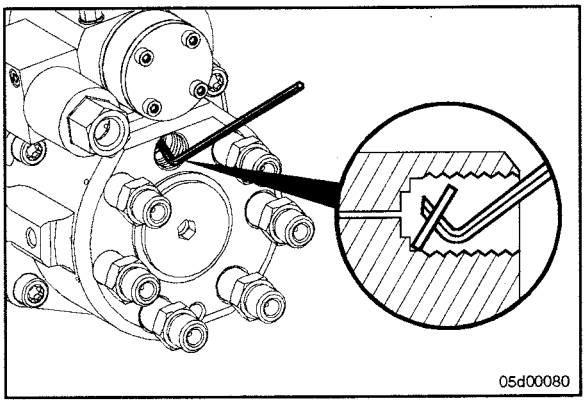
Removal of a "flat washer"

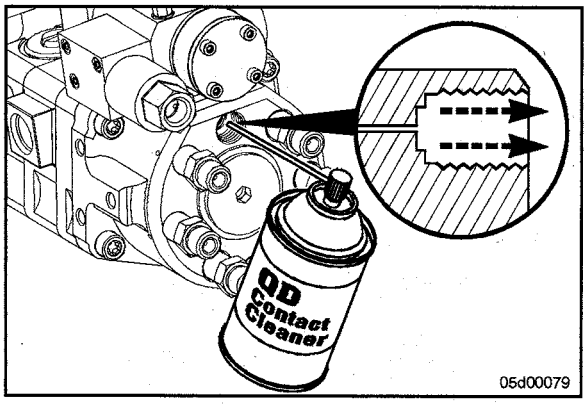
The flat sealing washer is swaged into the inlet fitting bore during installation. A special tool can be made to aid in its removal by grinding the short leg of a 1/8-inch or 3/16-inch Allen wrench so that the wrench is no longer than 13-mm [1/2-in] long (measured from the outside of the long leg). This tool acts as a mini heal bar to pry out the sealing washer without damaging the back of the hole.



Pry out the old sealing washer using the modified Allen wrench.

Quite a bit of force is required to remove the sealing washer.



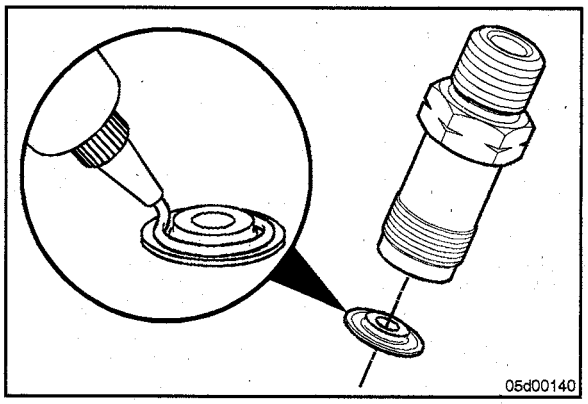


Clean and Inspect for Reuse

⚠CAUTION⚠

Any debris left in this fitting during assembly will run through the fuel pump. Damage the to fuel pump can occur.

Using QD contact cleaner, Part Number 3824510, clean the inlet fitting bore from the bottom of the bore outward.



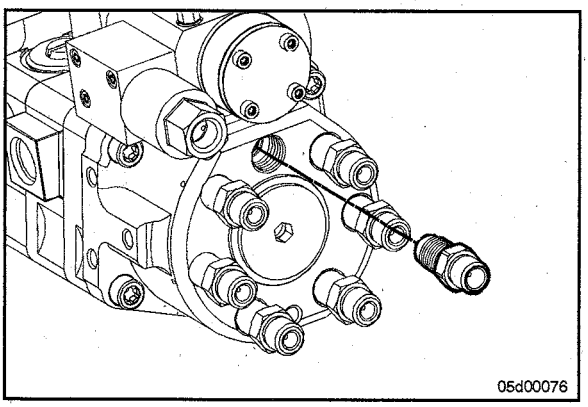
Install

⚠CAUTION⚠

Any dirt trapped in this fitting during assembly will run through the fuel pump. Damage to the fuel pump can occur.

Use clean grease to retain the sealing washer to the inlet fitting while it is being installed into the bore. Use Lubriplate™ 105, or equivalent.

Install sealing washer into counterbore in the inlet fitting.



Install a new inlet fitting.

Tighten the fitting after sealing washer is seated correctly.

Torque Value: Step1 5.7 N•m [50 in-lb]
Step2 Rotate 120 degrees clockwise

Finishing Steps

Install the rate shape tube assembly. Refer to Procedure 005-090.

Start the engine and check for fuel leaks at the rate shape tube connections.

Road-test the vehicle. Recheck for fuel leaks or active fault codes.

Fuel Pump Accumulator Module (005-085)

Preparatory Steps

⚠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.

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△

Make sure that steam does not spray directly on the electrical connections on the top of the accumulator block, or fault codes will possibly occur.

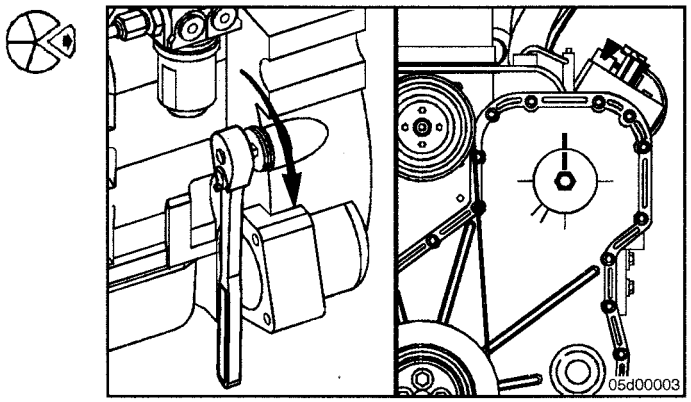
Thoroughly steam-clean the entire fuel pump.

Dry the fuel pump with compressed air.

Remove

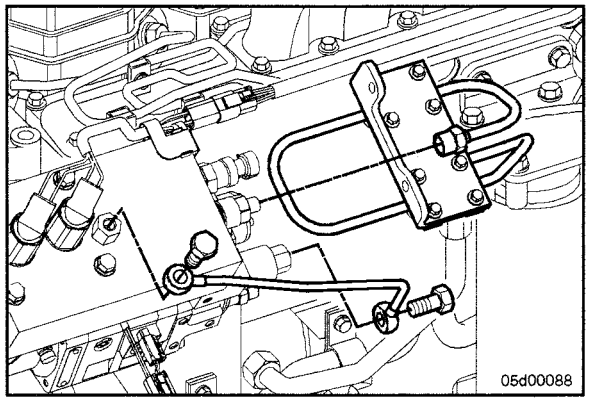
Remove the fuel pump drive gear cover.

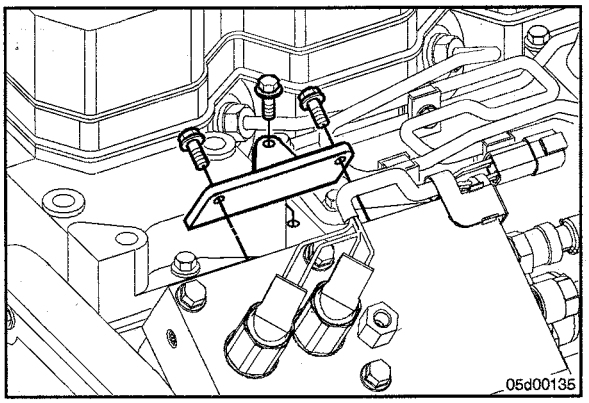
Locate top dead center for cylinder number 1 by barring the engine slowly until the line on the pump gear lines up with the line on the gear cover.



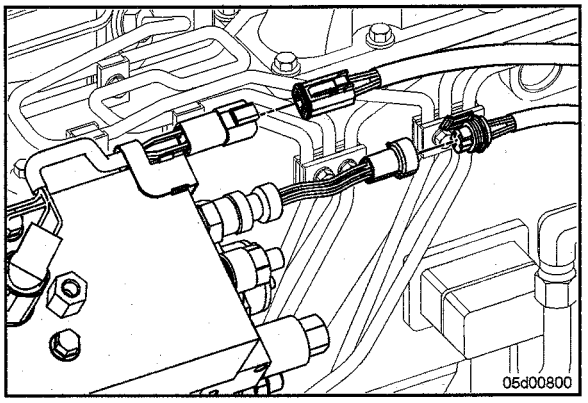
Remove the rate shape tube assembly. Refer to Procedure 005-090.

Remove the air bleed line. Refer to Procedure 006-056.





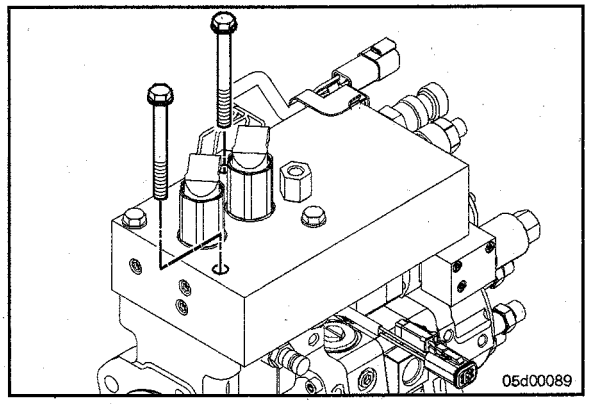
Remove the fuel pump upper support bracket.



Disconnect the 4-pin Deutsch connector for the pumping control valves.

Disconnect the pressure and temperature sensors.

NOTE: The pressure sensor connector has a potted pigtail connector. This sensor can **only** be disconnected at the engine harness end of the pigtail harness.



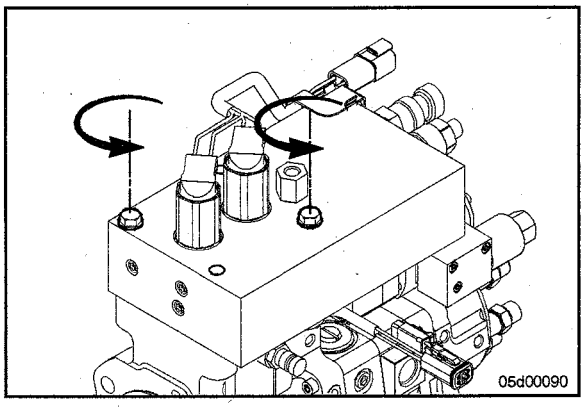
⚠WARNING⚠

The accumulator module weighs 11 kg [25 lb] and is free to move once the capscrews are removed. Do not drop; personal injury can occur.

△CAUTION△

Do not use air tools. The use of air tools will possibly damage the fuel pump.

Remove two of the four capscrews that are located diagonally from one another.



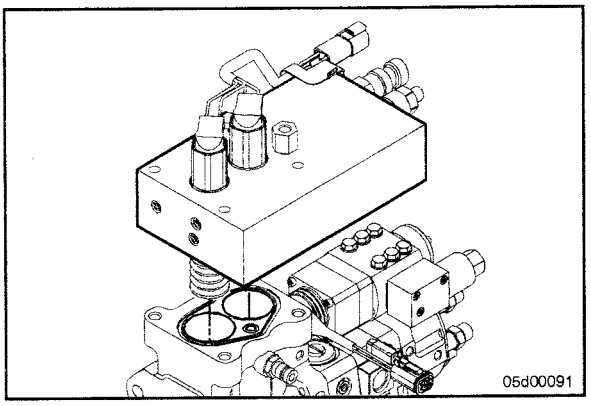
Remove the last two capscrews. Alternately loosen the capscrew to avoid binding. Loosen each capscrew about one turn at a time.

⚠WARNING⚠

The accumulator module weighs 11 kg [25 lb] and is free to move once the capscrews are removed. Do not drop; personal injury can occur.

Remove the accumulator module.

Use as much care as possible to avoid dislodging the springs from the bottom of the accumulator.



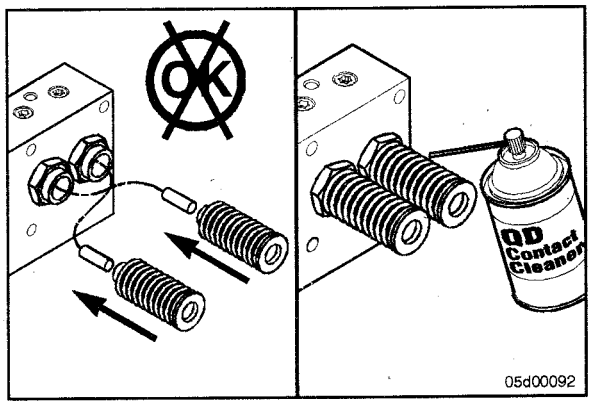
If the springs are dislodged, the ceramic plungers can fall out. The plungers are matched to each bore.

Reseat the springs fully onto plunger barrels.

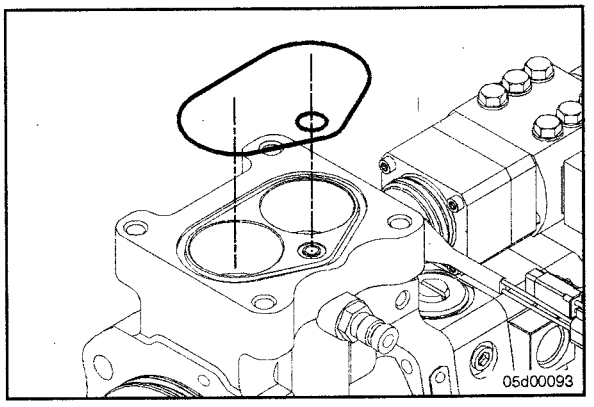
Do **not** interchange the plungers.

NOTE: Before replacing a ceramic plunger, special care needs to be taken to clean it.

Use QD contact cleaner, Part Number 3824510, to clean the plunger.



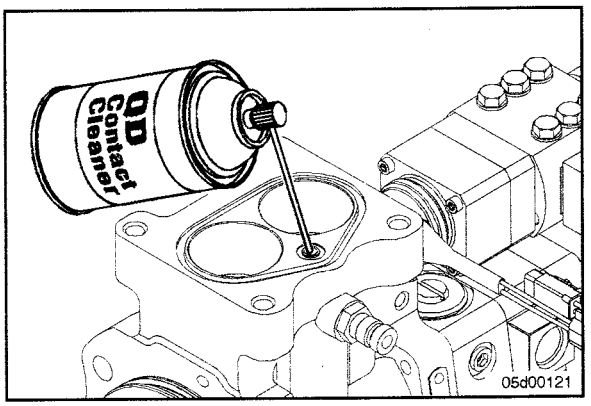
Remove the oil seal ring and fuel passage o-rings.

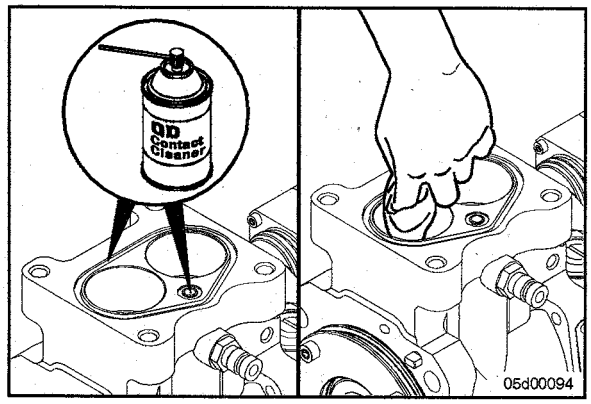


Clean and Inspect for Reuse

Clean the small fuel passage using the plastic tube provided with the contact cleaner.

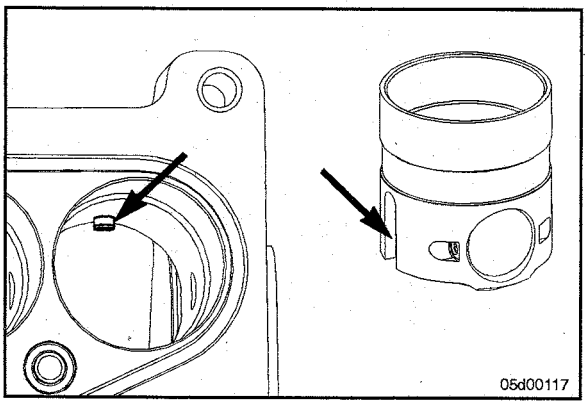
Use QD contact cleaner, Part Number 3824510.





Clean the o-ring groove and mounting surface on the cam housing and the accumulator.

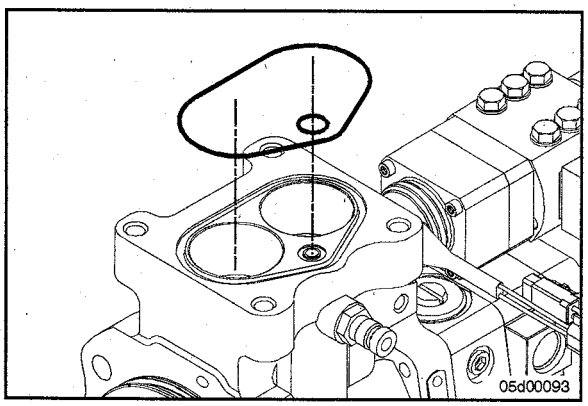
Make sure the top of the tappets in the cam housing are clean. Wipe out debris with a clean towel.



Check the tappets for proper alignment.

The tappets have a slot on the side that engages a pin on the engine side of the cam housing. The pin keeps the roller aligned with the camshaft. Make sure the tappet assembly is properly aligned. Make sure the tappet guide pins and guide pin grooves are **not** worn excessively.

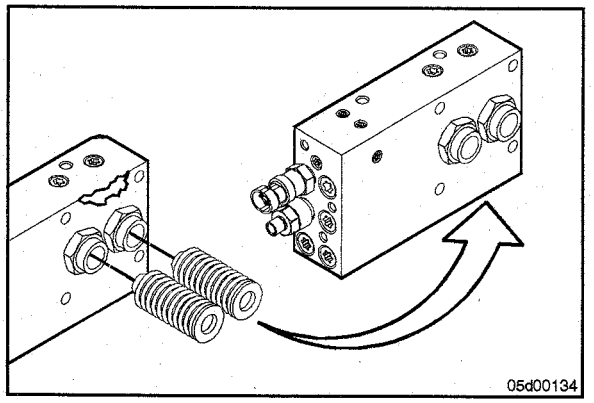
With the tappets removed, the tappet rollers and camshaft can be inspected. Linear scratches on the cam and rollers is expected; pitting on the nose of the camshaft is **not**.



Install

Install a new oil ring seal and fuel passage o-ring.

Apply Lubriplate™ 105, or equivalent, to the o-ring grooves to hold the o-rings in place.



⚠CAUTION⚠

The ceramic plungers can fall out when removing the plastic caps or old springs. Do not interchange the plungers. If they fall out, use QD contact cleaner, Part Number 3824510, to clean the plungers thoroughly before replacing them.

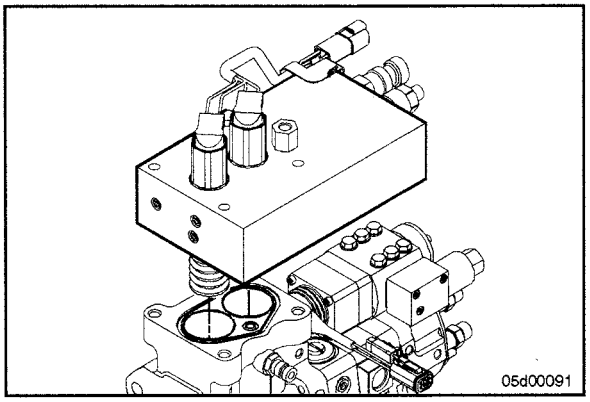
If replacing the accumulator module with a new one, remove the springs from the old accumulator module.

Fully install the springs on the plunger barrels of the new accumulator module.

NOTE: The use of two 10-mm x 80-mm studs will aid in the installation.

Install the accumulator module.

NOTE: Use care to avoid dislodging the springs on the accumulator and the o-rings on the cam housing.

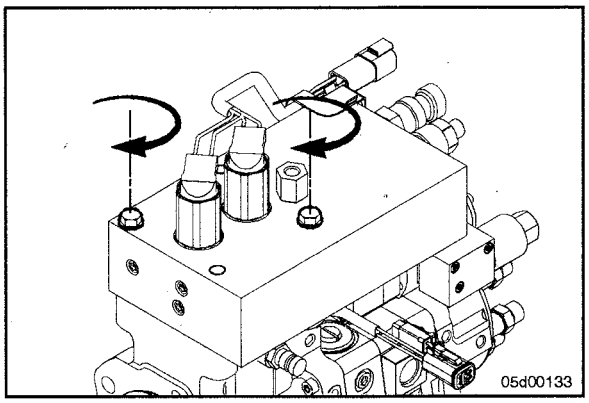


⚠CAUTION⚠
Do not use air tools. The use of air tools will possibly damage the fuel pump.

Install two of the four capscrews.

Draw the accumulator module down evenly. **Only** turn each capscrew about one turn at a time.

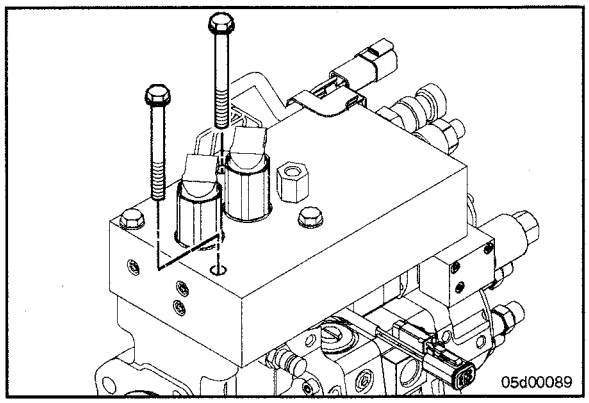
Make sure the o-rings are still in their grooves before the accumulator is fully tightened to the cam housing. Use a mirror if necessary.



Install remaining two capscrews.

Tighten the four capscrews.

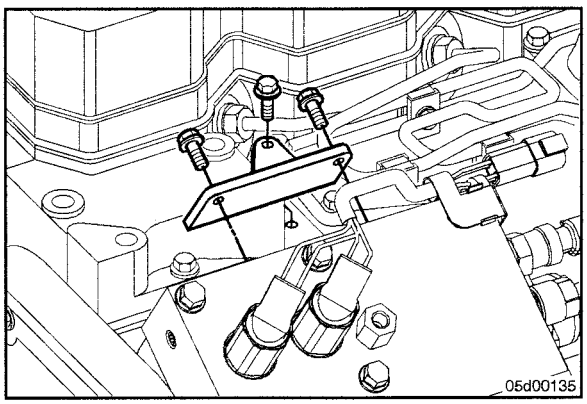
Torque Value: 68 N•m [50 ft-lb]



Install the upper support bracket.

Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]



Finishing Steps

Install rate shape tube assembly. Refer to Procedure 005-090.

Install the air bleed line. Refer to Procedure 006-056.

Install the drive gear cover.

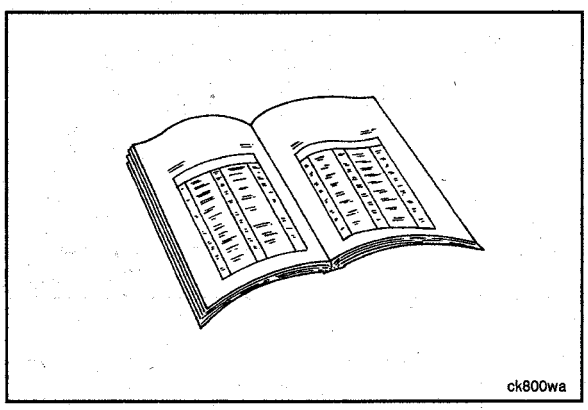
Connect the fuel pressure sensor and the fuel temperature sensors to the engine harness.

Connect the pumping control valve connector to the engine harness.

Start the engine and check for fuel leaks or active fault codes.

Road-test the vehicle.

Recheck for fuel leaks or active fault codes.


ck800wa

Fuel Pump Distributor and Injection Control Valve Module (005-086)

Preparatory Steps

⚠WARNING⚠

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

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△

Fault codes can occur if steam sprays directly on the electrical connections on top of the accumulator block.

- Thoroughly steam-clean the entire fuel pump.
- Dry the fuel pump with compressed air.
- Remove the air bleed line. Refer to Procedure 006-056.
- Remove the fuel pump from the engine, if necessary. Refer to Procedure 005-016.
- Mount the fuel pump in the vise ring. Orient the pump with the distributor facing upward to aid in disassembly.
- Remove the rate shape tube assembly. Refer to Procedure 005-090.

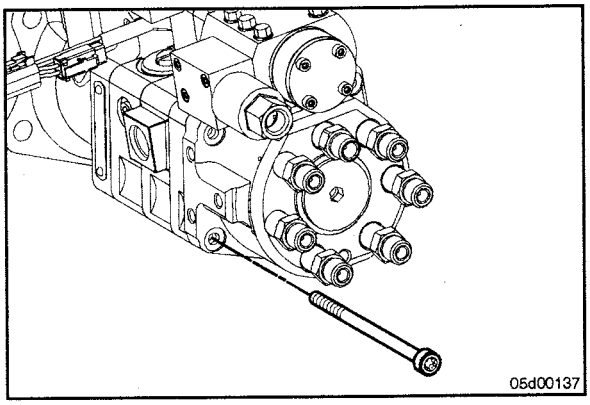
Remove

⚠CAUTION⚠

The capscrews also fasten the gear pump module. The gear pump is free to move after the capscrews are removed.

Loosen but do **not** remove the distributor plug.

Remove the four mounting capscrews on the distributor.

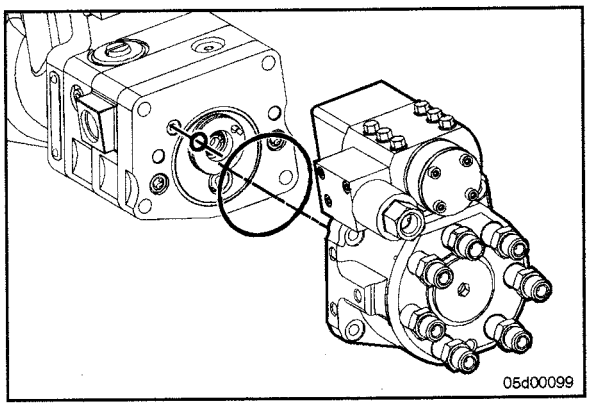


Remove the injection control valve/distributor module.

Remove the drive coupling.

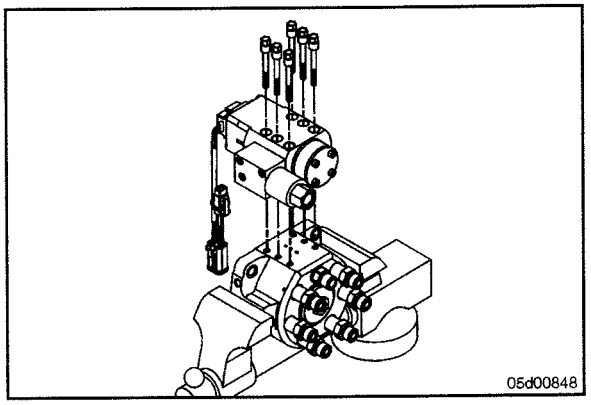
Discard the two o-rings.

Place the injection control valve/distributor module on a clean bench vise.



Remove the injection control valve from the distributor module and install the injection control valve on the new distributor module. Refer to Procedure 005-078.

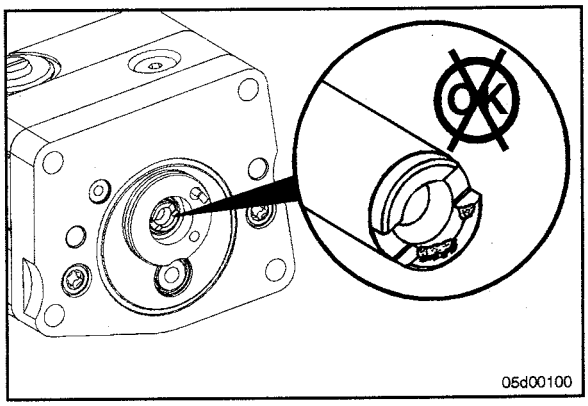
NOTE: Injection control valves built before January 2001 are **not** reusable. If removing an injection control valve built before January 2001, use the appropriate injection control valve kit to complete the repair.

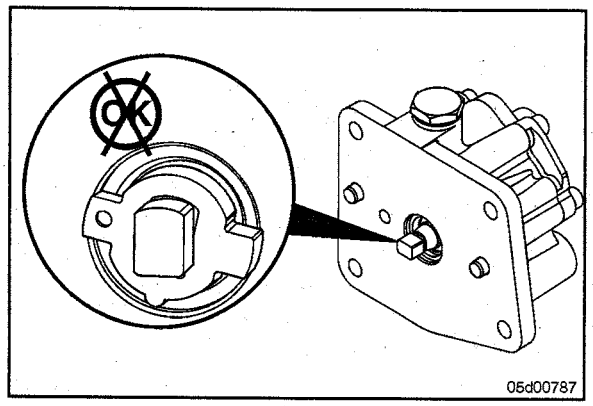


Clean and Inspect for Reuse

Inspect coupling and gear pump shaft ends for excessive wear. Wear may be found on the inside corners of the coupling groove; such wear is **not** common.

A polished surface is acceptable.

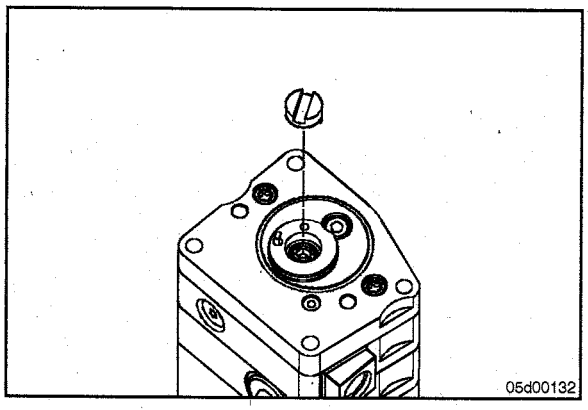




Replace the gear pump module if wear is visible.

Replace the gear pump module if the gear pump driveshaft is damaged.

NOTE: A distributor rotor seizure can cause damage to the gear pump. If rotor seizure is suspected, inspect the gear pump. Refer to Procedure 005-089.

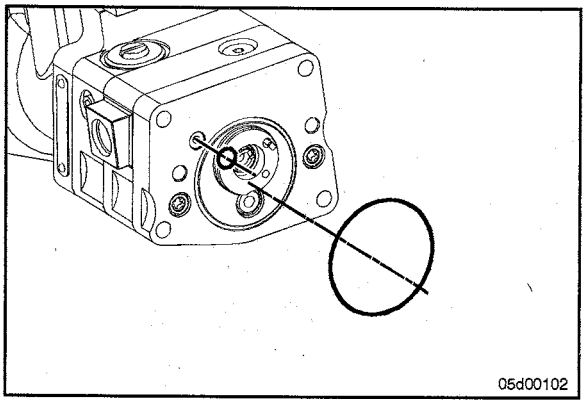


Install

Install the drive coupling.

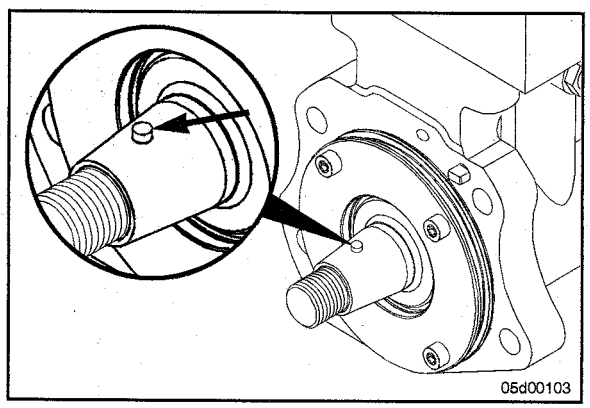
Center the coupling on the gear pump shaft.

Apply Lubriplate™ 105, or equivalent, to the coupling to keep it from sliding in the shaft groove during assembly.



Install new o-rings.

Apply Lubriplate™ 105, or equivalent, to the o-rings to keep them from falling out during assembly.



The dowel pin **must** be facing up toward the top of the pump.

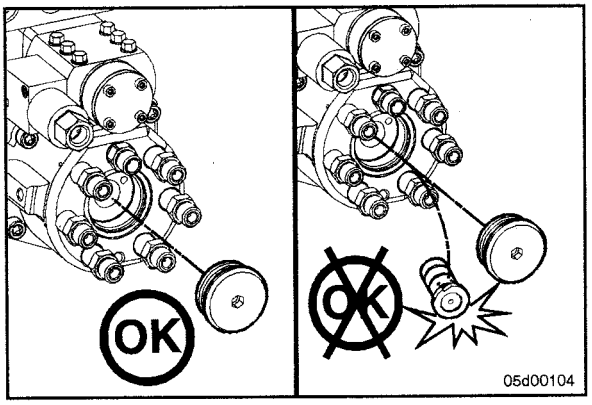
If the shaft needs to be rotated, install the fuel pump drive nut onto the shaft to provide a means for rotating the shaft.

⚠CAUTION⚠
The rotor can slide out once the distributor plug is removed.

⚠CAUTION⚠
Do not drop the rotor. Damaging the rotor will necessitate replacement of the entire distributor module.

Remove the large plug from the end of the distributor.

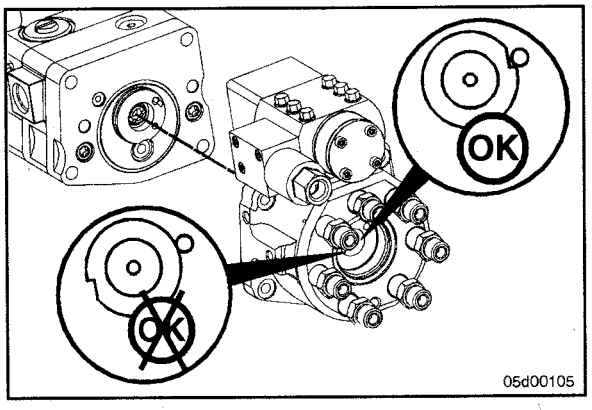
Do **not** remove the rotor.



Install the distributor module.

Lightly rotate the rotor with finger pressure until it drops into the slot in the drive coupling.

When properly engaged, the notch in the rotor will align with the hole in the distributor (when the engine is at top dead center for number 1 cylinder).

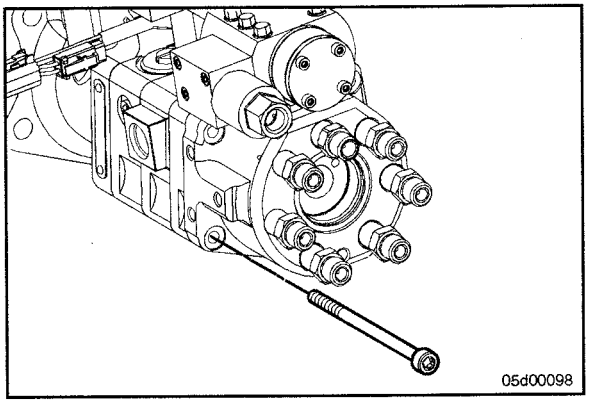


Do **not** pinch the o-rings.

Install the four distributor capscrews.

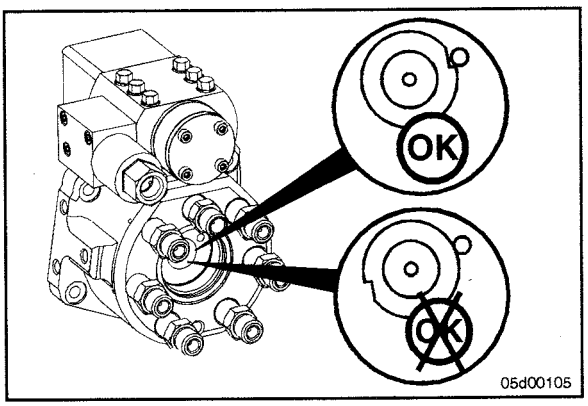
Tighten the capscrews.

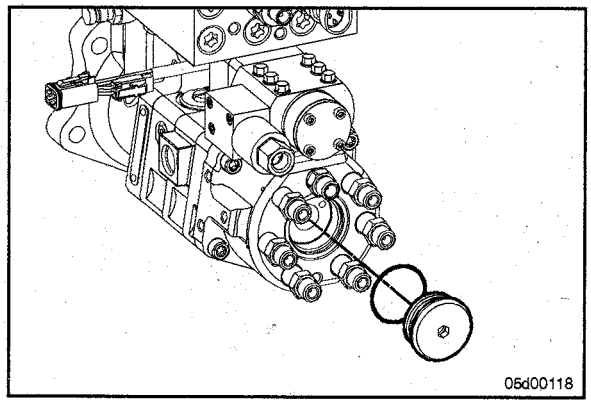
Torque Value: 48 N•m [35 ft-lb]



⚠CAUTION⚠
The rotor must be properly timed to the fuel pump camshaft. Improper assembly will cause the rotor to be 180 degrees out of time.

If **not** properly timed, reinstall the drive coupling and rotor. Refer to Procedure 005-072.



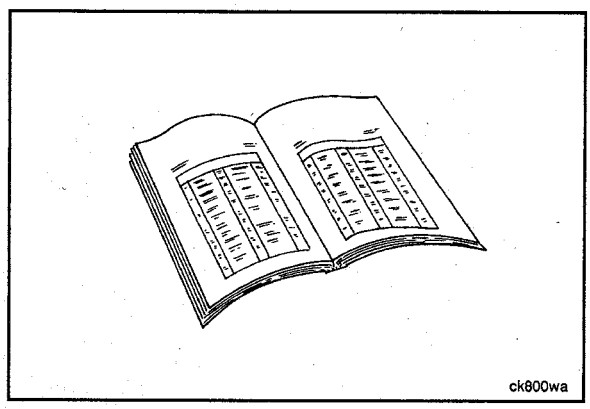


Install a new o-ring on the distributor plug.

Install the large plug at the end of the distributor.

Tighten the distributor plug.

Torque Value: 14 N•m [120 in-lb]



Finishing Steps

- Install the rate shape tube assembly. Refer to Procedure 005-090.
- Install the fuel pump on the engine. Refer to Procedure 005-016.
- Install the air bleed line. Refer to Procedure 006-056.
- Run the injection control valve click test using INSITE™. Refer to Procedure 005-078.
- Start the engine and check for fuel leaks or active fault codes.
- Road-test the vehicle for at least one mile. Recheck for fuel leaks or active fault codes.

Fuel Pump Cam Housing Module (005-088)

Preparatory Steps

⚠ WARNING ⚠

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

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△ CAUTION △

Make sure that steam does not spray directly on the electrical connections on the top of the accumulator block, or fault codes will possibly occur.

Thoroughly steam-clean the entire fuel pump.

Dry the pump with compressed air.

Bar the engine to TDC.

Remove

CAPS Fuel System

Remove the air bleed line (1). Refer to Procedure 006-056.

Remove the fuel pump from the engine. Refer to Procedure 005-016.

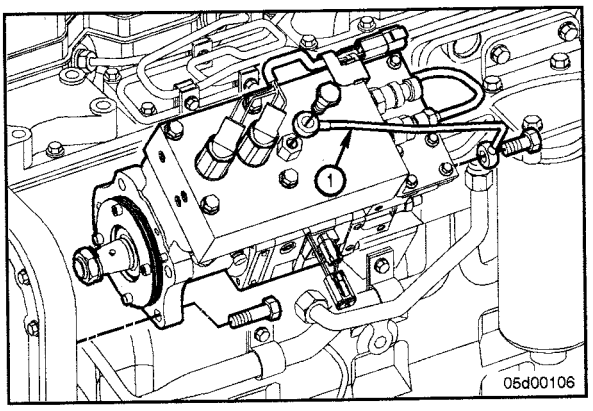
Mount the fuel pump to the mounting plate, Part Number 3162897, and orient the fuel pump with the distributor facing upward to aid in disassembly.

Remove the rate shape tube assembly. Refer to Procedure 005-090.

Remove the accumulator module. Refer to Procedure 005-085.

Remove the distributor module. Refer to Procedure 005-086.

Remove the gear pump module. Refer to Procedure 005-089.

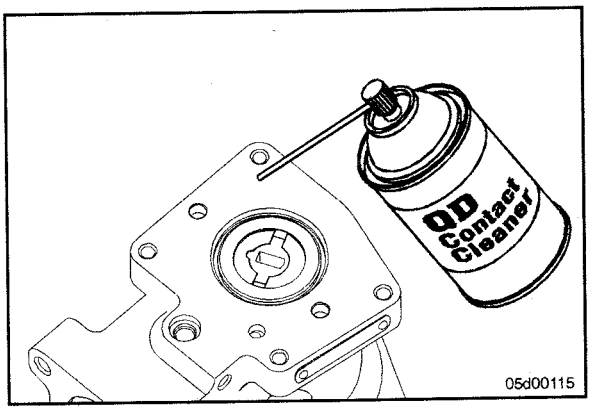


Clean and Inspect for Reuse

Clean the mounting surfaces of the cam housing.

Use QD contact cleaner, Part Number 3824510.

Inspect the camshaft coupling interface for wear. If the camshaft is worn excessively, replace the cam housing module.



⚠CAUTION⚠

If the tappets are removed, be sure to install them in the same bore they were removed from.

Remove the roller tappets from the cam housing bores.

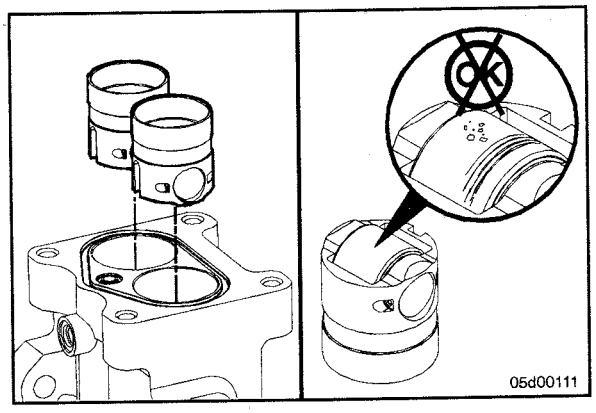
Inspect the roller surfaces for pitting and wear.

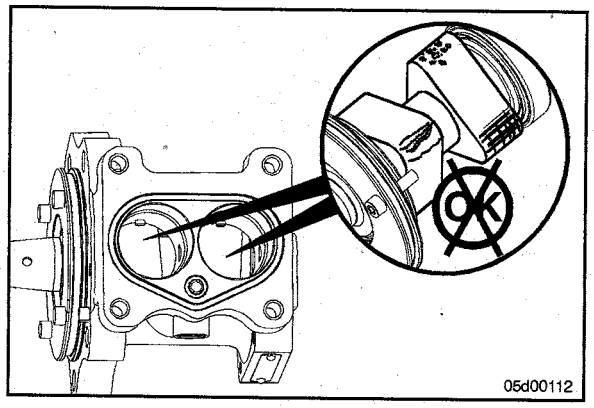
Make sure the roller rotates freely and smoothly.

Replace the cam housing module if the rollers are worn.

NOTE: It is normal to see lines (scratches) worn in the direction of roller travel. The cam housing or tappets should be replaced if the rollers are pitted.

Examine the tappets guide pin slots. If the guide pin slot is worn more than 25-percent of its original width, the tappet **must** be replaced.

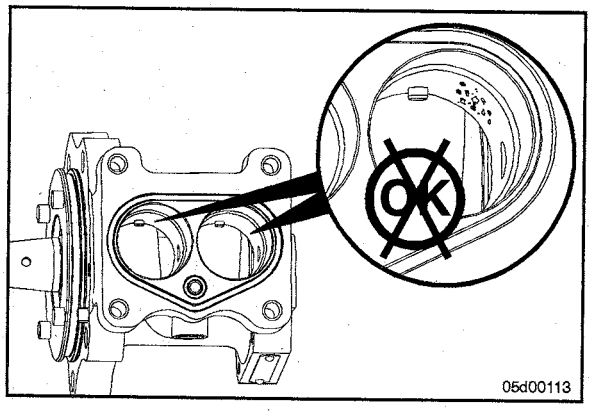




Inspect the guide pins. If the guide pins are worn or if oil leaks at the cam housing guide pin press fit, the cam housing **must** be replaced.

Inspect the camshaft lobes for pitting and wear. Replace the cam housing if there is any pitting or wear.

Inspect for raised burrs in the tappet bore. Replace the cam housing if raised burrs are present. Scratching or polishing is normal.

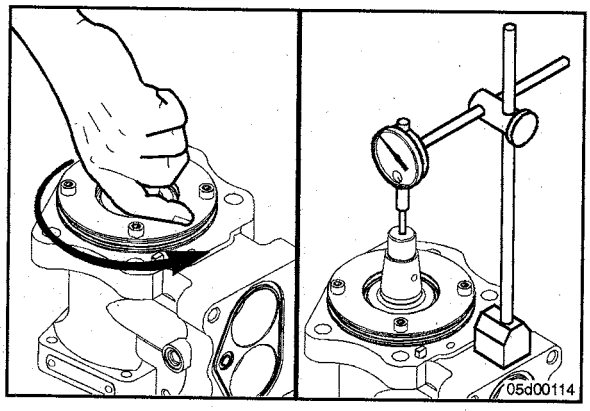


Inspect the tappet bores for scuffing or wear leading into the housing.

Polishing will occur in vertical bands at many places around the inside of the bores.

Polish in the bores is acceptable.

Replace the cam housing if there is severe tappet guide pin wear (more than 25-percent of tappet pin is worn).

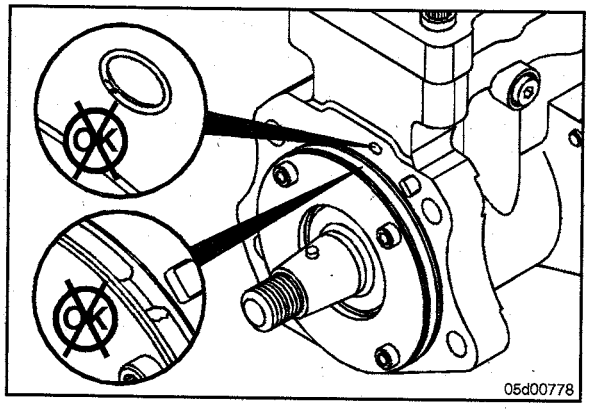


Using fingers, make sure the camshaft turns freely. The bearings **must** turn smoothly and freely during rotation.

Replace the cam housing if the bearings are tight or rough.

Check the camshaft for end-play.

Camshaft End-Play		
mm		**in**
0.05	MAX	0.002

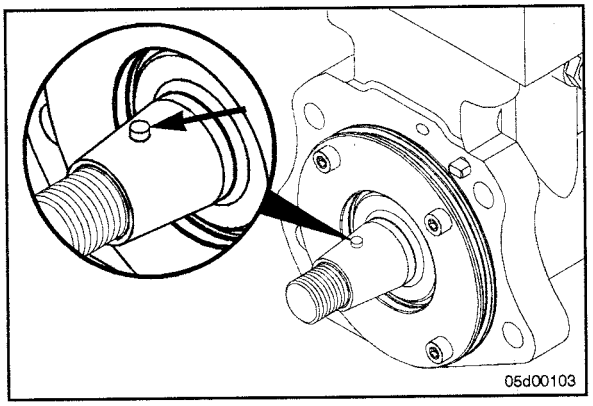


Inspect the oil feed and pump mounting o-ring.

Install

CAPS Fuel System

Make sure the timing dowel pin in the camshaft points toward the top of the fuel pump.

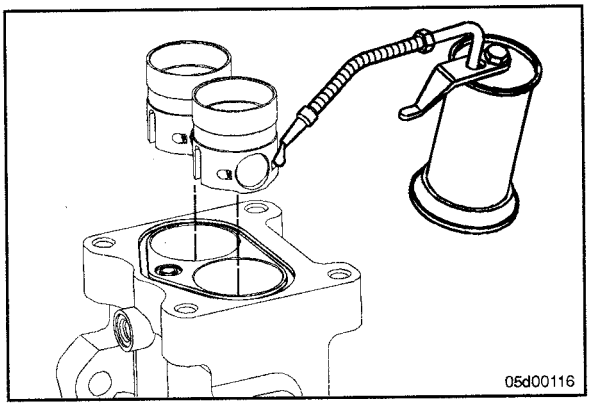


Lubricate the tappets and camshaft lobes with clean 15W-40 engine oil.

Install the roller tappets into the cam housing. Be sure that the tappets guide grooves are oriented correctly onto the tappet guide pins. Also, be sure that the tappet assemblies are installed in their original bores.

Check the tappets for proper alignment.

The tappets have a slot on the side that engages a pin on the engine side of the cam housing. The pin keeps the roller aligned with the camshaft. Make sure the tappet is properly aligned.

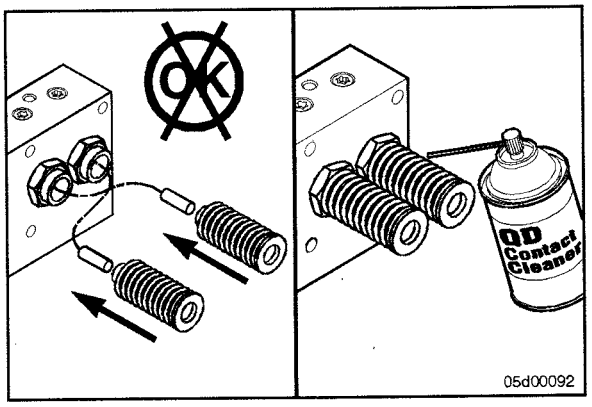


⚠CAUTION⚠

The ceramic plungers will possibly fall out when removing the springs. Do not interchange the plungers or change their upwards orientation. If the plungers are removed, use QD contact cleaner, Part Number 3824510, to clean them before replacing.

NOTE: When assembling the fuel injection pump, take care to keep the ceramic pumping plungers in their original orientation in the accumulator module.

If **not** already done, install the spring and tappet retainers onto the accumulator or fuel pump barrel assemblies.



Install the gear pump module. Refer to Procedure 005-089.

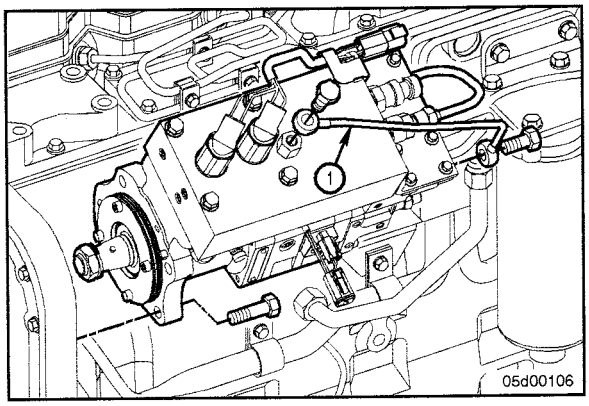
Install the distributor module. Refer to Procedure 005-086.

Install the accumulator module. Refer to Procedure 005-085.

Install the rate shape tube assembly. Refer to Procedure 005-090.

Install the fuel pump onto the engine. Refer to Procedure 005-016.

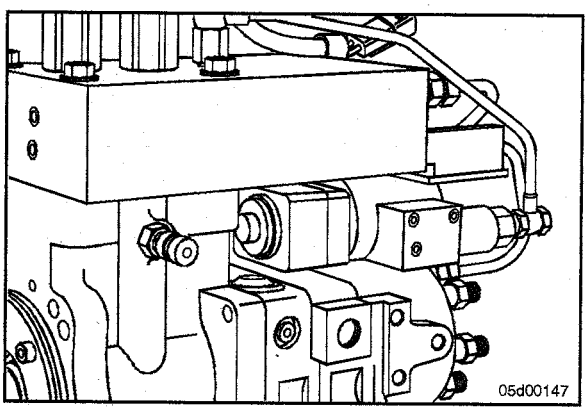
Install the air bleed line. Refer to Procedure 005-056.



Finishing Steps

Start the engine and check for fuel leaks or active fault codes.

Perform repeat throttle snaps to create increased accumulator or fuel rail pressure.



Fuel Pump Gear Pump Module (005-089)

Initial Check

Measure the outlet pressure at the diagnostic fitting on the CAPS pump at a rated flow condition and compare to the following chart.

Engine Speed (rpm)	Gear Pump Pressure kPa [psi]
200	14 [2]
700	138 [20]
1300	379 [55]
2200	827 [120]

Preparatory Steps

⚠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.

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris or dirt can cause personal injury.

△CAUTION△

Make sure that steam does not spray directly on the electrical connections on the top of the accumulator block, or fault codes will possibly occur.

Thoroughly steam-clean the entire fuel pump.

Dry the fuel pump with compressed air.

Remove the air bleed line. Refer to Procedure 006-056.

Remove the fuel pump from the engine. Refer to Procedure 005-016.

Mount the fuel pump in a vise ring. Orient the pump with the distributor facing upward to aid in disassembly.

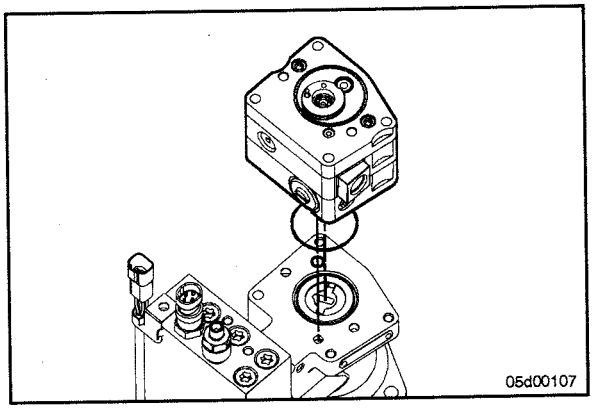
Remove the rate shape tube. Refer to Procedure 005-090.

Remove the distributor module. Refer to Procedure 005-086.

Remove

Remove the gear pump module.

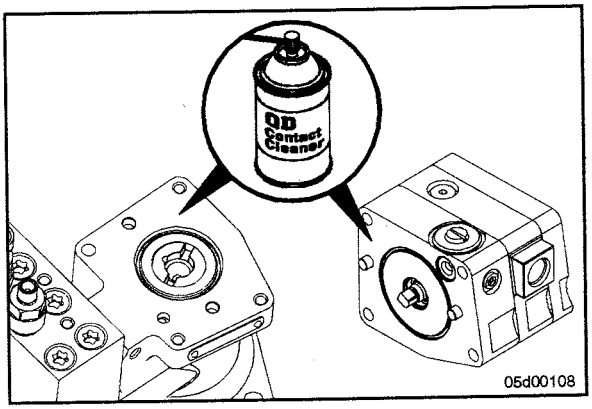
NOTE: Do **not** remove the two capscrews. The gear pump will slide off the dowel pins once the distributor is removed.

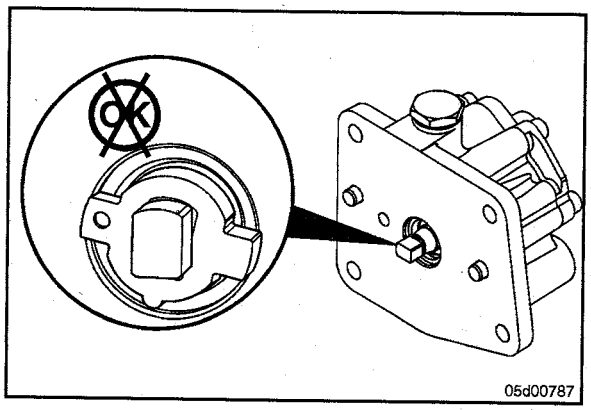


Clean and Inspect for Reuse

Clean the mounting surfaces of the gear pump and cam housing.

Use QD contact cleaner, Part Number 3824510.

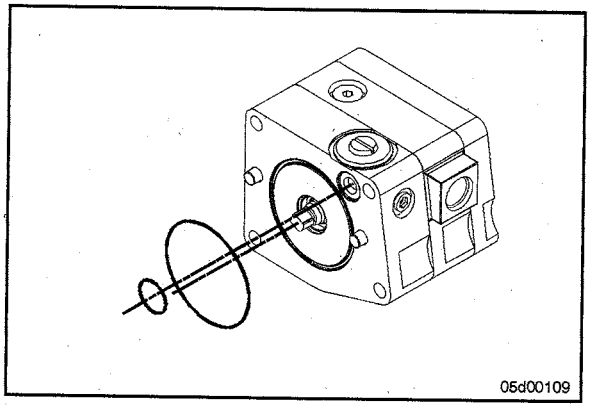




Inspect the drive coupling and shaft ends for excessive wear.

A polished surface is acceptable.

Replace the coupling if wear is visible.



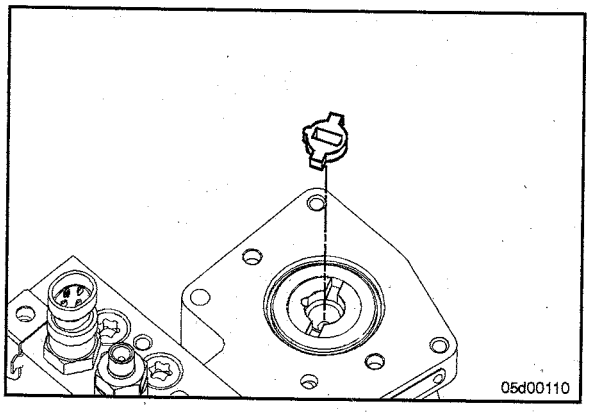
Install

⚠CAUTION⚠

The larger o-rings on either end of the gear pump differ in size. The longer o-ring goes to the side facing the cam housing.

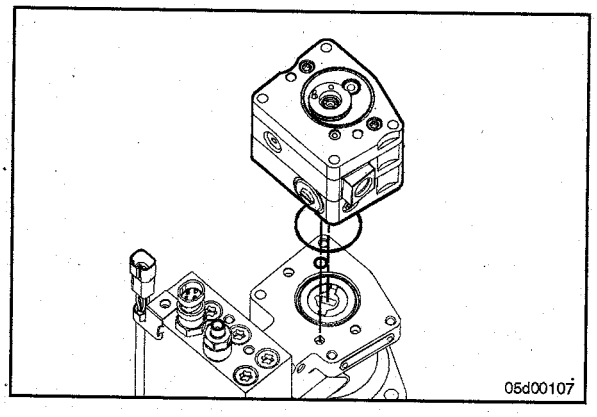
Install new o-rings.

Apply Lubriplate™ 105, or equivalent, to the o-rings to keep them from falling out during assembly.



Install the drive coupling.

Center the coupling in the shaft.



Align the gear pump shaft with drive the coupling and install the gear pump module.

Make sure the o-rings are **not** pinched.

Make sure the timing dowel pin is facing toward the top of the fuel pump.

Finishing Steps

Install the distributor module. Refer to Procedure 005-086.

Install the rate shape tube. Refer to Procedure 005-090.

Install the fuel pump on the engine. Refer to Procedure 005-016.

Install the air bleed line. Refer to Procedure 006-056.

Start the engine and check for fuel leaks or active fault codes.

Road-test the vehicle for at least one mile. Recheck for fuel leaks or active fault codes.

Fuel Pump Rate Shape Tube (005-090)

Preparatory Steps

⚠WARNING⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠CAUTION⚠

Make sure that direct steam spray stream does not contact the electrical connections on the top of the accumulator block; fault codes will possibly occur.

Thoroughly steam-clean the entire fuel pump.

Dry the fuel pump with compressed air.

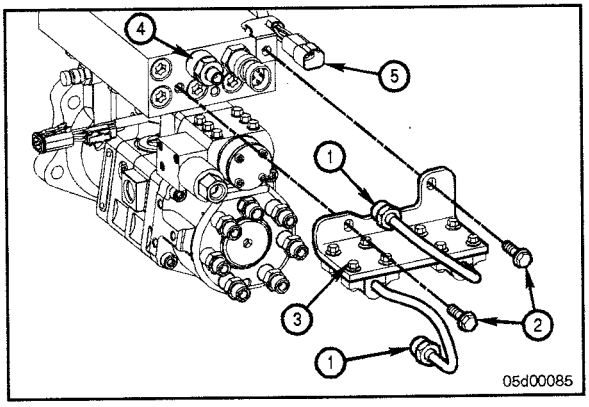
Remove

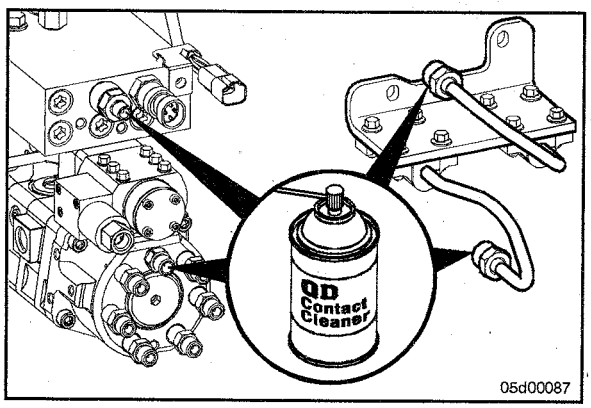
Loosen the two rate shape tube nuts (1).

Remove the two bracket capscrews (2).

Remove the rate shape tube assembly.

Do **not** loosen or remove the isolator capscrews (3).





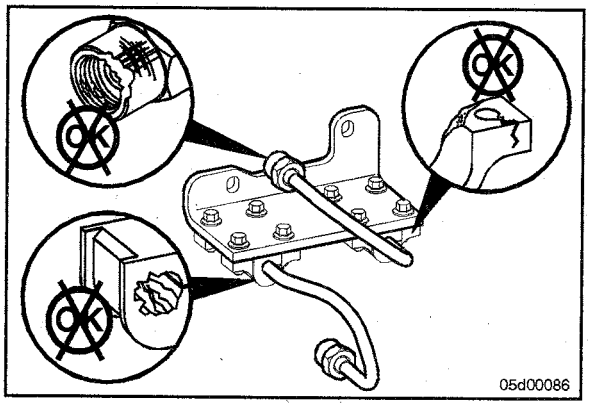
Clean and Inspect for Reuse

Clean the ends of the rate shape tube.

Clean out the rate shape tube with contact cleaner if debris is suspected of entering the tube.

Flush any dirt from the snubber fitting and distributor inlet fitting.

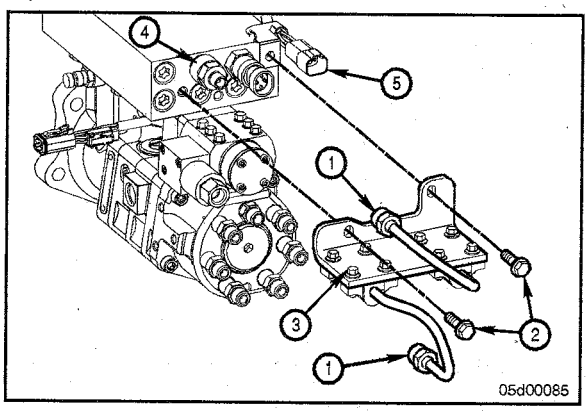
Use QD contact cleaner, Part Number 3824510.



Inspect isolators for signs of wear or cracks.

Replace the rate shape tube assembly if any isolator is worn, cracked, or missing.

Inspect the ends of the rate shape tube for damage.



Install

Install the rate shape tube assembly using the following steps:

1. . Install the tube nuts (1) and capscrews (2) finger tight
2. . Tighten the rate shape tube nuts (1)

Torque Value: 46 N•m [34 ft-lb]

3. Tighten the two bracket capscrews (2).

Torque Value:

Capscrew	41 N•m	[30 ft-lb]
Thermistor Adapter	34 N•m	[25 ft-lb]

NOTE: If any force is required to flex the rate shape tube in order to start the tube nuts, the rate shape tube **must** be replaced with a new tube.

NOTE: Make sure the harness clip is installed between the bracket and capscrew, **not** between the bracket and accumulator.

Finishing Steps

Start the engine and check for fuel leaks at the rate shape tube connections.

Fuel Pump Head Outlet Fitting (005-226)

Preparatory Steps

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris or dirt can cause personal injury.

Thoroughly clean the entire fuel pump.

Dry the fuel pump with compressed air.

Remove the high-pressure fuel line from the fuel pump actuator housing. Refer to Procedure 006-051.

Remove the fuel drain line from the actuator housing. Refer to Procedure 006-013.

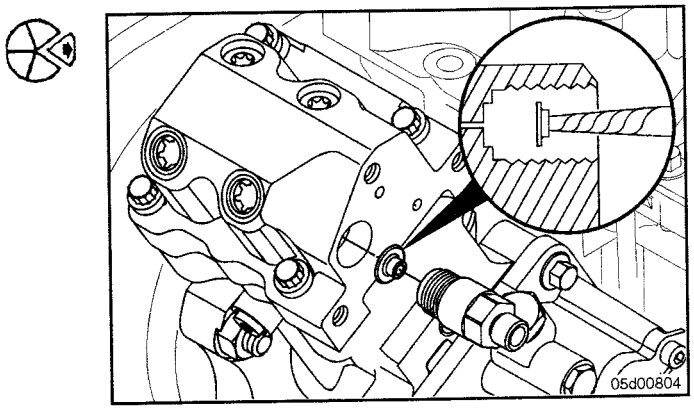
Remove the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024.

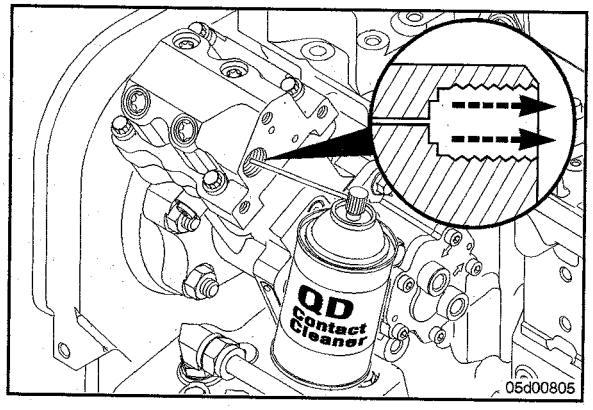
Remove the fuel pump actuator housing from the high-pressure fuel pump. Refer to Procedure 005-228.

Remove

Remove the fuel pump head outlet fitting and the seal washer from the threaded hole in the back of the high-pressure pump head.

NOTE: It is necessary to remove the seal washer with the aid of a tapered punch. Insert a tapered punch into the center of the seal washer and work the seal out from the bore in the back of the high-pressure pump head.





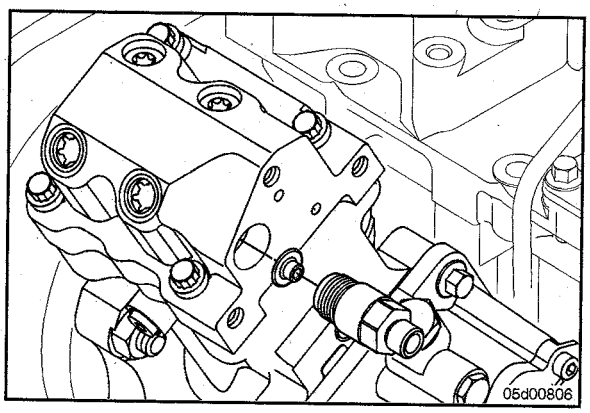
Clean and Inspect for Reuse

Clean the threaded hole in the high-pressure pump head with QD contact cleaner, Part Number 3824510.

Inspect the threads and cavity in the high-pressure pump head for burrs or debris.

Inspect the seal washer end of the outlet fitting. There should be a polished crown that is free of nicks or inclusions. If the crown is damaged or severely flattened, the male union **must** be replaced.

Clean any burrs with a wire brush then flush the bore clean.



Install

NOTE: This joint is designed to seal in excess of 179,264 kPa [26,000 psi]. Seal washers **must not** be reused.

Install a new seal washer onto the outlet fitting. The seal washer should pilot into the outlet fitting. A small amount of very clean grease, such as Lubriplate™, will help in keeping the seal attached to the outlet fitting during installation.

Torque Value: Step1 5.6 N•m [50 in-lb]
Step2 Rotate 120 degrees

Finishing Steps

Install the fuel pump actuator housing to the high-pressure fuel pump. Refer to Procedure 005-228.

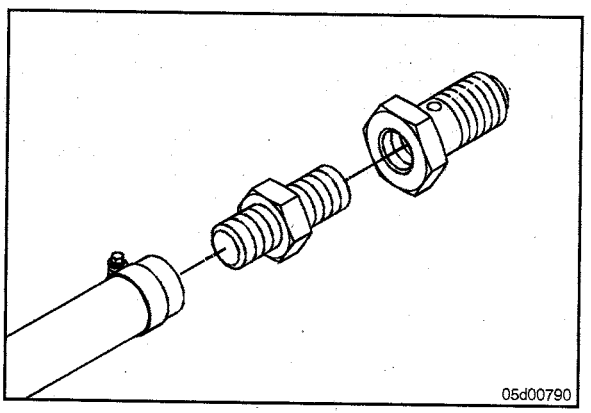
Install the high-pressure fuel line to the fuel pump actuator housing. Refer to Procedure 006-051.

Install the fuel drain line to the actuator housing. Refer to Procedure 006-013.

Install the fuel supply line to the fuel pump actuator housing. Refer to Procedure 006-024.

Operate the engine and check for leaks.

Perform several throttle snaps so that increased fuel rail pressure may be developed.



Fuel Pump Head (005-227)

Initial Check

This test utilizes a flow adapter fitting. The purpose of the flow adapter fitting is to route the drain flow of the fuel pump **only** into a collection device so that leakage may be measured.

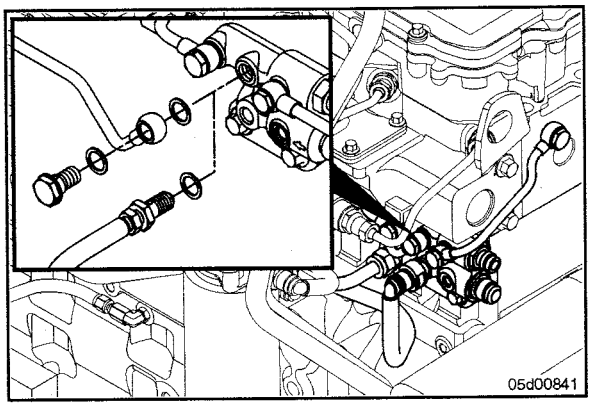
This tool, Part Number 3164618, can be purchased or constructed according to the procedures in Procedure 006-026.

Test Setup

Remove the banjo bolt from the fuel pump drain line at the fuel drain manifold.

Install a banjo flow adapter fitting at the fuel drain manifold and route a hose from this adapter to a bucket or the vehicle's fuel tanks.

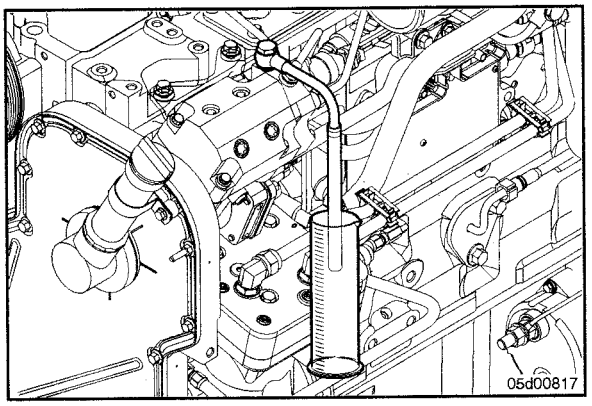
The pump drain line connects at the center connection point on the fuel drain manifold.



Alternate Test Setup

If the drain manifold is **not** easily accessed, a M14 banjo may be attached at the pump head drain port with a fuel hose that is routed to the collection container.

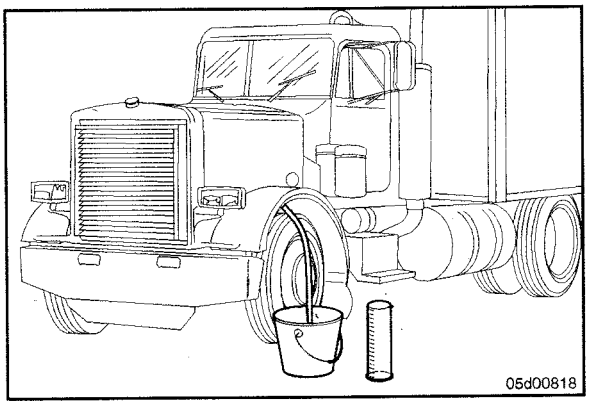
In this setup a bolt, nut, and washers are needed to prevent drain flow from flowing backwards and leaking from the unused drain line.



⚠CAUTION⚠

The high-pressure leakage test in the INSITE™ electronic service tool will cause the engine to operate at elevated pressures while the engine idles. The engine noise will change when this test is being performed due to the higher fuel injection pressures. Safety glasses should be worn while working near the running engine. Fuel lines should not be adjusted while performing this test.

Close the engine cover(s) while performing these tests.



Test (Engine Will Not Start)

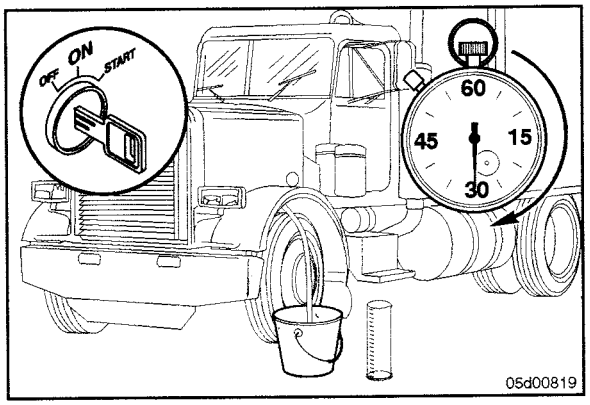
Turn the keyswitch ON and allow the lift pump to complete its cycle. Afterward the cycle is completed, begin cranking the engine until fuel exits the drain line.

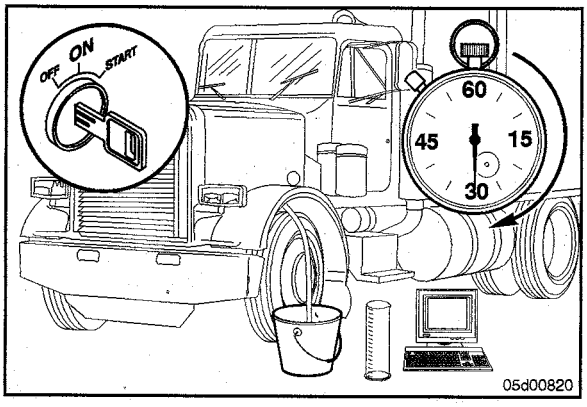
When fuel begins to exit the drain line, route the drain flow to a graduated cylinder and continue cranking for 30 seconds.

Maximum Volume of Fuel During Cranking

cc [oz]	seconds
200 [7]	30

If 200 cc [7 oz] pump head drain flow is collected in less than 30 seconds of cranking, the pump head has failed and **must** be replaced.



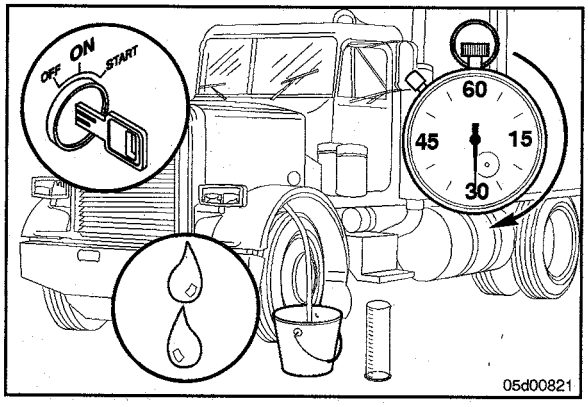


Test (Engine Will Start)

If the engine will start, perform the high-pressure leakage test using Cummins INSITE™ electronic service tool.

Connect the INSITE™ electronic service tool.
Start the engine and allow the engine to idle with fuel flowing into a collection device.
Begin the high-pressure leakage test using INSITE™.
Measure the time necessary to collect 300 cc [10 oz] of fuel pump head drain flow while performing the high-pressure leakage test.

Use a graduated cylinder for this measurement.

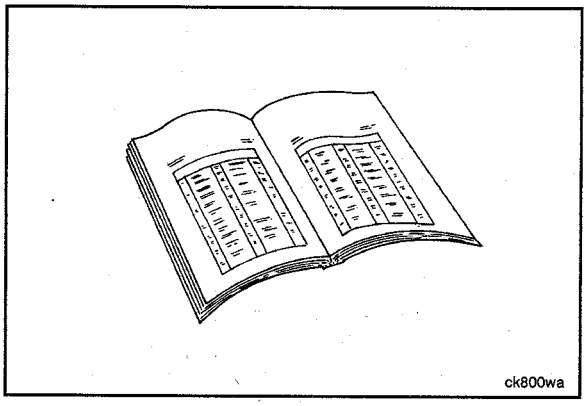


Maximum Volume of Fuel During High-Pressure Leakage Test

cc [oz]	seconds
300 [10]	30

If 300 cc [10 oz] pump head drain flow is collected in less than 30 seconds, the pump head has failed and **must** be replaced.

This specification is valid for engines operating on diesel fuels. Low fuel viscosity will increase the leakage rate; for example, kerosene or aviation fuels will result in excessive leakage. Verify the fuel type before replacing a fuel pump head for excessive leakage.



Preparatory Steps

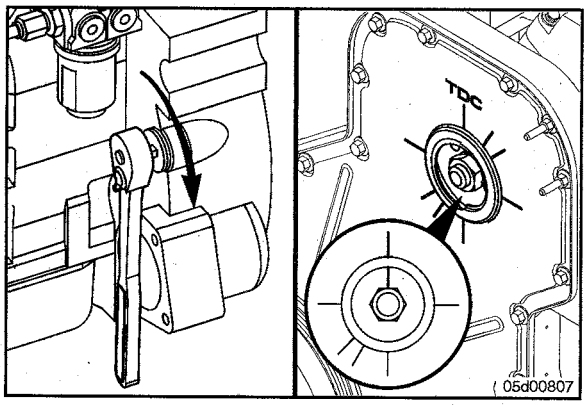
Remove the high-pressure fuel line from the high-pressure pump. Refer to Procedure 006-051.

Remove the fuel drain line from the fuel pump actuator housing. Refer to Procedure 006-013.

Remove the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024.

Disconnect the wire harness from the fuel pump actuator.

Remove the fuel pump actuator housing. Refer to Procedure 005-228



Remove the fuel pump drive gear cover.

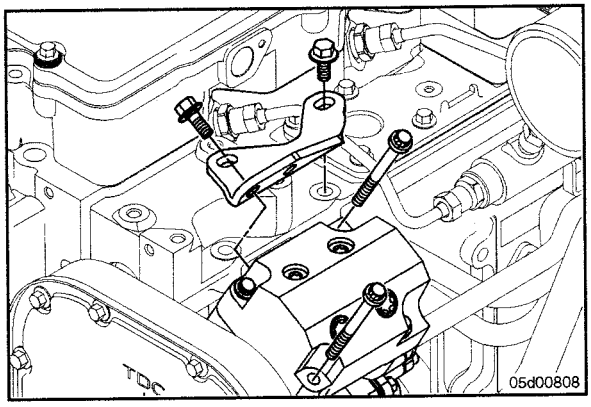
Locate top dead center for cylinder number 1 by barring the engine slowly until the line on the pump gear lines up with the line on the gear cover.

⚠CAUTION⚠

Do not use air tool. The use of air tools will possibly damage the fuel pump.

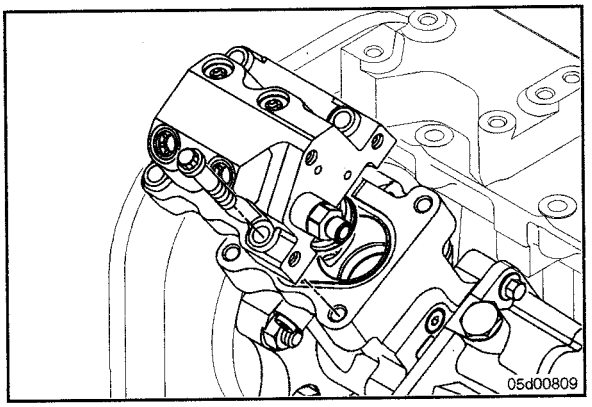
Remove the upper support bracket.

Remove two of the four capscrews that are located diagonally from one another.



Remove the last two capscrews. Alternately loosen the capscrew to avoid binding. Loosen each capscrew about one turn at a time.

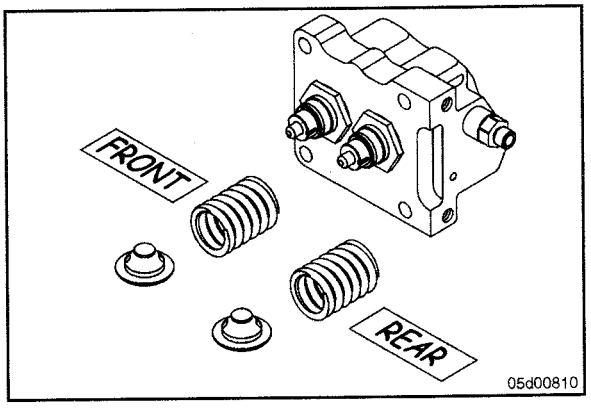
Carefully lift the fuel pump head from the cam housing, being careful to keep the tappet springs attached to the pump head, and place the head on a clean surface.



Clean and Inspect for Reuse

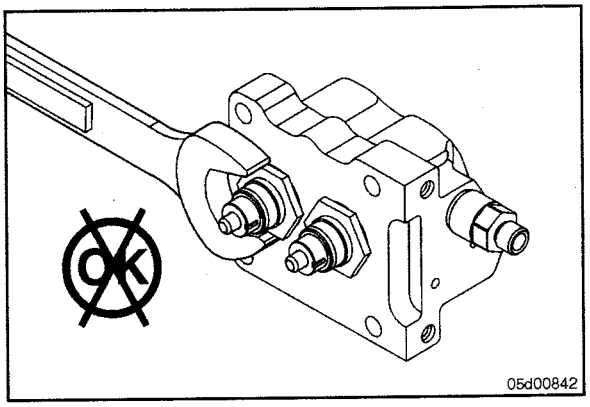
Remove the springs and spring retainers from the barrel retainers.

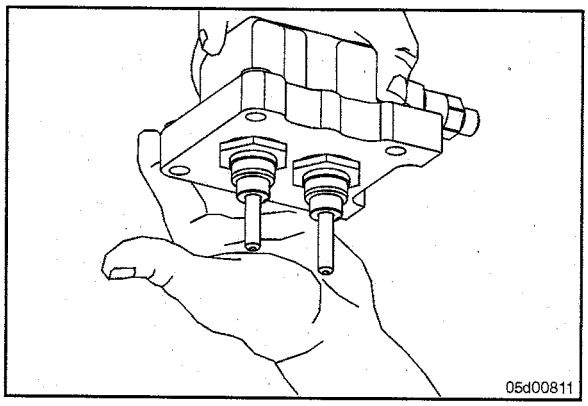
Make certain to keep track of which spring came from the front and rear. It is recommended that these parts be installed in the same order even if a new high-pressure pump head is installed.



⚠CAUTION⚠

Do not remove the barrel retainers. Damage to the pump head and barrel retainers will result.

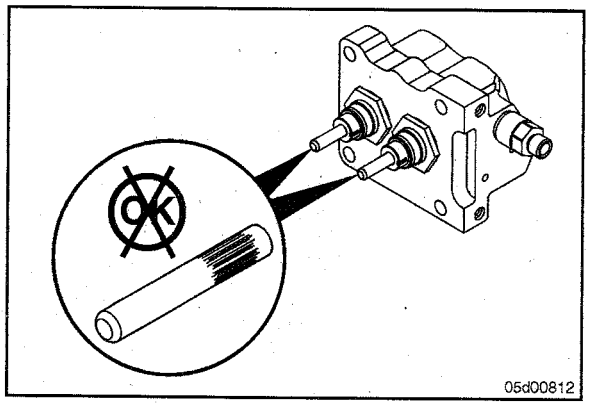




If the plungers are pressed fully upward, the fluid above the plunger and the inlet check valve seal can hold it in place.

Special care **must** be taken to be sure these parts are kept extremely clean if removed. Cover the cam housing with a clean shop towel while the head is removed.

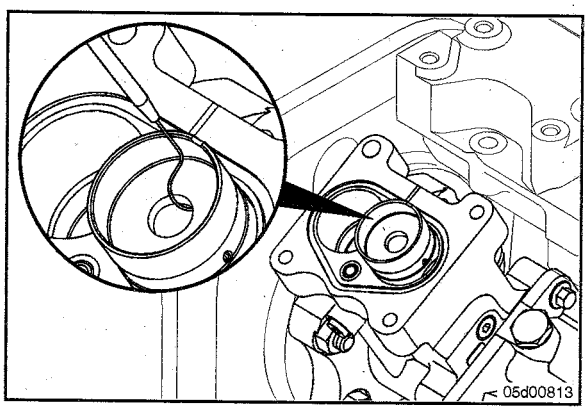
Do **not** use cleaning agents, other than contact cleaner, on pump components.



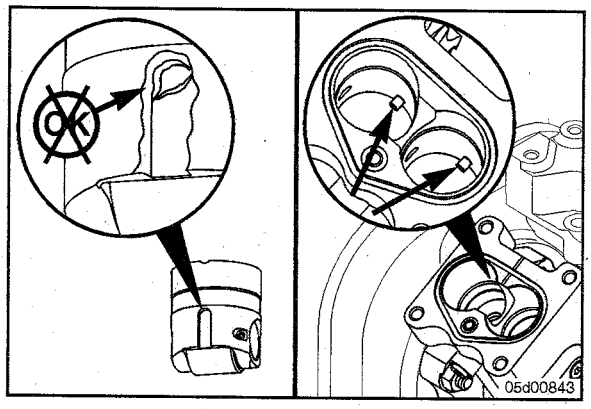
⚠CAUTION⚠

Each plunger must be installed in the same orientation and in the same barrel, or engine damage can result. Marking the bottoms of the plungers with a felt tip marker will help to ensure that correct orientation is maintained.

If the plungers are removed, inspect the plungers. Slight discoloration can be evident. Deep scoring **must not** be evident. If scoring or scratches exist that can be felt, the fuel pump head **must** be replaced.

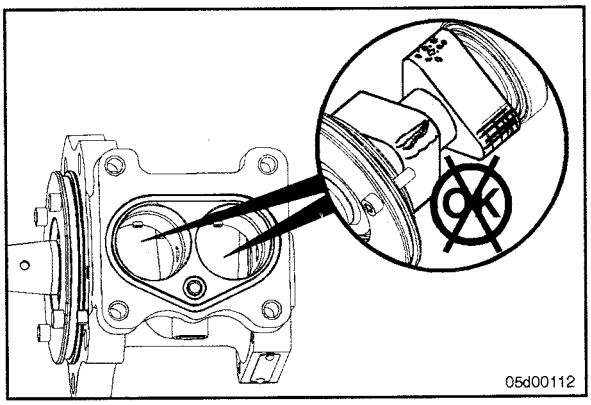


While the fuel pump head is removed, inspect the cam housing. The tappets can be removed using an o-ring pick as the removal tool.

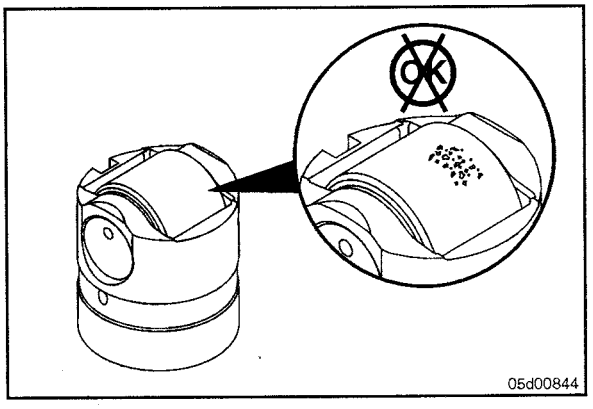


Inspect the tappet guide pins and tappet guide pin grooves for excessive wear. If more than 25-percent guide pin or groove wear is observed, the fuel pump **must** be replaced.

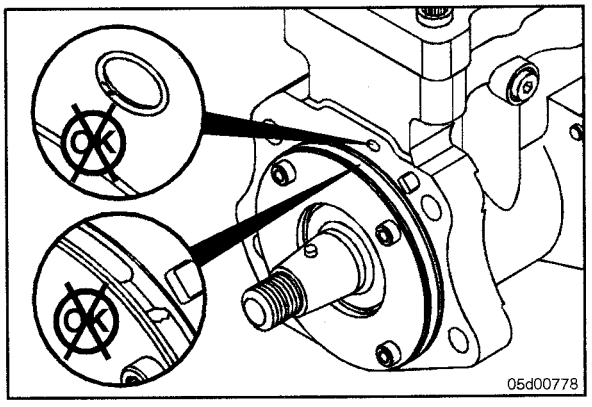
With the cam housing tappets removed, inspect the camshaft for wear. If excessive pitting on the nose of the camshaft is observed, the fuel pump **must** be replaced.



Inspect the tappet rollers for wear. If excessive pitting on the rollers is observed, the tappet(s) **must** be replaced.



If damage to the camshaft, tappets, or cam housing is observed, it is possible the fuel pump is **not** receiving adequate lubricating oil. When replacing the fuel pump, inspect the gear housing to make sure no blockages exist in the oil supply to the fuel pump.

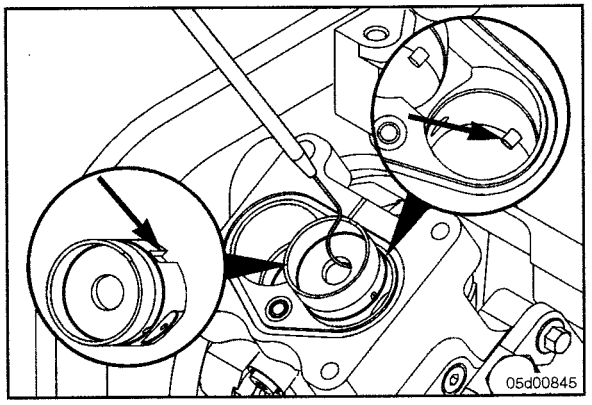


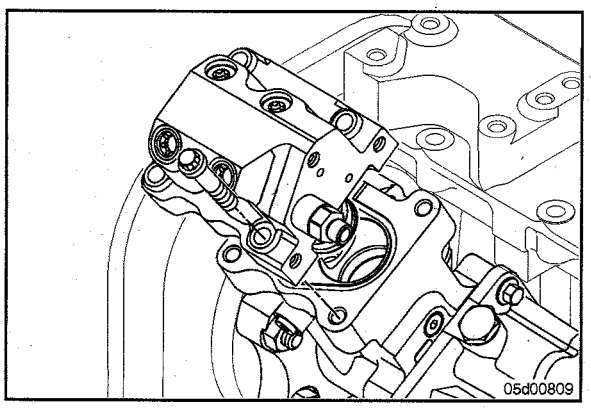
Install

Install the tappets in their original tappet bores.

Be certain the tappets are installed in their original locations.

Be certain that the tappet guide pins engage the guide the guide pin grooves.





Install new fuel pump head o-rings onto the cam housing.

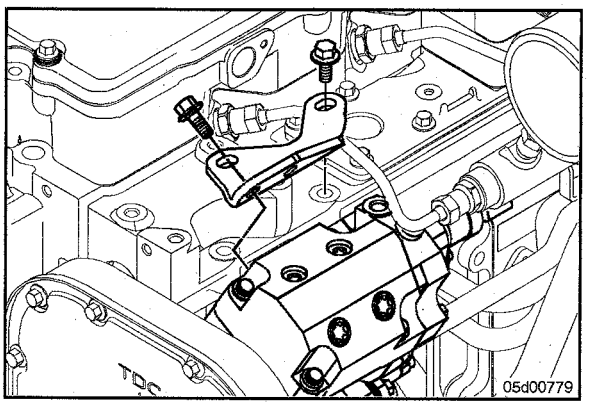
If installing a new or rebuilt pump head, install the new tappet springs and retainers provided with the pump head.

Place the high-pressure pump head onto the high-pressure pump cam housing.

Draw the high-pressure pump head down by alternately tightening the four high-pressure pump head bolts until the head just contacts the cam housing.

Tighten the four high-pressure pump head bolts to their final torque.

Torque Value: 68 N•m [50 ft-lb]



Connect the upper support bracket to the high-pressure pump head in the following order:

1. . Connect the upper support bracket bolts to the high-pressure pump head and tighten finger tight.
2. . Connect the upper support bracket bolts to the cylinder head and tighten to their final torque.

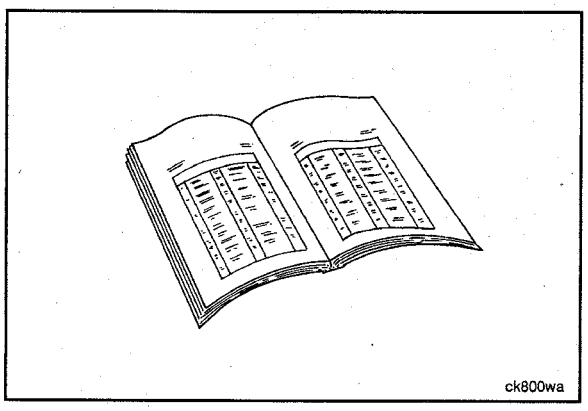
Torque Value:

Support Bracket to Cylinder Head	43 N•m	[32 ft-lb]

3. Tighten the bolts that attach to the high-pressure pump head to their final torque.

Torque Value:

Support Bracket to Pump Head	43 N•m	[32 ft-lb]



Finishing Steps

Install the fuel pump actuator housing. Refer to Procedure 005-228.

Connect the high-pressure fuel supply line. Refer to Procedure 006-051.

Connect the fuel drain line from the fuel pump actuator housing. Refer to Procedure 006-013.

Connect the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024.

Connect the engine harness to the fuel pump actuator.

Operate the engine and check for leaks.

Fuel Pump Actuator Housing (005-228)

Preparatory Steps

Disconnect the wire harness from the fuel pump actuator.

Disconnect the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024.

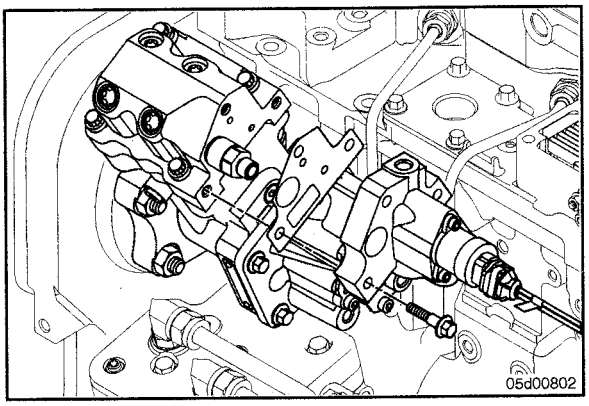
Disconnect the high-pressure fuel line from the fuel pump actuator housing. Refer to Procedure 006-051.

Disconnect the fuel drain from the fuel pump actuator housing. Refer to Procedure 006-013.

Remove

Remove the three bolts that hold the fuel pump actuator housing to the high-pressure fuel pump head.

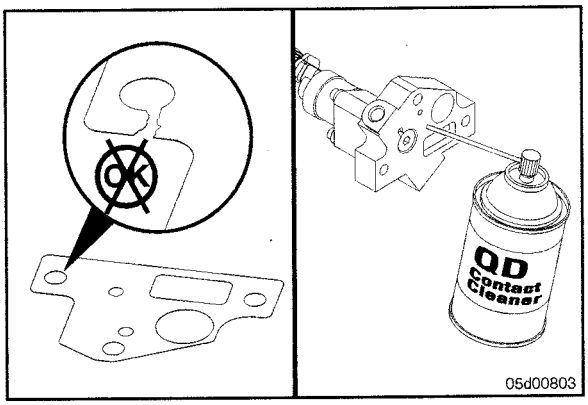
Remove the fuel pump actuator housing and the gasket.



Clean and Inspect for Reuse

Inspect the fuel pump actuator housing gasket. Do **not** reuse the gasket if the material is damaged, cracked, or torn.

Be sure that the mounting surfaces of the high-pressure pump head and the fuel control valve adapter block are clean. Use contact cleaner to clean these surfaces.



Install

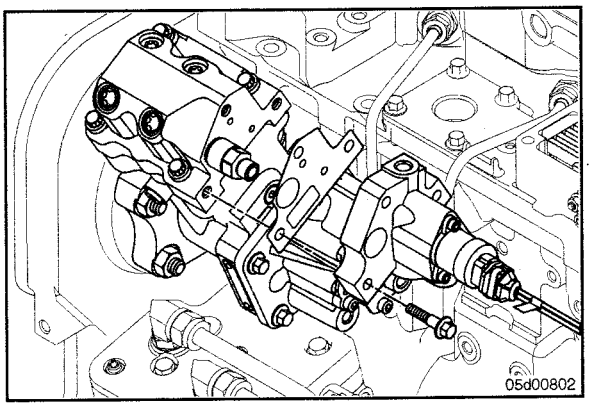
Insert the three mounting bolts through the fuel pump actuator housing.

Install the gasket over the bolts. The gasket **must** be installed dry.

Install the actuator housing.

Tighten the mounting bolts.

Torque Value: 34 N•m [25 ft-lb]



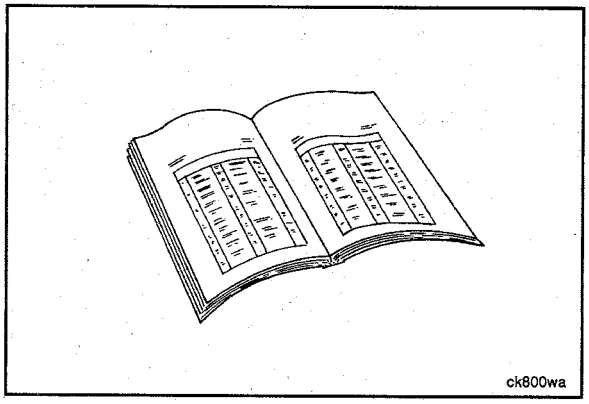
Finishing Steps

Connect the high-pressure fuel line to the fuel pump. Refer to Procedure 006-051.

Connect the fuel supply line to the fuel pump. Refer to Procedure 006-024.

Connect the fuel drain line to the fuel pump. Refer to Procedure 006-013.

Connect the wire harness to the fuel pump actuator.



Fuel Injection Pump (005-229)

Preparatory Steps

Disconnect the injection pump supply line. Refer to Procedure 006-024.

Remove the injector supply lines. Refer to Procedure 006-051.

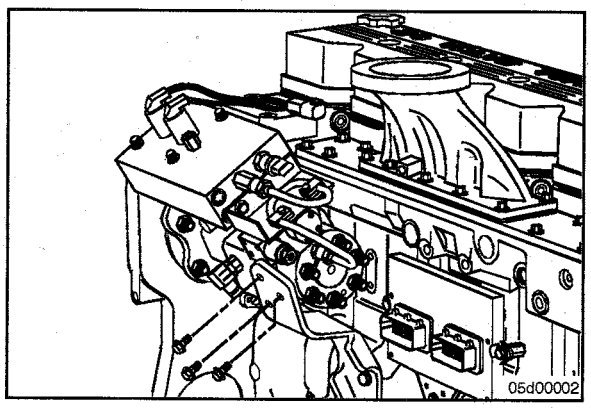
Disconnect the fuel drain line. Refer to Procedure 006-013.

Disconnect the pumping control valve 4-pin Deutsch connector.

Disconnect the injection control valve 4-pin Deutsch connector.

Disconnect the accumulator pressure sensor.

Disconnect the accumulator temperature sensor.

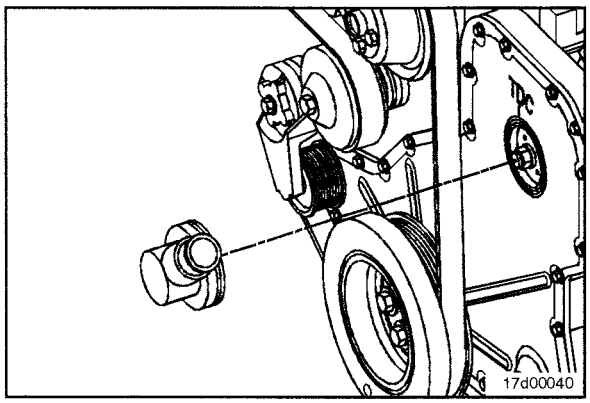


Remove

Remove the injection pump upper support bracket.

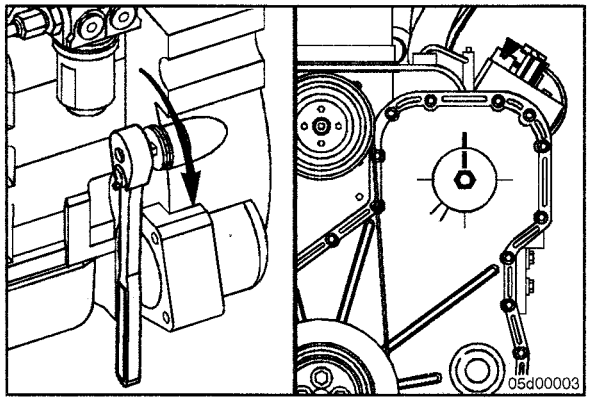
Remove the injection pump tail support bracket.

Remove the fuel pump gear access plug.

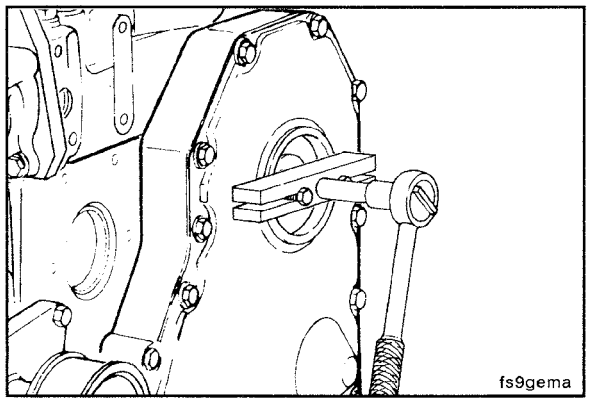


Locate top dead center for cylinder number 1 by barring engine slowly until the line on the pump gear lines up with the line on the gear cover.

Remove the fuel pump drive gear retaining nut and washer.

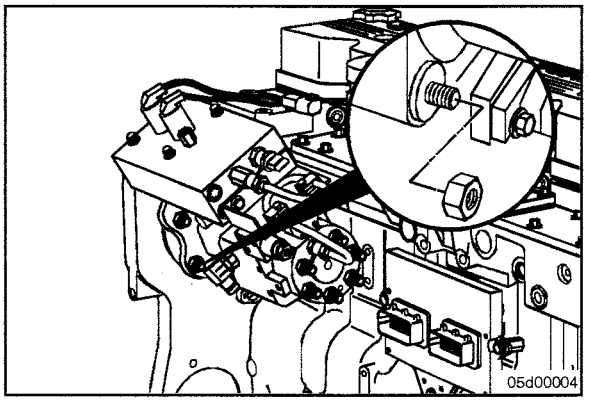


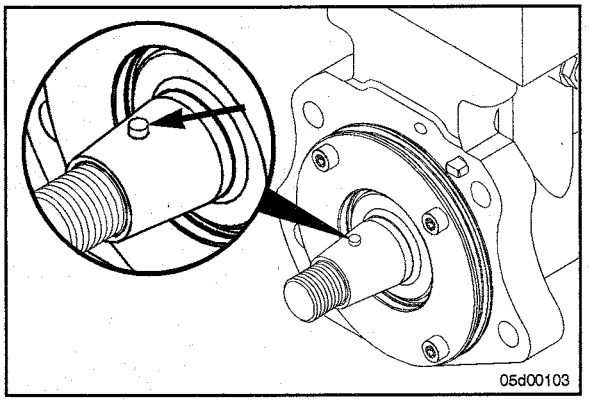
Pull the fuel injection pump drive gear loose from the pump driveshaft.



Remove the four mounting nuts.

Remove the fuel injection pump.



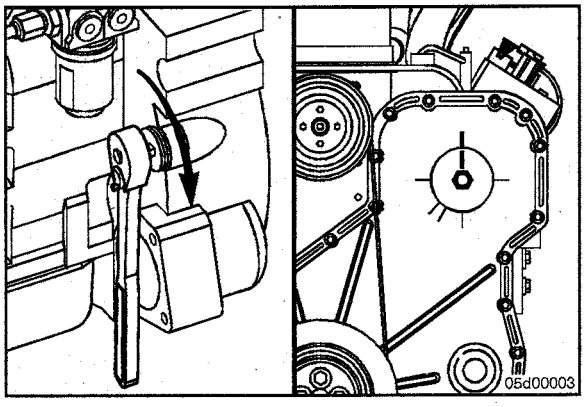


Clean and Inspect for Reuse

The fuel pump driveshaft key **must not** be sheared.

If the key is sheared, the cam housing module of fuel pump **must** be replaced and the drive gear **must** be replaced.

Check that the locating dowel is installed in the cam housing.



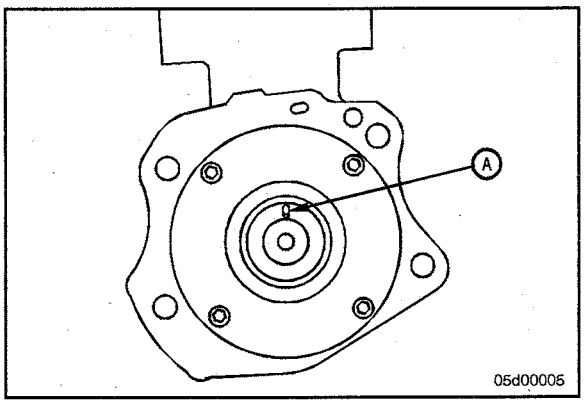
Install

Be sure the engine is at number 1 cylinder top dead center. The fuel pump gear timing mark should align with the top dead center mark on the gear housing.

Clean the fuel injection pump drive shaft with an evaporative cleaner.

Clean the fuel pump gear inside diameter with an evaporative cleaner.

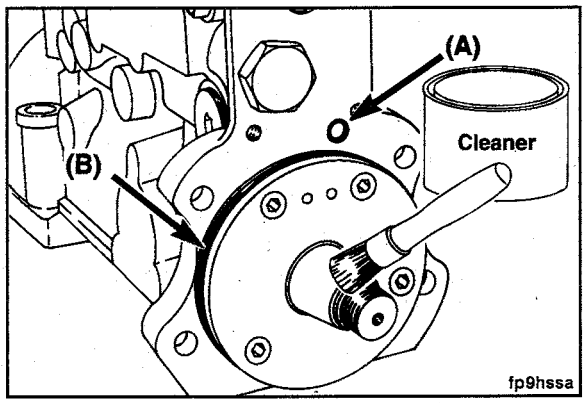
The fuel pump drive gear inside diameter and the drive shaft outside diameter **must** be clean and dry before installing the gear.



Make sure the fuel injection pump is at its top dead center position.

The fuel injection pump is at number 1 cylinder top dead center when the dowel pin in the shaft (A) is perpendicular to the top of the accumulator.

Be sure that the dowel is installed in the pump driveshaft.



Make sure the o-ring seals for the oil feed orifice (A) and pilot (B) are correctly installed and are **not** damaged.

Lubricate the mounting flange with cleaner.

The fuel pump drive gear inside diameter and the shaft outside diameter **must** be clean and dry before installing the gear.

Slide the fuel injector pump shaft through the drive gear and position the fuel injection pump flange onto the mounting studs.

Make sure the dowel pin in the shaft (A) lines up with the keyway in the fuel injection pump gear.

Make sure the dowel pin in the fuel injection pump flange lines up with the hole in the gear housing.

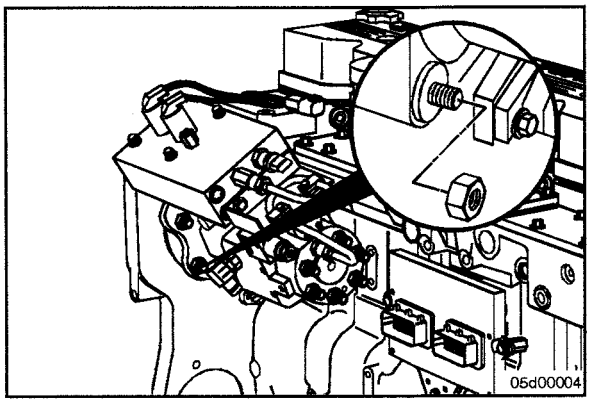
Install the mounting nuts.

Install the fuel injection pump upper support bracket.

Install the fuel injection pump tail support bracket.

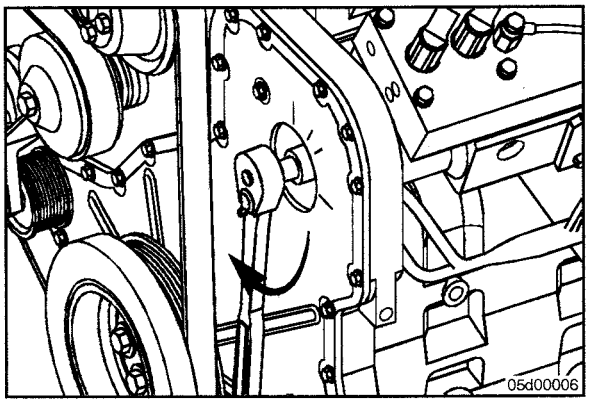
Torque Value:

Fuel Pump Mounting Nuts	44 N•m	[32 ft-lb]
Fuel Pump Support Brackets (8.8 or 9.8 capscrews)	44 N•m	[32 ft-lb]
Fuel Pump Support Brackets (10.9 capscrews)	65 N•m	[48 ft-lb]



Tighten the fuel injection pump drive gear nut.

Torque Value: 108 N•m [132 ft-lb]



Finishing Steps

Install the gear cover access cap hand tight.

Connect the injection pump supply line. Refer to Procedure 006-024.

Connect the injector supply lines. Refer to Procedure 006-051.

Connect the fuel drain line. Refer to Procedure 006-013.

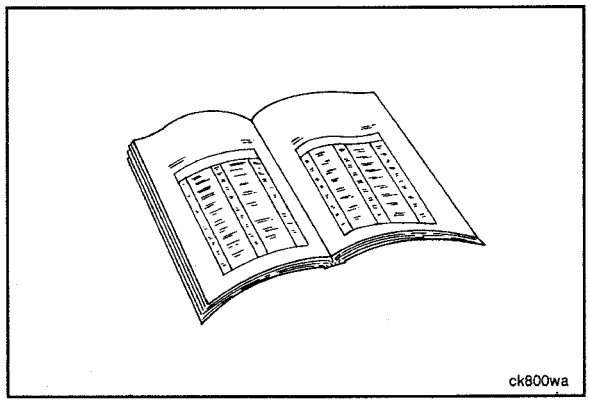
Connect the pumping control valve 4-pin Deutsch connector.

Connect the injection control valve 4-pin Deutsch connector.

Connect the accumulator pressure sensor to the engine harness.

Connect the accumulator temperature sensor to the engine harness.

Operate the engine and check for leaks.



Notes

Section 6 - Injectors and Fuel Lines - Group 06

Section Contents

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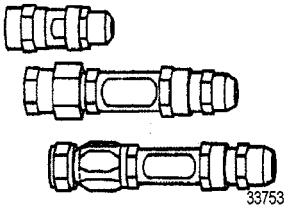
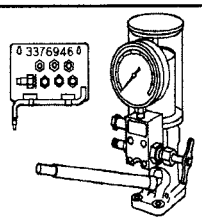
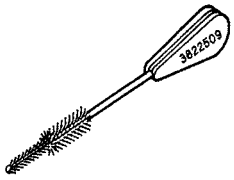
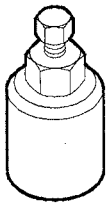
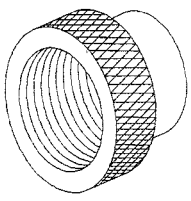
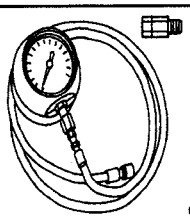
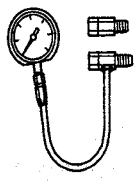
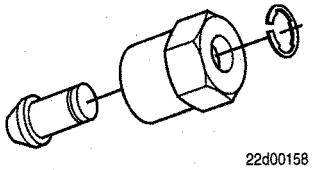
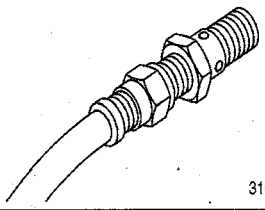
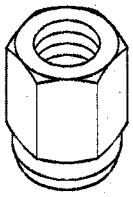
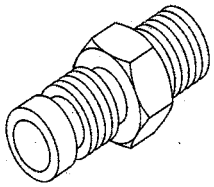
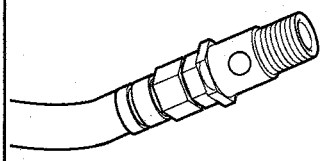
Service Tools

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
3375362	**Sight Glass (#10 Size)** Used to observe fuel flow to detect for air in fuel.	
3376946	**Injector Nozzle Tester** Used to test opening pressure, leakage, chatter and spray pattern.	
3822509	**Injector Bore Brush** Used to clean the injector bore.	
3825156	**Injector Puller** Used to pull the injectors on CAPS fuel system.	
3825157	**Fuel Connector Puller** Used to pull the fuel connector.	
ST-1273	**Pressure Gauge (0 to 1905 mm Hg [0 to 75 in Hg])** Used to measure engine intake manifold pressure, exhaust restriction, lift pump output pressure, and pressure drop across fuel filter.	

Tool No.	Tool Description	Tool Illustration
ST-434	**Vacuum Gauge (0 to 762 mm Hg [0 to 30 in Hg])** Used to measure lift pump inlet restriction. Hose Adaptor, Cummins Part No. ST-434-2, and vacuum gauge, Cummins Part No. ST-434-12, are used to perform the test.	 eg8togc
3164325	**Fuel System Leak Tester** Used to block a single injector and high pressure fuel connector from the pressurized fuel. This tool helps identify a failed injector when injector return flow is excessive.	 22d00158
3164618	**Fuel Return Flow Hose** This tool uses a special fitting to connect to the fuel return circuits to measure return flow from the injectors and fuel pump (Cummins Common Rail Fuel System).	 3164614
3164025	**Fuel Connector Remover** Used to pull the fuel connector (Cummins Common Rail Fuel System).	 22d00081
3824842	**M10 STORM Compuchek® Diagnostic Fitting** Used to measure fuel pressure or vacuum wherever STORM M10 diagnostic ports exist.	 22800572
4164617	**Banjo Fuel Flow Fitting** This tool uses a special banjo fitting to connect to the fuel return circuit to measure return flow from the rail pressure relief valve.	 3164618

Air in Fuel (006-003)

Setup

Obtain a 1.09 mm [0.043 in] orificed diagnostic fuel line, Part Number 3164621. This tool can also be constructed following the steps below.

Obtain a container suitable for collection of fuel that exits the diagnostic fuel line (a five gallon bucket is recommended).

Construct a sight tube (CAPS fuel systems **only**) using the following steps.

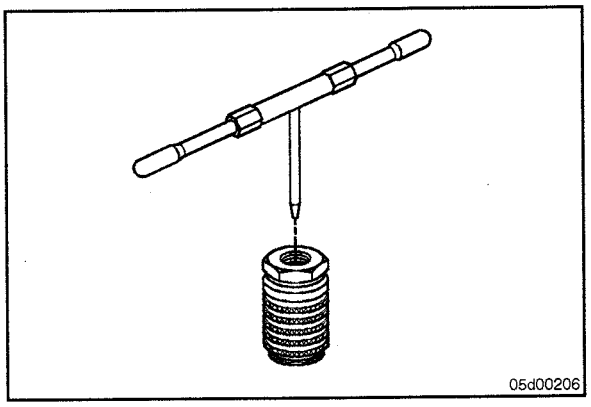
Construct a 1.09 mm [0.043 in] orificed diagnostic fuel line.

NOTE: This tool is available for purchase, Part Number 3164621.

A 0.043-inch orifice diagnostic fuel line is used in procedures to create rated flow through the low pressure fuel system without the need to operate the engine under load.

Tap a female quick connect, Part Number 3376859.

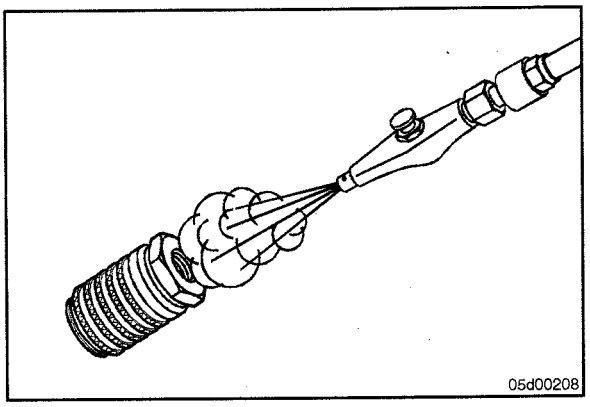
Tap size: 8-36 national fine (U.S.)



⚠WARNING⚠

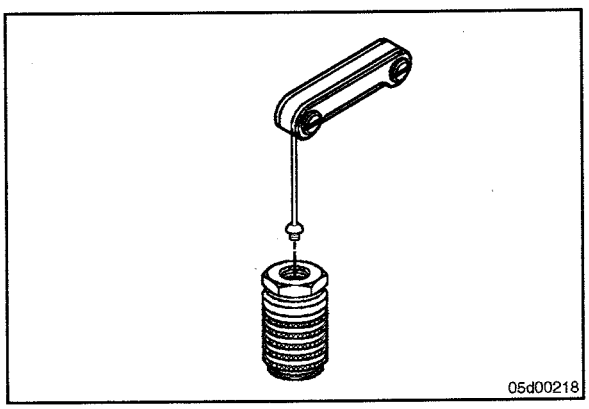
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

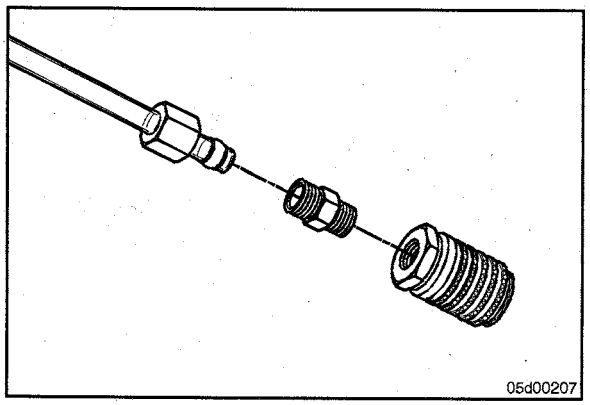
Clean the female quick connect, Part Number 3376859, with compressed air.



Assemble a 1.09 mm [0.043 in] injector orifice, Part Number 3045018, with washer, to the female quick connect, Part Number 3376859.

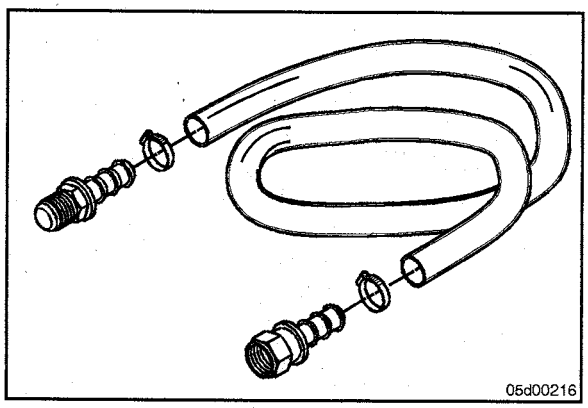
NOTE: To obtain correct flow, use a 1.09 mm [0.043 in] injector orifice, Part Number 3045018.





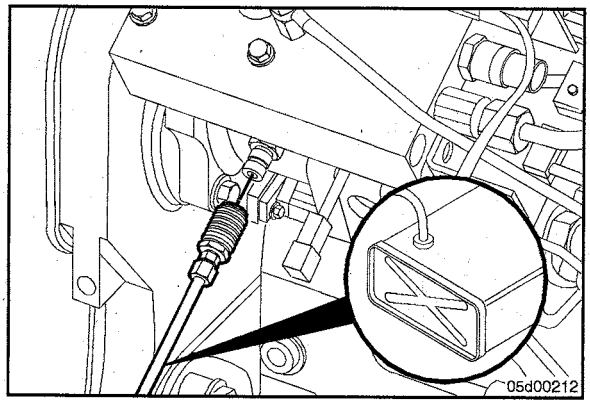
Attach the orifice to an appropriate length (it **must** reach from the fuel pump to the fuel tank) of 1/4-inch, or larger, tubing.

NOTE: It is recommended that this tool be marked and identified as having a 1.09 mm [0.043 in] orifice installed. This is to ensure that there is no confusion when using this tool in the future.



Construct a sight tube (CAPS fuel systems **only**):

Assemble two (one male and one female, 7/8-14 thread barb-tite fittings and hose clamps to a 61 cm [2 ft] long number-10 clear hose approved for use with diesel fuel.

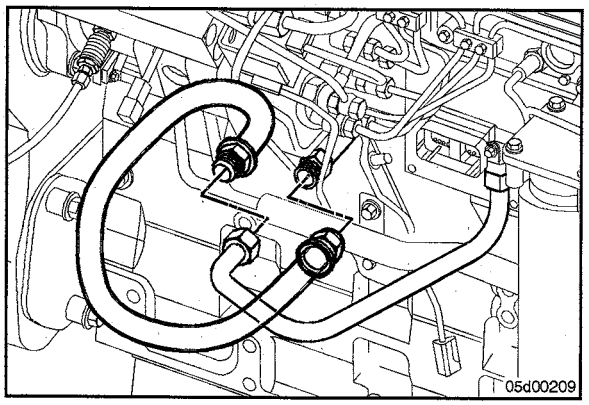


Measure

CAPS Fuel System

Attach the 1.09 mm [0.043 in] diagnostic fuel line at the fuel injection pump's diagnostic fitting.

Run the outlet of the diagnostic fuel line into the fuel collection container (or the vehicles fuel tank).



Install the sight glass between the fuel filter head and the fuel injection pump inlet.

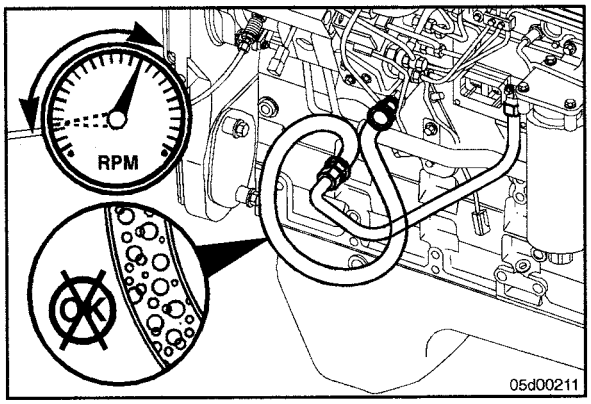
Run the engine from idle to high idle several times to purge the air induced while installing the diagnostic fuel line.

Run the engine up to high idle while another technician checks for air in the system.

NOTE: A small amount of air in the inlet line is acceptable. Ignore any air that is observed in the tube running back to the fuel tank.

Afterwards, operate the engine at idle and observe any air in the fuel supply. If air is observed, isolate the air to the following components:

- Fuel filter assembly
- Fuel heater
- Fuel lift pump assembly
- OEM fuel plumbing
- Fuel tank stand-pipe.

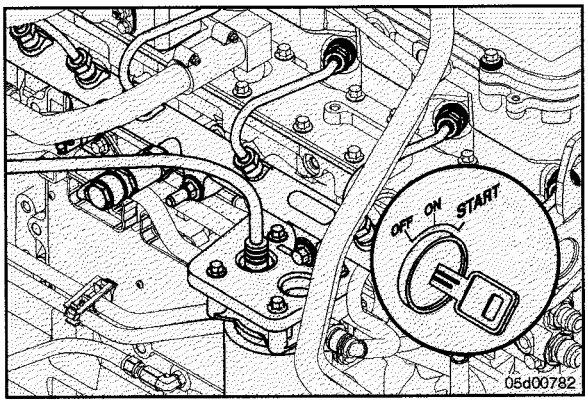


Cummins Common Rail Fuel System

NOTE: A symptom of air-in-fuel for the ISC and ISL engine equipped with a Cummins Common Rail Fuel System is an audible surge associated with fuel system pressure fluctuations due to air in the fuel supply.

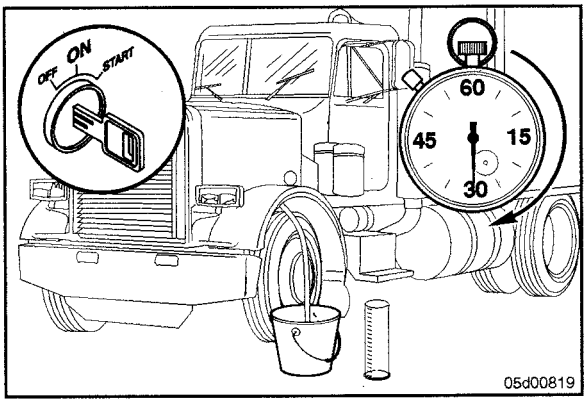
The following test method will simulate rated fuel flow through the system so that air in fuel problems may be diagnosed.

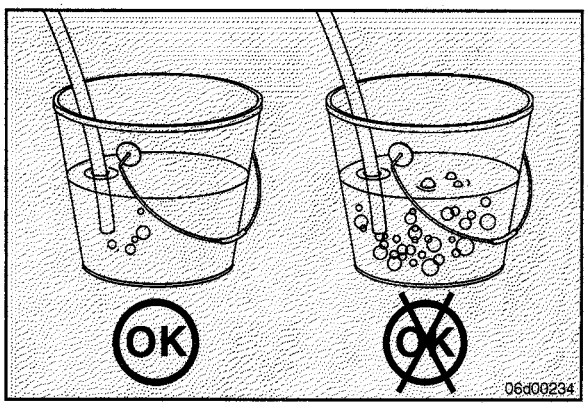
Install a Compuchek® fitting, Part Number 3824842, at the inlet to the 2 um fuel filter and attach the 1.09 mm [0.043 in] diagnostic fuel line.



Route the outlet of the 0.043-inch diagnostic fuel line into a colletion device of suitable size (a 5-gallon bucket is recommended).

Start the engine and run the from idle to high idle several times to purge the air induced while installing the diagnostic fuel line.





Observe the fuel flow exiting the diagnostic fuel line while the engine runs at idle.

A few bubbles exiting the line is expected. A foamy appearance is indication of a leak that allows air to enter, a severe inlet restriction that causes cavitation, or a system that is **not** yet primed. If fuel inlet restriction (refer to Procedure 006-020) is **not** excessive, the source of air entry should be isolated to one of the following:

- Suction fuel lines
- ECM cooling plate assembly
- OEM fuel lines
- Suction-side fuel filter assemblies
- Stand-pipe(s) in the fuel tank(s).

Finishing Steps

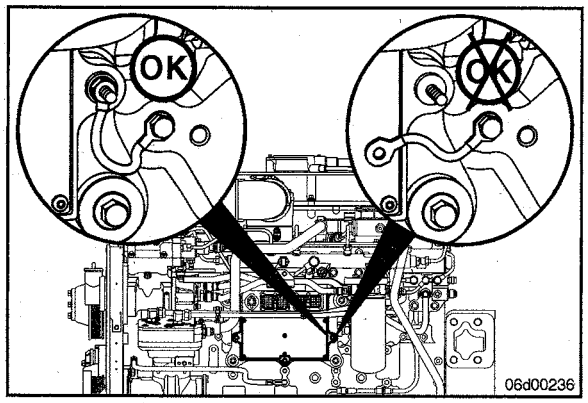
Remove all test fuel lines and install the low pressure fuel lines. Refer to Procedure 006-024.

ECM Cooling Plate, Fuel Cooled (006-006)

Initial Check

The ECM cooling plate assembly provides a vibration isolated mounting location for the ECM. The cooling plate also provides ECM cooling and incorporates the fuel lift pump. A check valve at the outlet port in the ECM cooling plate makes sure that the fuel system is primed while the fuel lift pump is running.

Check the ECM cooling plate for damaged vibration isolators, loose capscrews, or fuel leaks.



Make sure that the ground strap is properly installed. A missing or poorly connected ground strap may cause intermittent engine performance problems.

The ground strap **must** be connected between the head of the ECM mounting bolt and the ECM.

The ground strap **must** be connected to an unpainted block surface that is free of corrosion.

Preparatory Steps

⚠WARNING⚠

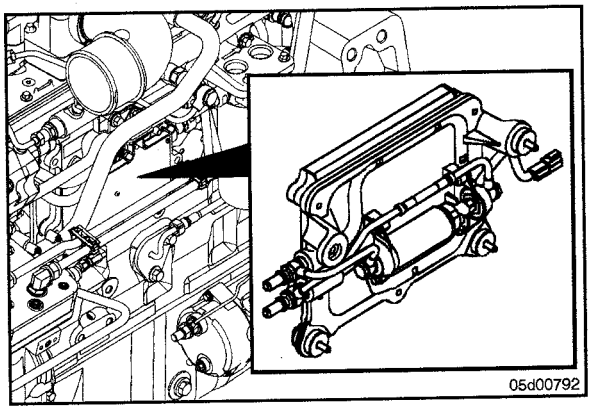
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the negative (-) battery cable first.
- Disconnect the harness connections from the ECM.
- Disconnect the ECM ground strap.
- Disconnect the engine harness from the electric fuel priming pump.
- Disconnect the fuel supply lines from the ECM cooling plate. Remove the suction fuel lines, if necessary.
- Remove the ECM from the cooling plate. Refer to Procedure 019-031 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC, QSC8.3, ISL and QSL9 Engines, Bulletin 4021416.

Remove

Remove the ECM cooling plate capscrews and the ECM cooling plate form the engine block.

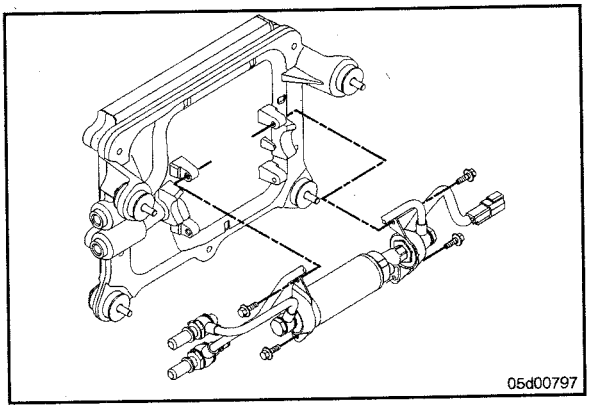
NOTE: The electric fuel priming pump and priming pump fuel lines will be attached to the ECM cooling plate while the cooling plate is being removed.

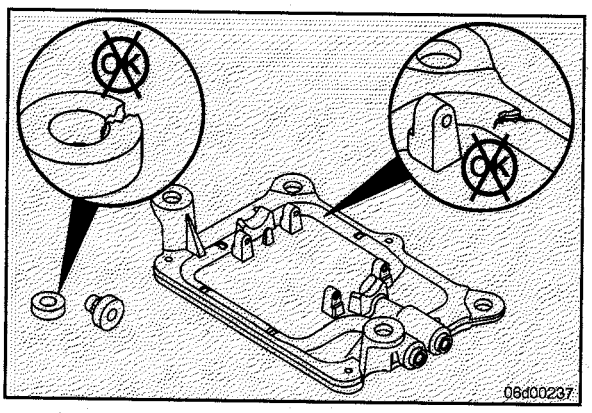


Disassemble

Remove the following components from the ECM cooling plate:

- Male banjo quick disconnect fitting
- Male banjo check valve fitting
- Fuel lift pump supply lines
- Fuel lift pump brackets
- Fuel lift pump.





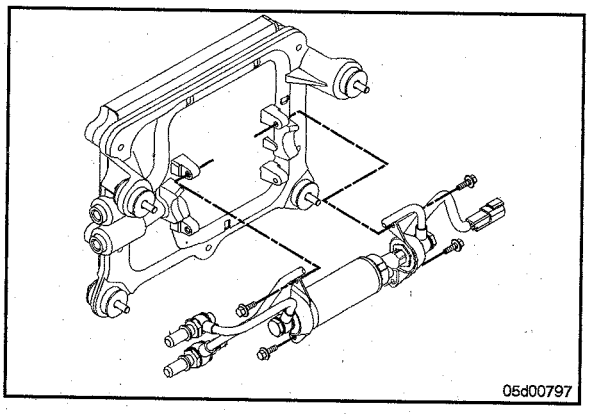
Inspect for Reuse

Inspect the ECM cooling plate for leaks (note that the fuel passages are contained in a tube that is cast into the cooling plate).

Replace any damaged vibration isolators.

Inspect for leaks in the electric fuel supply pump priming circuit; look for cracked fuel tubes, damaged o-rings or damaged seal washers.

Inspect the check valve for debris or damage.



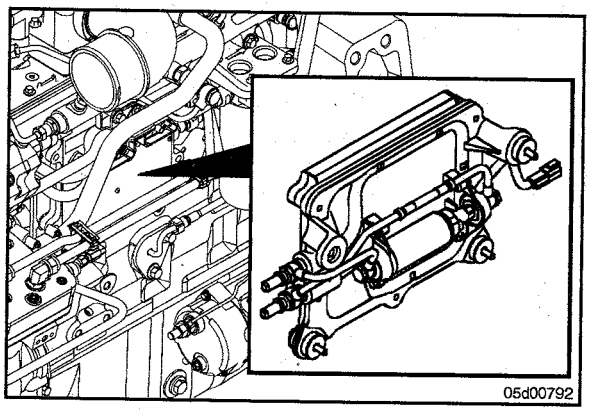
Assemble

Install the electric fuel priming pump. Refer to Procedure 005-045.

Install the fuel priming circuit fuel lines. Refer to Procedure 005-045.

Be sure the lines are supported while tightening the banjo screws. The lines **must** not be permitted to bind.

Be sure the ECM check valve is installed into the bottom (outlet) fitting of the ECM cooling plate.



Install

Install the ECM cooling plate assembly on the engine block. Tighten the capscrews.

Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

⚠CAUTION⚠

Failurce to properly install the ECM ground strap may cause intermittent engine symptoms including intermittent engine stalls. One end of the ground strap must be installed between the ECM housing and the head of the bottom most ECM mounting capscrew. The other end of the ground strap must be tightly bolted to an unpainted block surface that is free from corrosion.

NOTE: Be sure the vibrations isolators are installed correctly. The isolators fit in a single direction into the chamfered locators.

- Install the ECM on the ECM cooling plate. Refer to Procedure 019-031 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC, QSC8.3, ISL and QSL9 Engines, Bulletin 4021416.
- Install the fuel supply lines. Refer to 006-024.
- Cycle the keyswitch a few times to allow the system to prime.
- Operate the engine and check for leaks.

Fuel Drain Line Restriction (006-012)

Preparatory Steps

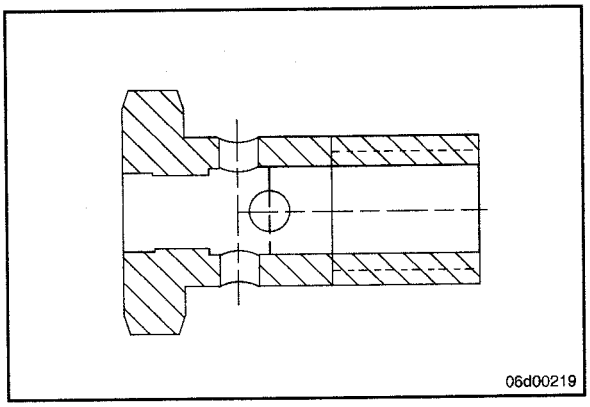
Obtain or construct a M12 banjo pressure gauge tool.

A banjo-style pressure gauge adapter may be used to measure pressure or vacuum at any point in the low-pressure fuel system where a banjo bolt exists at a fuel line.

The ISC and ISL engines with high-pressure common rail fuel systems use M12 x 1.5 banjo bolt connections. This tool may be used for measurement of drain line restriction (pressure) at the fuel drain manifold.

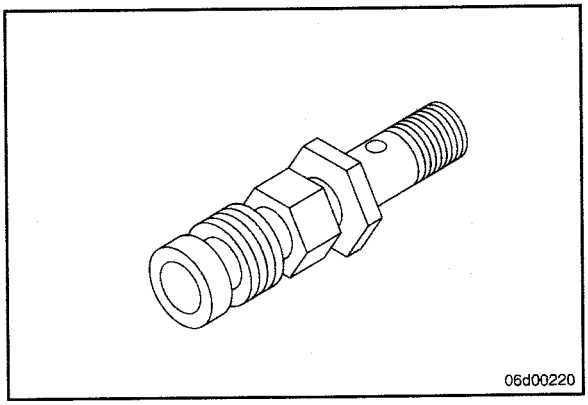
Make a banjo bolt pressure gauge tool by drilling and tapping the hex face of a M12 x 1.5 banjo bolt, Part Number 3903035, or equivalvent.

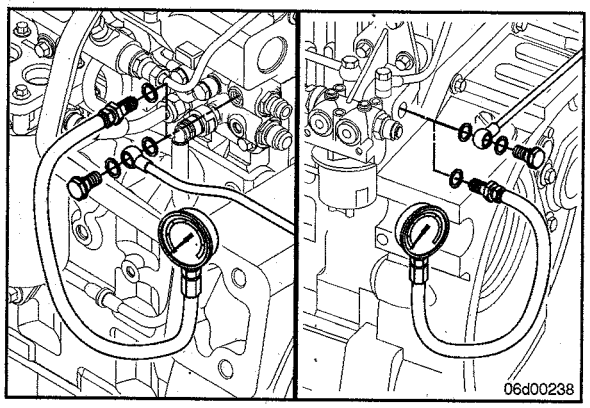
Drill and tap the banjo bolt to the size of Compuchek® fitting, or other hose union, being used (example 1/8-inch NPT Compuchek® fitting, Part Number 3377244, or M10 Compuchek® fitting, Part Number 3824842).



Assemble the banjo pressure gauge adapter.

1. . Install the Compuchek® or other type fitting in the hex face of the banjo bolt.
2. . Attach a hose or pressure gauge to the banjo pressure adapter.

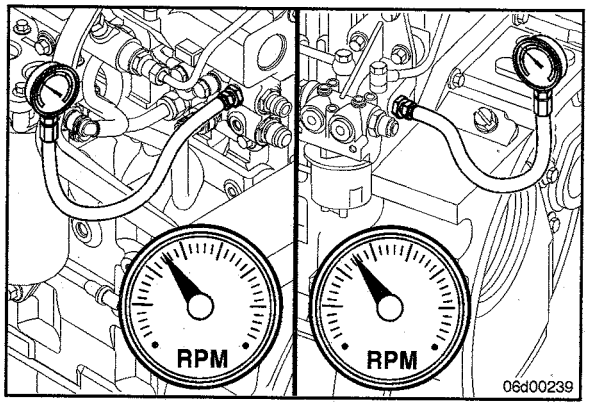




Install the M12 banjo pressure gauge adapter in place of the injector drain line banjo at the fuel drain manifold (Cummins Common Rail fuel systems).

Install the M12 banjo pressure gauge adapter in place of the banjo bolt that attaches the injector drain line to the electric lift pump drain manifold (CAPS fuel systems).

Install a 0 to 762 mm Hg [0 to 30 in Hg] pressure gauge at the M12 banjo pressure gauge adapter.



Measure

Operate the engine at rated speed and no load.

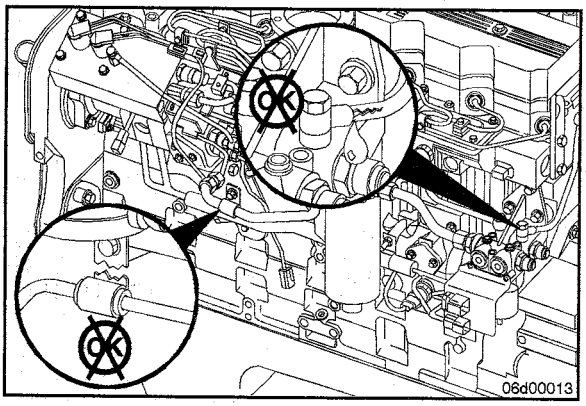
Observe the reading on the gauge.

Fuel Drain Line Pressure		
mm Hg		in Hg
254.0	MAX	10.0

If the drain line pressure is out of specification, check for bends or kinks in the drain lines. Look for places where the OEM fuel lines may be pinched by wire ties or p-clips. Check for block fuel tank vents.

Finishing Steps

Remove all test fittings and reinstall drain lines. Refer to Procedure 006-013.



Fuel Drain Lines (006-013)

Initial Check

Inspect the drain lines for any signs of leaks, cracks, chafing, loose or broken brackets.

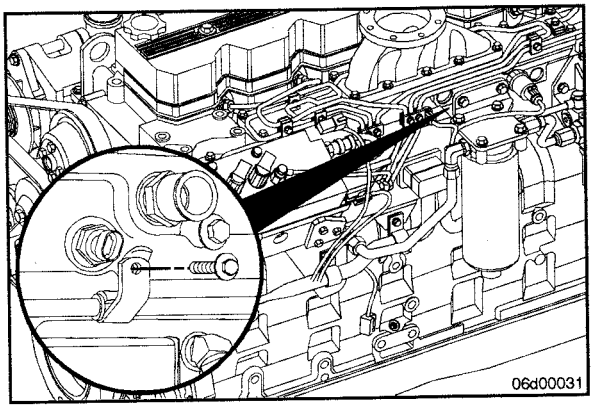
Remove

CAPS Fuel System

There are two drain lines on the engine:

1. . The fuel injection pump drain line routes fuel from the fuel injection pump to the fuel lift pump drain manifold. This line has a p-clip brace that attaches to the cylinder head.
2. . The injector drain line which routes fuel from the rear of the cylinder head to the fuel lift pump drain manifold.

These lines are removed by removing the banjo bolts and sealing washers.

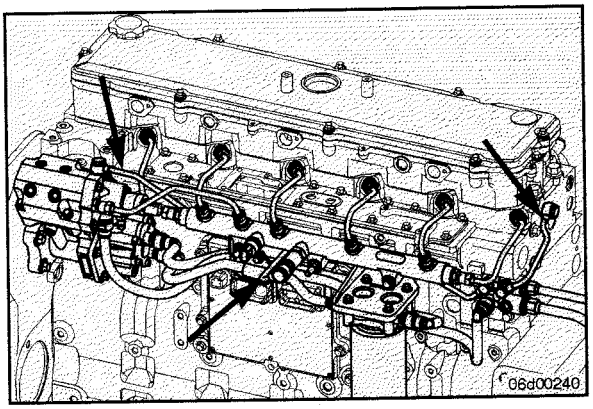


Cummins Common Rail Fuel System

There are three drain lines on the engine:

1. . The fuel pump drain line connects the fuel pump to the fuel drain manifold. This line has a p-clip brace that attaches to the engine cylinder head.
2. . The fuel rail pressure relief valve drain line connects the fuel rail pressure relief valve to the fuel drain manifold.
3. . The injector drain line connects the back of the cylinder head to the fuel drain manifold.

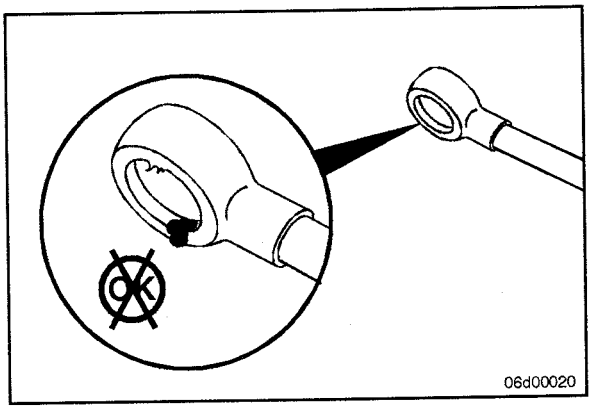
These lines are removed by removing the banjo bolts and sealing washers.



Inspect for Reuse

Inspect the lines for damage.

Inspect the banjo seal washers for damage.



Install

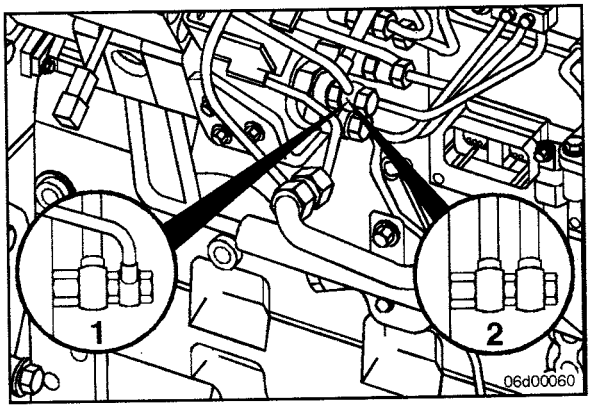
CAPS Fuel System

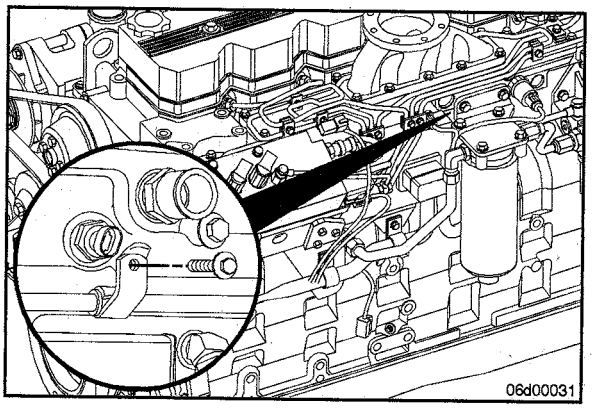
Connect the fuel drain line at the fuel pump banjo fitting at the rear of the cylinder head and at the lift pump. Use two (2) wrenches when installing the drain line at the fuel pump return.

Torque Value:

Style One (1)	24 N•m	[18 ft-lb]
Style Two (2)	24 N•m	[18 ft-lb]

Refer to Procedure 006-056 for the air bleeding installation procedure.

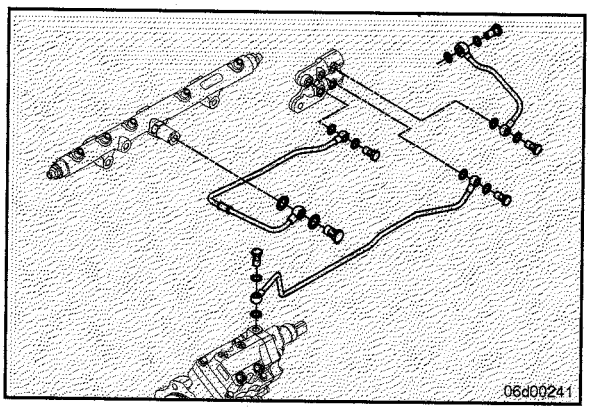




Install and tighten the clamp capscrews.

Torque Value:

M12 Bolts	Banjo	24 N•m	[18 ft-lb]
P-Clip Capscrew		24 N•m	[18 ft-lb]



Cummins Common Rail Fuel System

Install the three drain lines on the engine.

- High pressure fuel pump drain:
  - Install the p-clip bracket
  - Install the banjo bolt at the fuel drain manifold
  - Install the banjo bolt at the fuel pump.
- Pressure relief valve drain line:
  - Install the banjo bolt at the fuel drain manifold
  - Install the banjo bolt at the pressure relief valve. Hold the line so that it may **not** twist and wear against the bottom of the cylinder head.
- Injector drain line.

Torque Value:

M12 Bolts	Banjo	24 N•m	[18 ft-lb]
M16 Bolts	Banjo	43 N•m	[32 ft-lb]
P-Clip Capscrew		24 N•m	[18 ft-lb]

Finishing Steps

Operate the engine under a load and check for leaks.

Fuel Filter (Spin-On Type) (006-015)

General Information

CAPS Fuel System

The CAPS fuel system requires the use of a single fuel filter. The filter **must** have the following characteristics:

- water-separating
- 10-micron rating
- water-in-fuel sensor
- water-drain valve
- engine mounted or chassis mounted.

Fleetguard® FS1022 meets these requirements.

Cummins Common Rail Fuel System

The Cummins Common Rail fuel system requires the use of two fuel filters. The suction side filter **must** have the following characteristics:

- water-separating
- 10-micron rating
- water-in-fuel sensor with shunt resistor
- water-drain valve
- **always** chassis mounted.

Fleetguard® FS1003 meets these requirements.

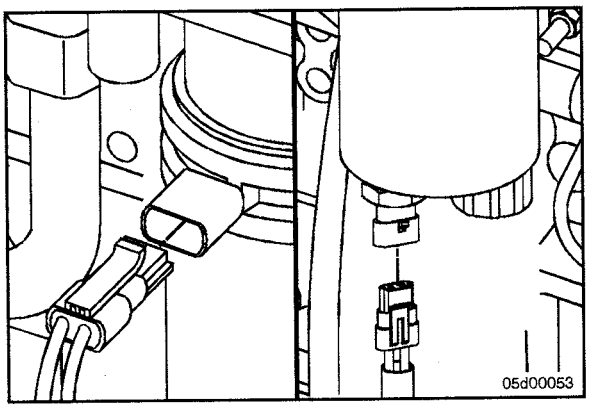
The pressure side filter **must** have the following characteristics:

- 2-micron rating
- engine mounted or chassis mounted.

Fleetguard® FF5488 meets these requirements.

Refer to Section E for Engine Identification. The CM554 engine uses the CAPS fuel system. The CM850 engine uses the Cummins Common Rail fuel system.

Remove



Disconnect the wiring harness from the water-in-fuel sensor, if equipped.

Disconnect the wiring harness from the fuel heater, if equipped.

Loosen and remove the fuel filter.

Make sure the seal ring does **not** stick to the filter head.

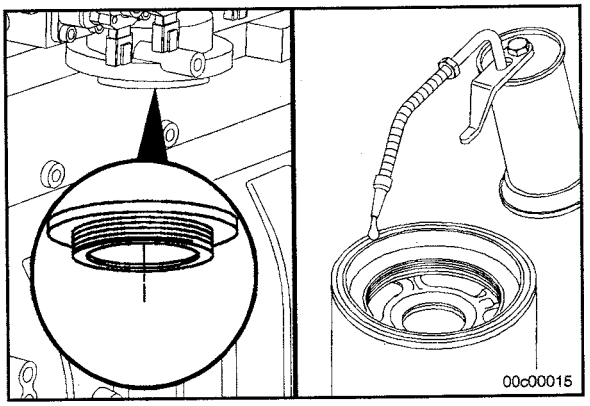
Remove the ring with an o-ring pick, if necessary.

Install

CAPS Fuel System

⚠CAUTION⚠

Mechanical overtightening can distort the threads as well as damage the filter element seal or filter canister.

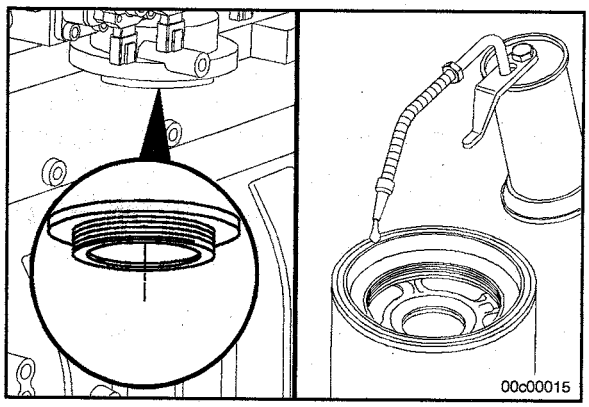


Do **not** fill the fuel filter with fuel before installation; instead, prime the fuel system using the fuel lift pump.

Be sure the center seal ring is installed onto the filter spud.

Install the filter as specified by the filter manufacturer.

Connect the water-in-fuel sensor and the fuel heater, if equipped.



Cummins Common Rail Fuel System

⚠CAUTION⚠

Mechanical overtightening can distort the threads as well as damage the filter element seal or filter canister.

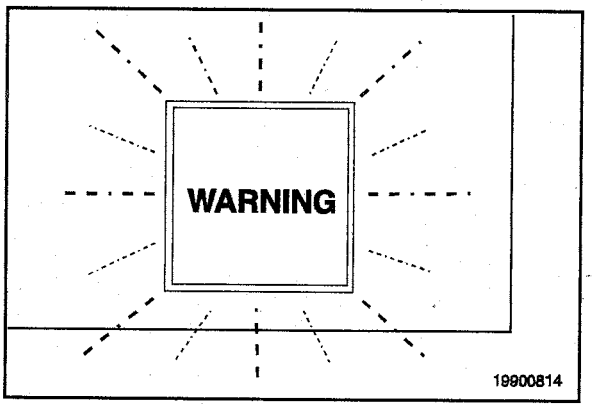
It will be necessary to fill the 10-micron water stripping (suction side) fuel filter with fuel.

Do **not** fill the 2-micron (pressure side) fuel filter with fuel before installation; instead, prime the fuel system using the fuel lift pump.

Be sure the center seal ring is installed onto the filter spud.

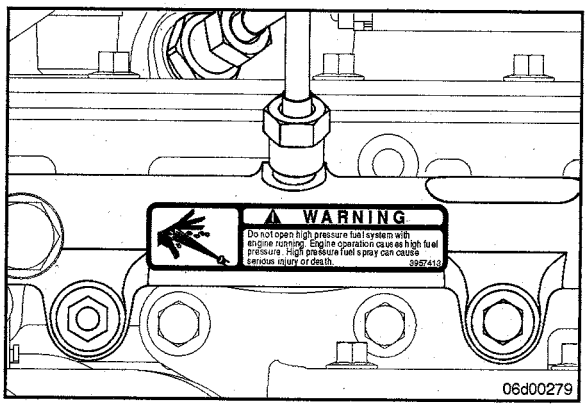
Install the filter as specified by the filter manufacturer.

Connect the water-in-fuel sensor and the fuel heater, if equipped.



The Cummins Common Rail Fuel System is capable of detecting the presence of the correct water-in-fuel sensor.

If the water-in-fuel sensor is incompatible or disconnected, the engine WARNING lamp will illuminate.



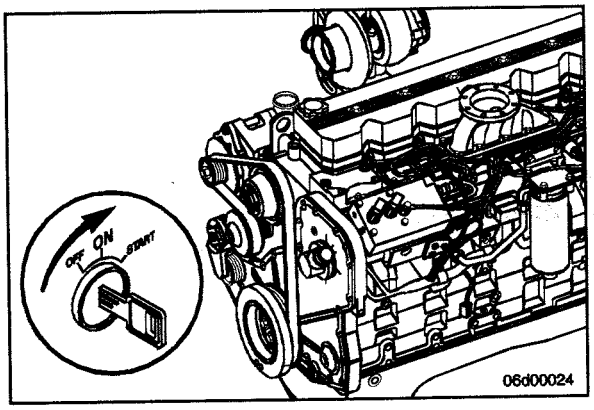
Prime

⚠WARNING⚠

Do not open the high-pressure fuel system with the engine running. Engine operation causes high fuel pressure. High-pressure fuel spray can cause serious injury or death.

Cycle the keyswitch and allow the lift pump to run. The lift pump will run for 30 seconds. Afterwards, turn the keyswitch off and back on again allowing the lift pump to run again.

Allow the lift pump to run for three or four 30-second cycles before attempting to start the engine.



Finishing Steps

Operate the fuel lift pump to help prime the fuel system. Turn the keyswitch to RUN, but do **not** attempt to start the engine. This will cause the ECM to operate the fuel lift pump through a priming cycle which lasts at least 30 seconds. Cycle the lift pump several times by keying off, waiting 10 seconds and keying back on again.

Once the engine is started, slowly increase the engine speed while air is purged from the fuel plumbing.

Fuel Filter Head Bracket (006-018)

Preparatory Steps

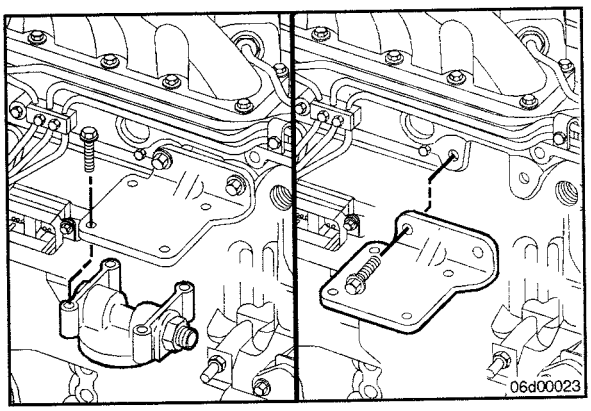
Remove the fuel filter. Refer to Procedure 006-015.

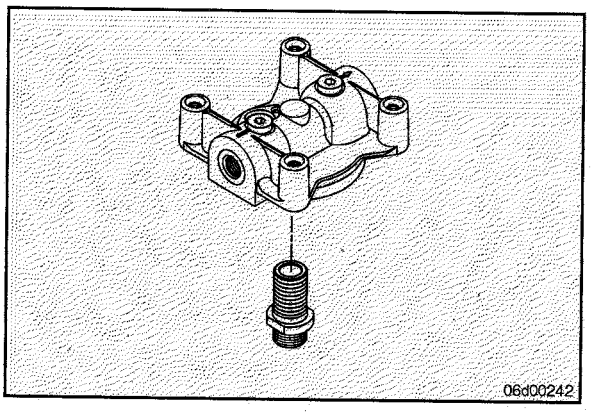
Remove the fuel supply lines from the filter head. Refer to Procedure 006-024.

Remove

Remove the four (4) capscrews retaining the filter head.

Remove the filter head bracket from the engine.

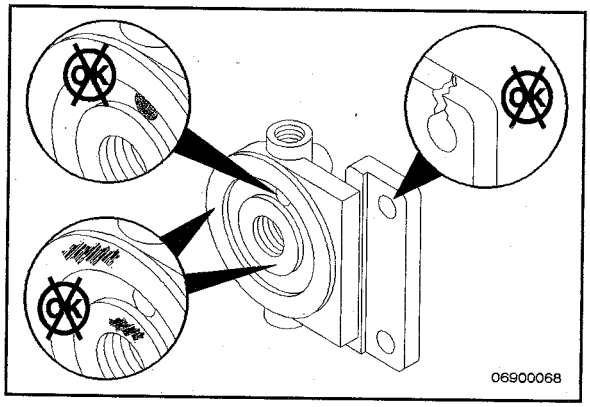




Disassemble

Fuel heater equipped engines have a filter spud that can be removed for the purpose of removing the fuel heater.

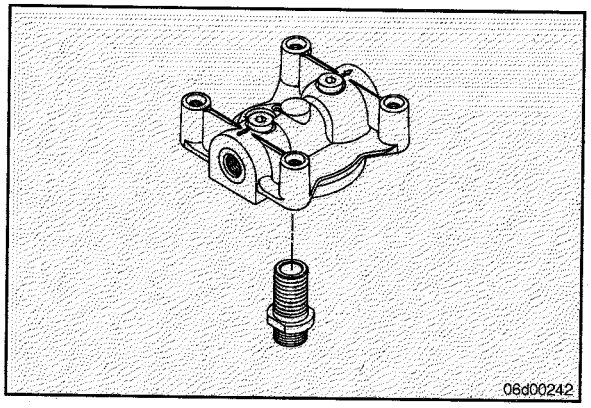
Remove the fuel heater and filter spud, if equipped.



Clean and Inspect for Reuse

Inspect the filter head for cracks, passage blockage, material or debris on the sealing surfaces.

Clean any loctite from the filter adapter threads.



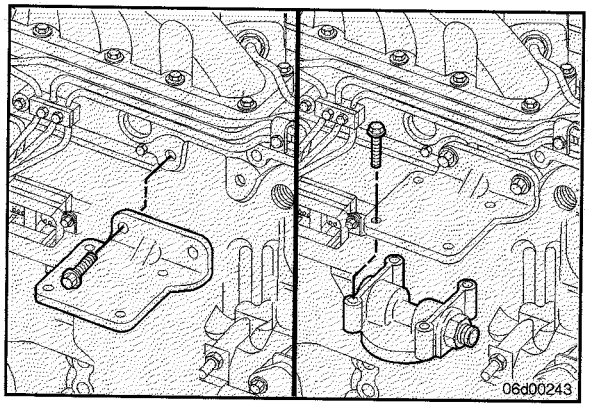
Assemble

Apply Loctite™ 277, or equivalent, to the filter adapter threads that are engaging the filter head.

Assemble the filter head.

Install the filter adapter and fuel heater (if equipped).

Torque Value: 27 N•m [20 in-lb]



Install

Install the bracket and filter head. Tighten the retaining capscrews.

Torque Value: 43 N•m [32 ft-lb]

Finishing Steps

Install the fuel filter. Refer to Procedure 006-015.

Install the fuel supply lines. Refer to Procedure 006-024.

Operate the engine and check for leaks.

Fuel Inlet Restriction (006-020)

Preparatory Steps

CAPS Fuel System

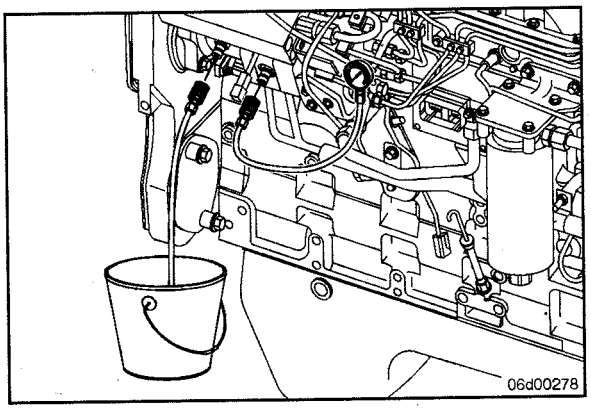
Obtain a 0.043-inch orificed diagnostic fuel line, Part Number 3164621. This tool can also be constructed. Refer to Procedure 006-003.

Obtain a container suitable for collection of fuel that exits the diagnostic fuel line. A 5-gallon bucket is recommended.

Install a 1/8-inch NPT Compuchek® diagnostic fitting, Part Number 3042618, at the inlet to the fuel injection pump (Cummins Accumulator Pump System **only**).

Attach the 0.043-inch orificed diagnostic fuel line at the fuel injection pump cam housing Compuchek® fitting. Route this hose into a collection container or into the fuel tank.

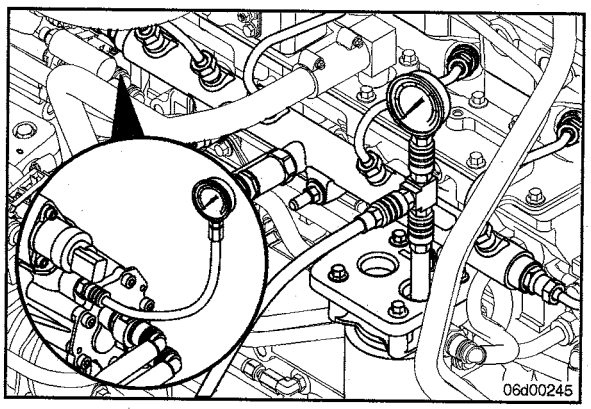
Attach a 0 to 762 mm Hg [0 to 30 in Hg] vacuum gauge at the gear pump inlet Compuchek® port.



Cummins Common Rail Fuel System

Obtain a 0.043-inch orificed diagnostic fuel line, Part Number 3164621. This tool can also be constructed. Refer to Procedure 006-003.

Obtain a container suitable for collection of fuel that exits the diagnostic fuel line. A 5-gallon bucket is recommended.

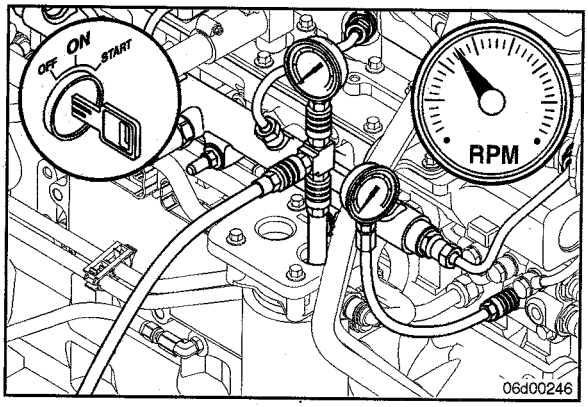


Install a M10 Compuchek® fitting, Part Number 3824842, at the inlet to the fuel gear pump (Cummins Common Rail Fuel Systems **only**).

Install a M10 Compuchek® fitting, Part Number 3824842, at the fuel filter head.

Attach the 0.043-inch orificed diagnostic fuel line at the fuel filter head Compuchek® fitting. Route this hose into a collection container or into the vehicle fuel tank.

Attach a 0 to 762 mm Hg [0 to 30 in Hg] vacuum gauge at the gear pump inlet Compuchek® port.

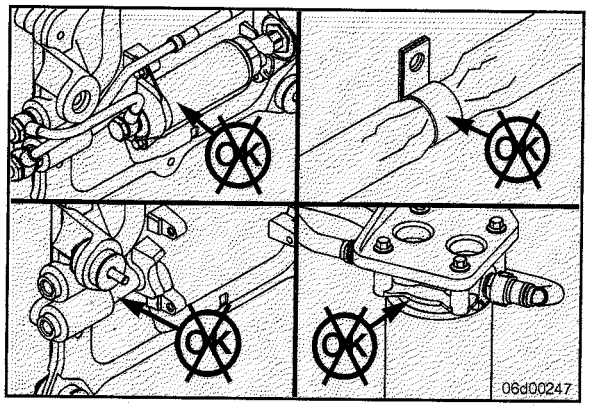


Measure

Operate the engine at idle and measure the inlet vacuum.

Maximum Fuel Inlet Restriction (CAPS Fuel Systems)		
mm Hg		**in Hg**
102.0	At OEM connection	4.0
254.0	At inlet to fuel gear pump (dirty filter)	10.0

Maximum Fuel Inlet Restriction (Cummins Common Rail Fuel System)		
mm Hg		**in Hg**
203.2	At OEM connection (dirty filter) loaded condition	8.0
304.8	At inlet to fuel gear pump (dirty filter) loaded condition	10.0



If the inlet restriction is excessive, look for the root cause:

- Suction side fuel filters plugged
- Fuel heater valves are restricted
- ECM cooling plate plugged
- ECM cooling plate check valve restriction
- OEM fuel lines pinched or restricted
- Fuel tank stand pipes restricted.

NOTE: Do **not** leave Compuchek® fittings installed on the suction side of the gear pump. A Compuchek® fitting on the suction side of the gear pump can allow air to enter the fuel flow resulting in performance problems.

Disconnect all diagnostic test fittings and reinstall all plugs.

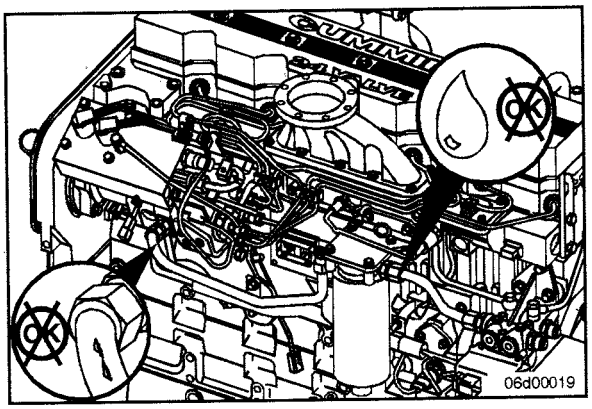
Fuel Supply Lines (006-024)

Initial Check

Inspect all fuel supply lines and fittings. Look for cracks in the lines or leaking fittings.

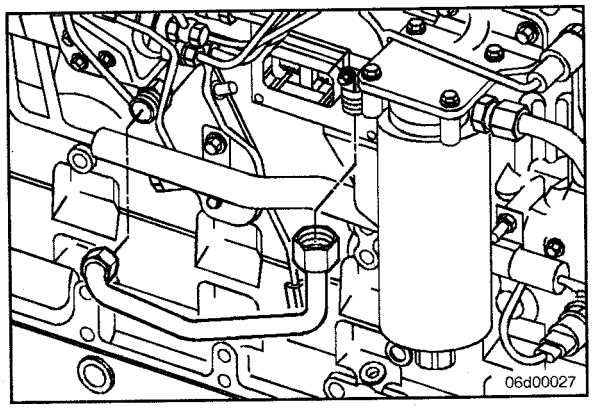
Inspect the straight thread o-ring metric hose fitting. Make sure that the lock nuts tighten against the o-ring rather than bottom out against the end of the fitting's threads (example: Cummins Accumulator Pump System fuel pump inlet and Cummins Accumulator Pump System fuel filter head).

Inspect the quick-disconnect style fittings for damaged o-ring connections or broken locking tangs.

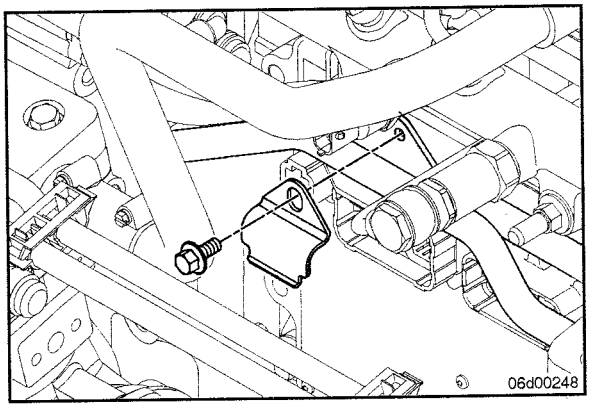


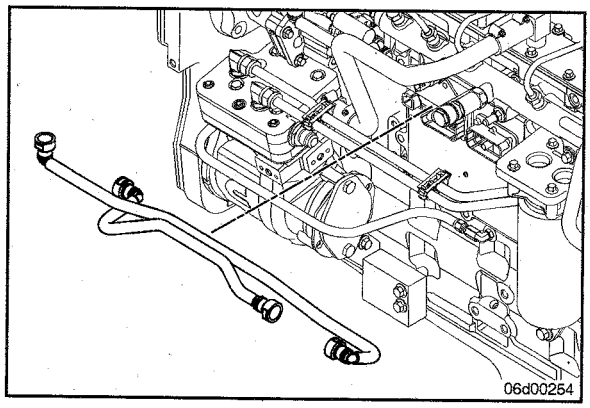
Remove

Remove the fuel supply lines.



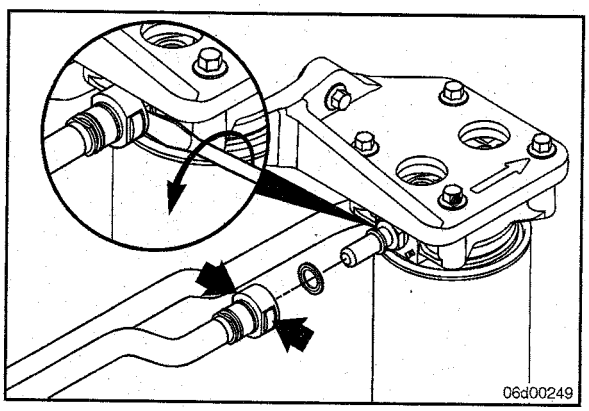
For quick disconnect style fuel lines, remove the clasp from the fuel line brace. This will allow the lines to move so they can be disconnected.





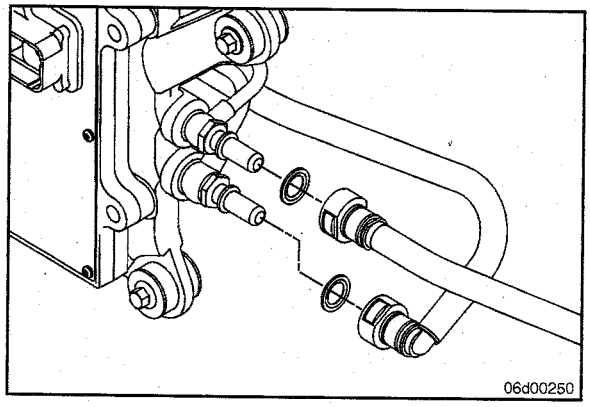
Loosen all quick disconnect lines from the brace.

To remove the gear pump outlet line, the gear pump inlet line **must** be removed first.

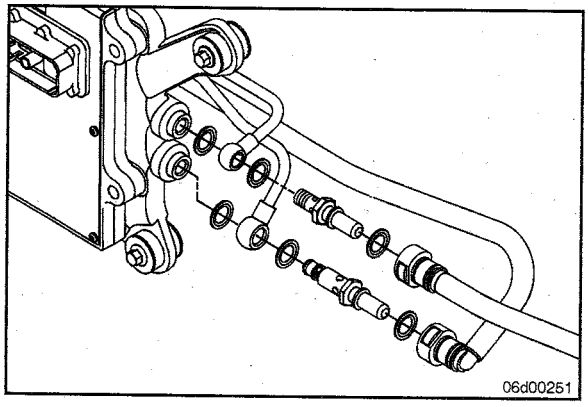


Remove the quick disconnect style fuel lines by pressing in the locking tangs on both sides of the quick disconnect fitting.

To aid removal, a screwdriver may be inserted between the fuel line end and quick disconnect male union. After pressing the opposing locking tangs, twisting the flat blade of the screwdriver helps to remove the fuel line.



If fuel leaks or suction side air entry is suspected, remove the fuel hoses or quick disconnect fittings.



Inspect for Reuse

Inspect for burrs or debris on metal connectors that may cause leaks.

On straight thread o-ring metric connectors, be certain the o-rings are **not** frayed or cut.

On quick disconnect style fittings, be certain the o-rings are **not** frayed or cut, and that the lock tangs are **not** damaged.

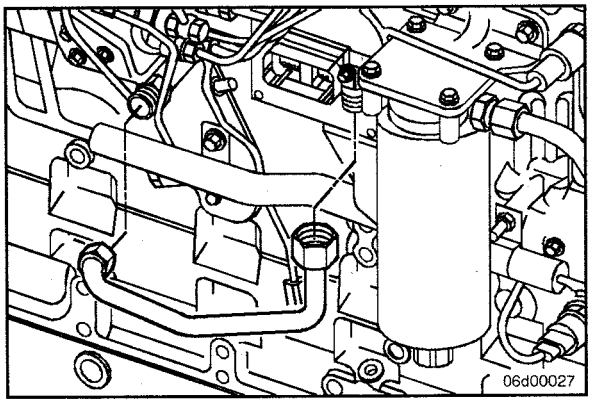
Inspect the banjo seal washers. Replace and damaged washers.

Install

Install the fuel supply lines.

Torque Value:

Number 10 Flare Fitting		37 N•m	[27 ft-lb]
M12 Quick Disconnect Union		24 N•m	[18 ft-lb]



Install the quick disconnect fuel lines (Cummins Common Rail Fuel Systems **only**).

Install the quick disconnect fittings.

Torque Value:

Torque Value	24 N•m	[18 ft-lb]

Make sure that the quick disconnect style fuel lines clasp onto the quick disconnect fittings.

Make sure the lines are routed and connected correctly. If the lines are connected incorrectly, the engine will **not** run.

For quick-disconnect style lines used with the Cummins Common Rail Fuel System, fuel lines are routed in the following order:

1. . OEM connection to the upper fitting at the ECM cooling plate
2. . Lower ECM cooling plate fitting to the upper gear pump fitting
3. . Lower gear pump fitting to the 2-micron fuel filter inlet
4. . 2-micron fuel filter outlet to the fuel pump fuel control actuator housing.

The fuel supply line brace holds the fuel lines in the following order:

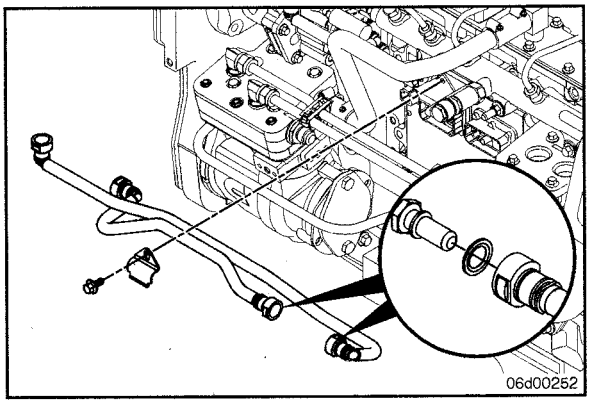
1. . The inside line connects the upper gear pump fitting to the lower ECM cooling plate fitting
2. . The middle line connects the 2-micron filter outlet to the fuel pump fuel control actuator housing
3. . The outside line connects the lower gear pump fitting to the 2-micron filter inlet.

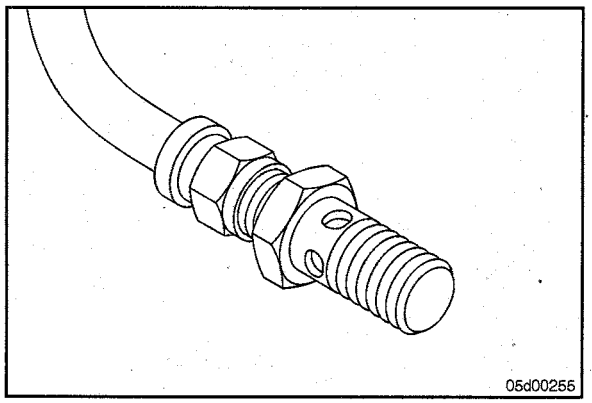
Install the fuel line brace clasp (quick disconnect style fuel lines **only**) and the brace, if necessary.

Torque Value:

Fuel Line Brace	24 N•m	[18 ft-lb]
Fuel Line Brace Clasp	24 N•m	[18 ft-lb]

Operate the engine and check for leaks.





Injector (006-026)

Initial Check

Cummins Common Rail Fuel System

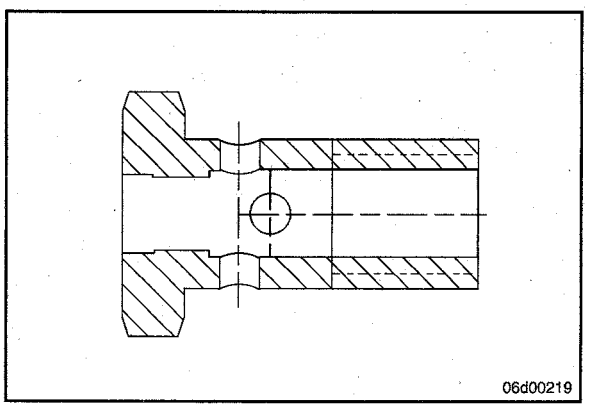
⚠CAUTION⚠

Installation of the banjo flow adapter at any place other than the fuel drain manifold can cause damage to high pressure fuel system components.

Return fuel is transmitted from the injectors, the fuel rail pressure relief valve and the fuel pump head by three different drain lines.

Measurement of fuel injector leakage requires use of a fuel return hose, Part Number 3164618.

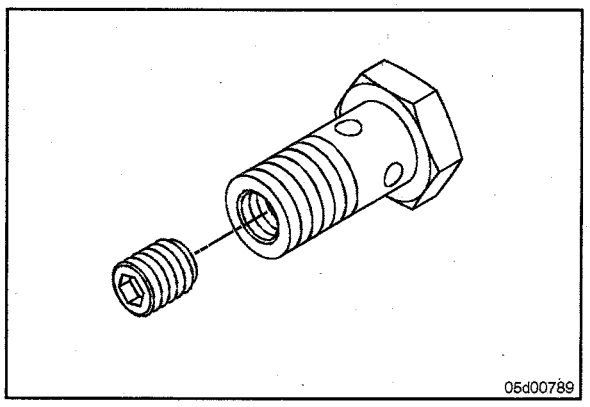
The tool is used to isolate the leakage from just the injectors so that it can be measured into a graduated cylinder.



If necessary, this tool can be constructed using the steps outlined below.

To make a banjo bolt flow adapter tool, drill and tap the hex face of a M12 x 1.5 banjo bolt, Part Number 3903035 or similar.

Drill and tap the hex face of the banjo bolt to the size of a male union (or other hose fitting) being used (example 1/8-inch NPT hose barb).



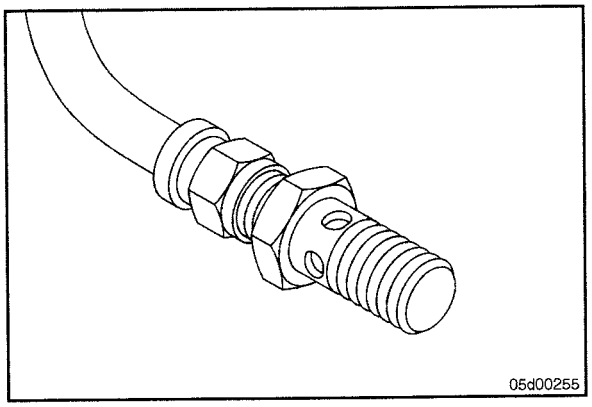
Next, drill and tap the open end of the banjo bolt for installation of a 5/16-24 set screw.

⚠CAUTION⚠

Installation of the banjo flow adapter at any place other than the fuel drain manifold can cause damage to high-pressure fuel system components.

Assemble the banjo flow adapter.

1. . Install a male union in the hex face of the banjo bolt.
2. . Attach a hose of sufficient length (it **must** reach an external container away from the engine compartment) to the male union or other type fitting.
3. . Install the 5/16-24 set screw in the open end of the banjo bolt.

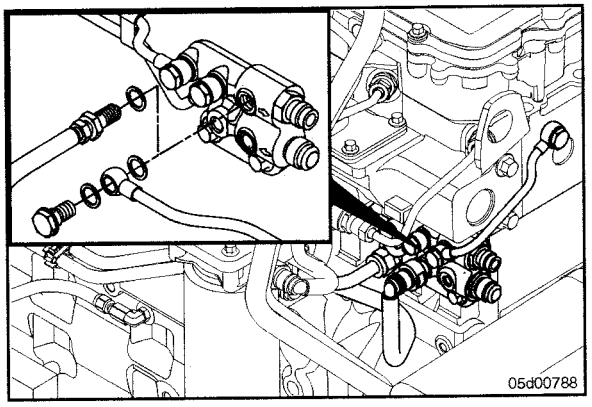


Remove the M12 banjo bolt that connects the fuel injector drain line to the fuel drain manifold.

Install the M12 fuel return hose, Part Number 3164618, at the fuel drain manifold.

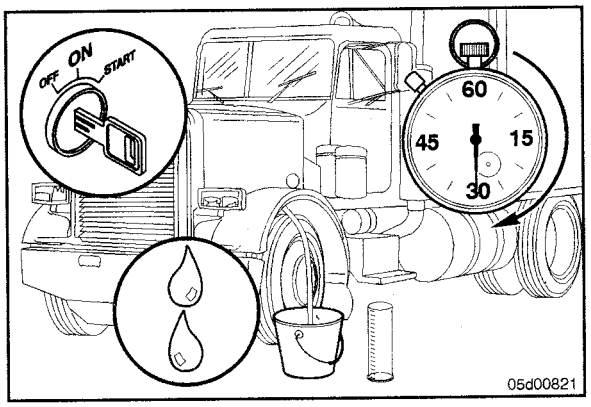
Route the fuel return hose into a collection device.

Obtain a graduated cylinder that is marked in cubic centimeters; example: graduated beaker, Part Number 3823705 or similar. A kitchen style measurement cup that is marked in cubic centimeters (cc's) works well.



Start the engine and allow the engine to idle until drain fuel from the injector drain line begins to flow into the collection container.

Connect INSITE™ electronic service tool.

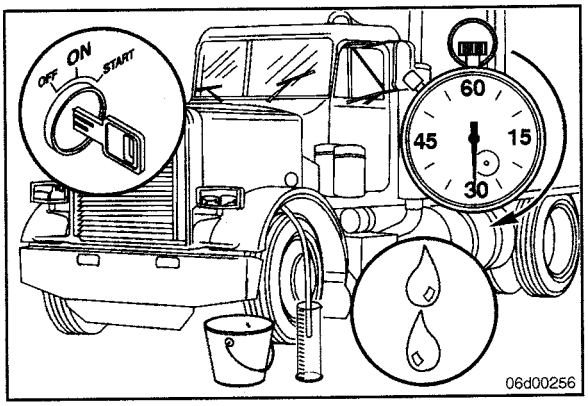


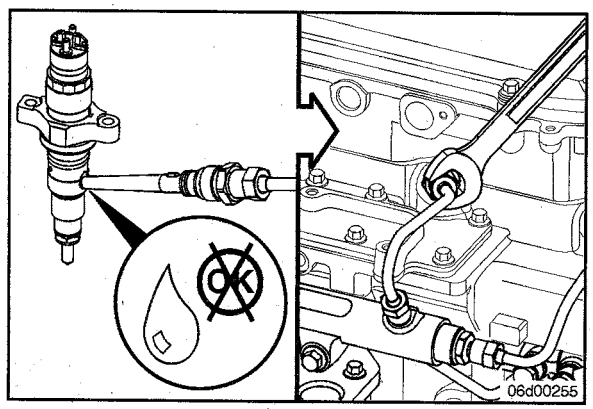
If the engine will **not** start, these procedures are still valid; however, the pass/fail specification is different.

If the engine will **not** start, drain flow **must** be measured while engaging the starter for 30 seconds at a time.

Leakage Specification if Engine Will Not Start

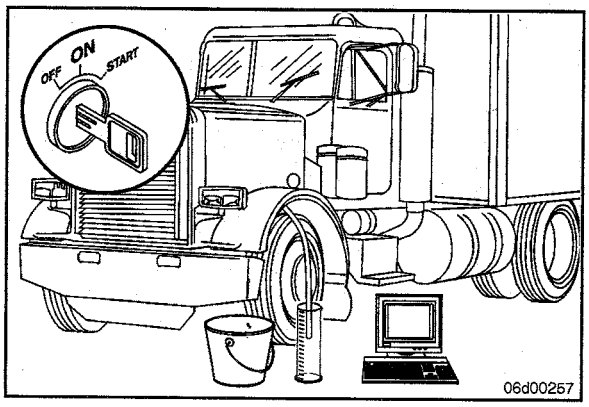
Maximum Leakage During 30 Seconds of Cranking	100 cc [3.38 oz]





If injector leakage is excessive during cranking and the engine will **not** start, check the following:

- High pressure fuel connector installation; refer to Procedure 006-052
- High pressure fuel connector damage; refer to Procedure 006-052
- Use the fuel leak test tool, Part Number 3164325, to isolate injectors from the fuel rail, one at a time.

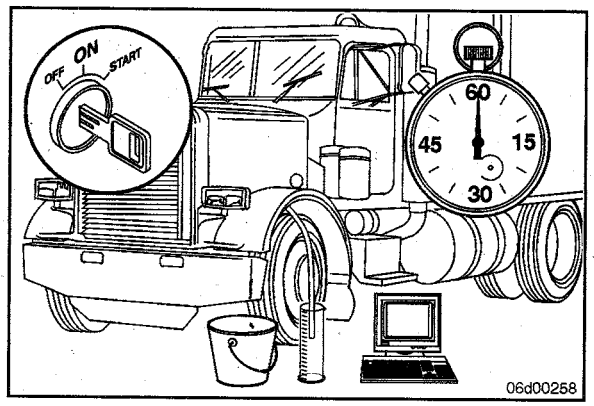


⚠CAUTION⚠

Fuel is at high pressure during this test. After connecting the test fitting, close the engine cover and stand clear of high-pressure fuel lines.

If the engine will start, the following steps will determine if the injector drain flow is excessive.

While the engine is running at idle, use INSITE™ High Pressure Leak Test to create high fuel rail pressure. INSITE™ will command 1500 BAR fuel rail pressure while the engine is at idle during this test.



Record the amount of time it takes for 300 cc [10.1 oz] of fuel to flow from the injector drain line performing the INSITE™ High Pressure Leak Test.

Leakage Specification With Engine Running

Maximum Leakage During 45 Seconds	300 cc [10.1 oz]

If 300 cc [10.1 oz] of fuel leaks from the injectors in less than 45 seconds, there is at least one loose or damaged high pressure fuel connector and/or injector.

NOTE: Fuel temperature and fuel type will influence this measurement. For example; as the engine is warmed up and the injectors become hot, the leakage rate will increase. Also, low viscosity fuels, such as kerosene, will cause the leakage rate to increase. The above specification is correct for on-highway diesel fuels where fuel inlet temperature is less than 49°C [120°F].

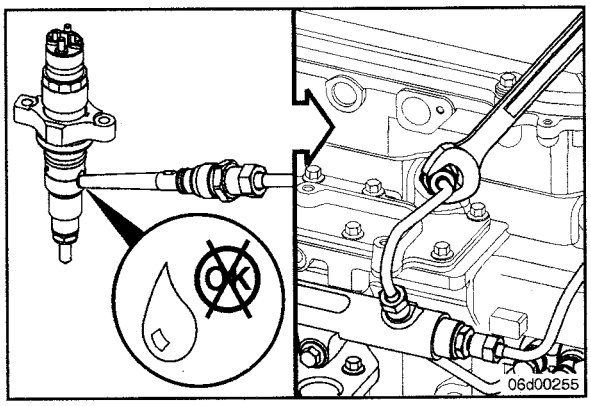
After recording the fuel leakage rate, stop the INSITE™ High Pressure Leak Test, and turn the keyswitch to OFF.

If injector drain flow is excessive, it will be necessary to isolate the injector(s) or fuel connector(s) that are damaged or worn.

A loose fuel connector retaining nut results in a poor seal at the interface between the fuel connector and the injector. This loose condition will result in leak of high-pressure fuel to the injector drain.

Verify first that the fuel connectors are properly tightened. Refer to Procedure 006-052.

If loose retaining nut(s) are found, retest for leaking after tightening the retaining nut(s).



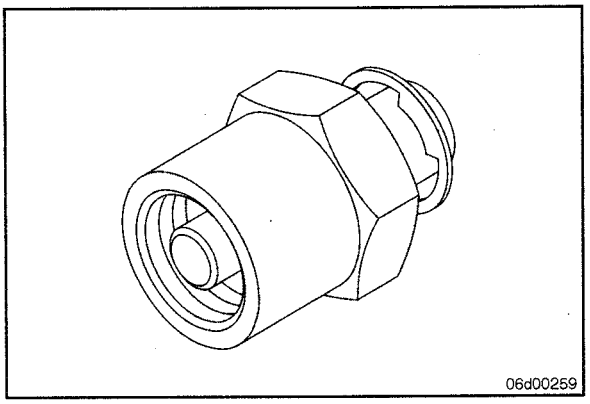
⚠CAUTION⚠

Do not install the isolation tool at the high pressure pump outlet fitting. Severe engine damage will result. This tool must only be installed at the fuel rail for the purpose of isolating the high-pressure fuel supply from individual injectors.

⚠CAUTION⚠

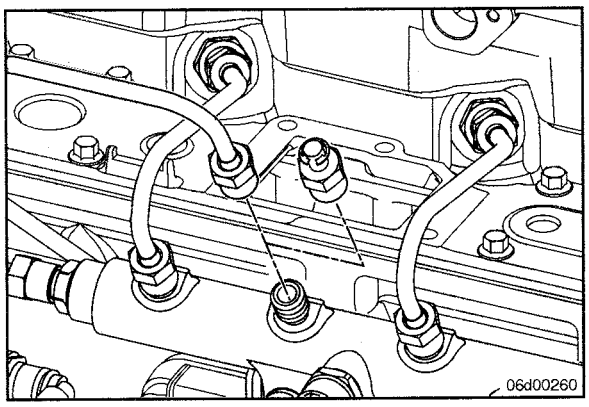
Make certain the keyswitch is in the OFF position (engine not running) when loosening or tightening high-pressure fuel lines.

Use leak test isolation tool, Part Number 3164325, to isolate excessive fuel drain from injectors or fuel connectors.



Isolate the injector and fuel connector for each cylinder by installing the isolation tool at the fuel rail in place of the high-pressure fuel line that supplies the fuel connector.

Torque Value: 43 N•m [32 ft-lb]



Record the amount of time it takes for 300 cc [10.1 oz] of fuel to flow from the injector drain line while the engine is running using the INSITE™ High Pressure Leak Test. Do this up to six (6) times, once while each line is isolated.

If isolating a single injector and high-pressure fuel connector causes the leakage time to increase significantly compared to the rest of the set, that injector and fuel connector **must** be inspected.

Inspect the suspect fuel connector. Refer to Procedure 006-052. If the fuel connector is **not** damaged then replace both the injector and the fuel connector.

Cylinder	Time
1	
2	
3	
4	
5	
6	

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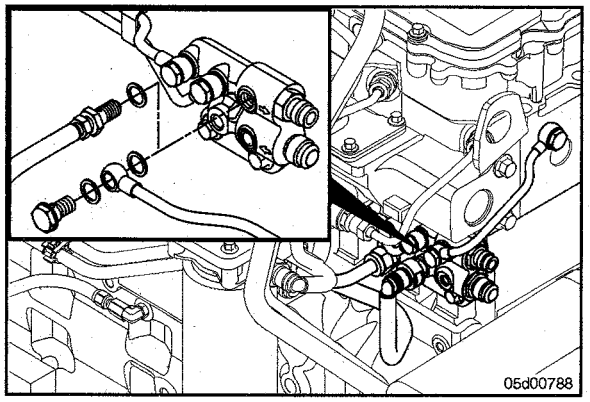


Remove the M12 diagnostic flow adapter from the fuel drain manifold and install the M12 banjo. Refer to Procedure 006-013.

Install all high-pressure fuel lines. Refer to Procedure 006-051.

Operate the engine and check for leaks.

Preparatory Steps

CAPS Fuel System

⚠CAUTION⚠

Attempting to remove the injector without first removing the fuel connector will cause damage to the injector body and/or fuel connector.

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

Remove the engine brake, if equipped. Refer to Procedure 020-004.

Remove the fuel connector. Refer to Procedure 006-052.

Cummins Common Rail Fuel System

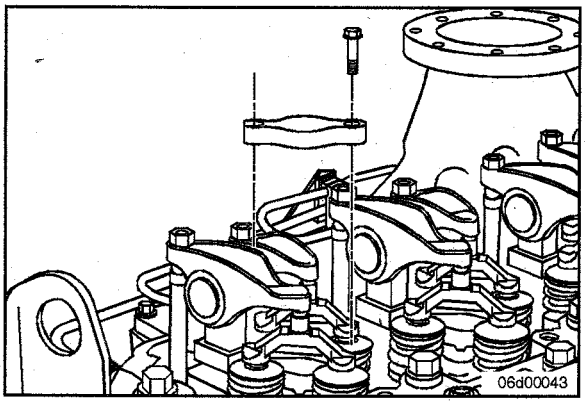
⚠CAUTION⚠

Attempting to remove the injector without first removing the fuel connector will cause damage to the injector body and/or fuel connector.

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

Remove the engine brake, if equipped. Refer to Procedure 020-004.

Remove the fuel connector. Refer to Procedure 006-052.



Remove

CAPS Fuel System

Remove the injector hold-down bolt that is nearest the exhaust manifold side of the engine.

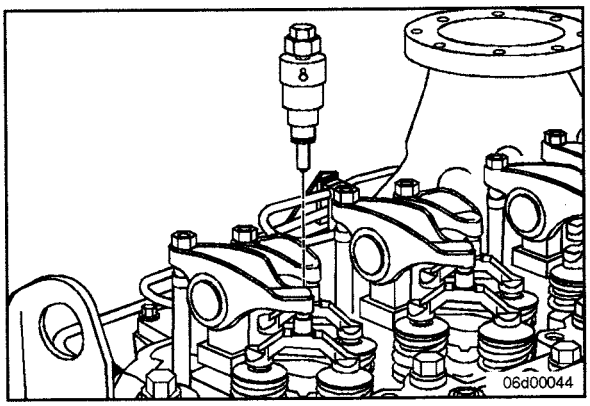
Remove the injector hold-down.

Remove the high-pressure fuel connector. Refer to Procedure 006-051.

Using the injector puller, Part No. 3825156, pull the injector out of the head.

Alternatively, a rocker cover capscrew can be installed into the top of the injector and used to pull the injector from the cylinder head.

Be sure that the injector seal washer is removed from the injector bore.



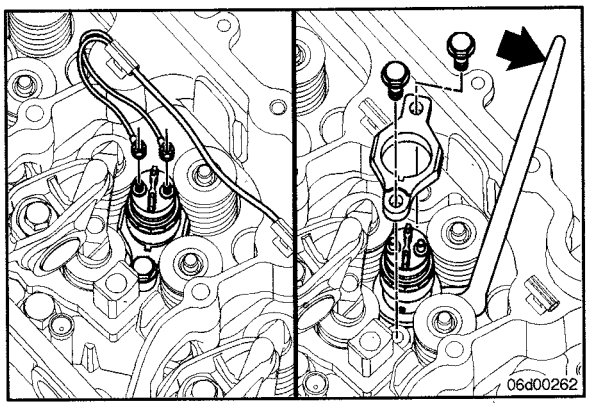
Cummins Common Rail Fuel System

Disconnect the injector wire harness from the injector.

Remove the exhaust rocker lever assembly. Refer to Procedure 003-008.

Remove the two injector hold-down capscrews and remove the injector hold down clamp.

Using a small heel-bar, pry up on the injector clamp hold-down flange (part of the injector body just above the cylinder head casting).



Test

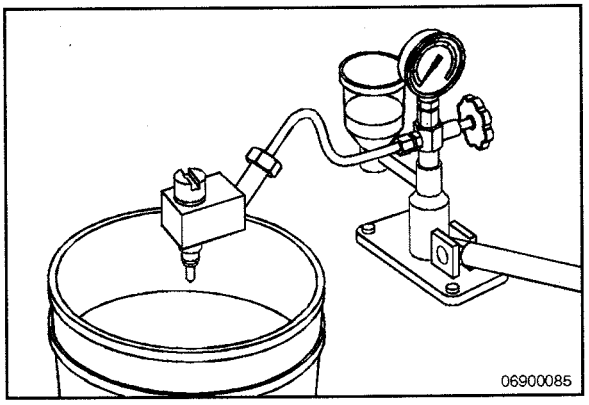
Mechanical Injectors

⚠ WARNING ⚠

While testing the injectors, keep hands and body parts away from the injector nozzle. Fuel coming from the injector is under extreme pressure and can cause serious injury by penetrating the skin.

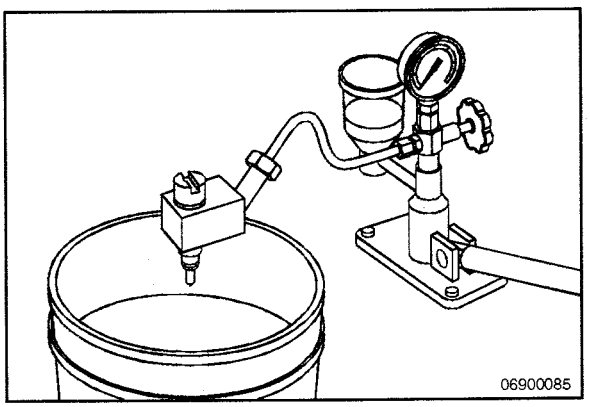
Install the injectors on an injector test stand. Open the bypass valve for the pressure gauge so the spray pattern can be checked.

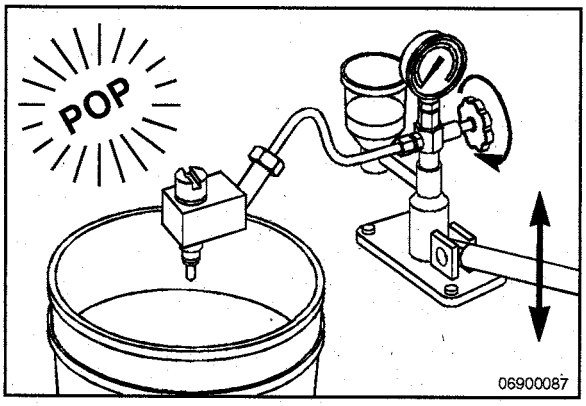
Use injector test fixture, Part Number 3162269, with the injector nozzle test, Part Number 3376946.



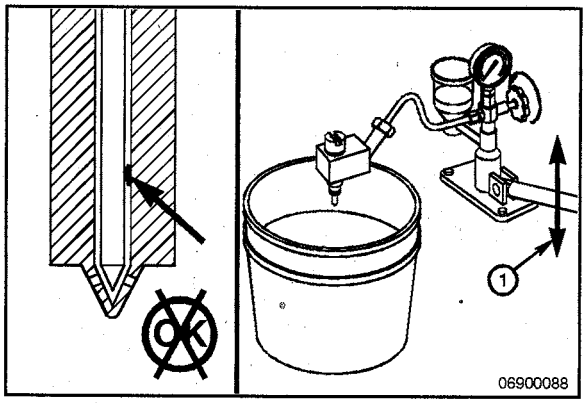
Operate the test stand lever quickly several times to check the spray pattern of the injectors. Verify that the correct number of plumes are present for the number of holes in the injector. Also pay close attention to the size and shape of each plume. If possible, compare the spray pattern to that of a new injector with the same assembly number.

NOTE: The injector spray pattern is an excellent indicator of the nozzle hole condition. Check each plume carefully. It is possible that **only** a single hole has been damaged resulting in degraded engine performance.





Close the bypass valve for the pressure gauge and operate the test stand lever to check the nozzle opening pressure. There **must** be a good crisp pop when the nozzle opens and the pressure **must** be within specification for the assembly number. Refer to the Master Repair Manual, Injection Pumps and Injectors, Midrange Engines, Bulletin 3666037-05 or later.

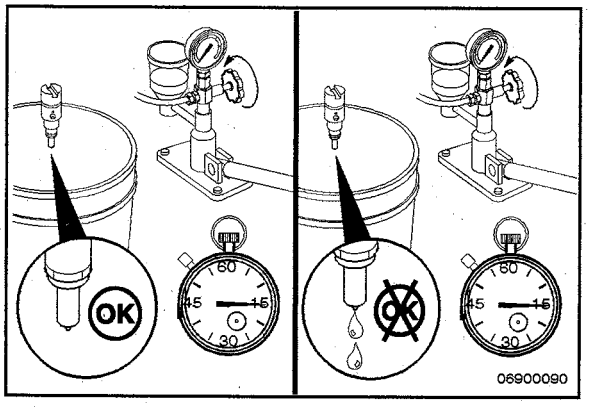


If the nozzle opening pressure is excessively low and/or the nozzle sprays excessive fuel, the injector needle can be sticking. The needle can be stuck due to poor lubrication or debris.

Sometimes it is possible to unstick an injector needle by using the injector test stand. Open the bypass valve for the pressure gauge and operate the test stand lever rapidly for 10 to 20 strokes.

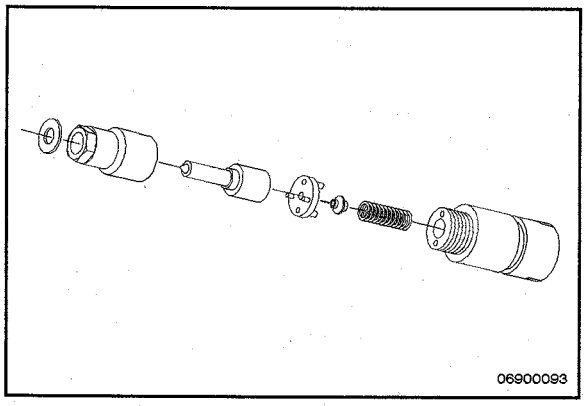
Recheck the nozzle opening pressure and spray pattern to see if the injector has returned to normal operation.

If the injector is still out of specification, replace the injector.



Check the injector for drip and/or excessive leak down. Close the bypass valve for the pressure gauge and build pressure to within 10 bars of the opening pressure of the nozzle.

A drop of fuel **must** not form within 15 seconds.



Disassemble

Mechanical Injectors

Place the injector in the injector clamp and remove the nozzle retaining nut.

NOTE: Injectors covered under warranty by the manufacturer **must not** be repaired. Refer to the manufacturer's warranty instructions.

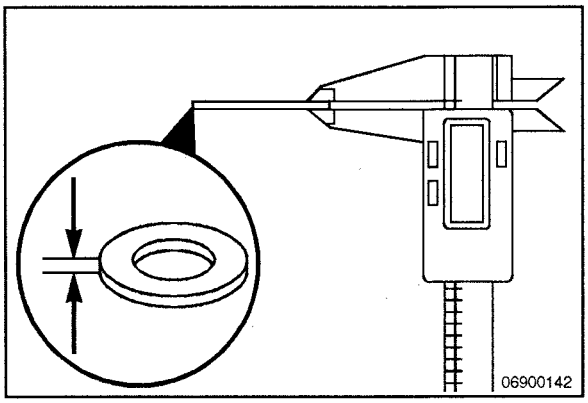
Remove the nozzle, intermediate plate, spring, and shims from the injector.

Clean and Inspect for Reuse

Verify the injector sealing washer is the correct thickness. The incorrect sealing washer can cause high pressure fuel leaks, and/or performance problems due to incorrect injector protrusion.

Refer to the injector part number for correct sealing washer shim thickness.

NOTE: All ISC and ISL engines which use mechanical ("POP") style injectors use a 1.5 mm [0.06 in] injector seal washer.

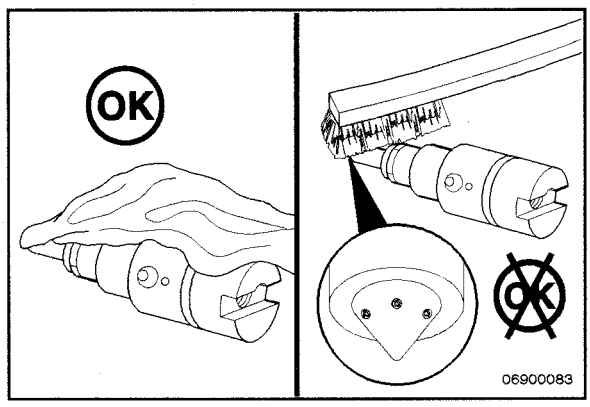


⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

△CAUTION△
Do not use a steel wire brush or glass beading to clean the injectors. This will damage the nozzle holes and cause performance problems.

Clean injector tip and body with safety solvent and soft clean rag.

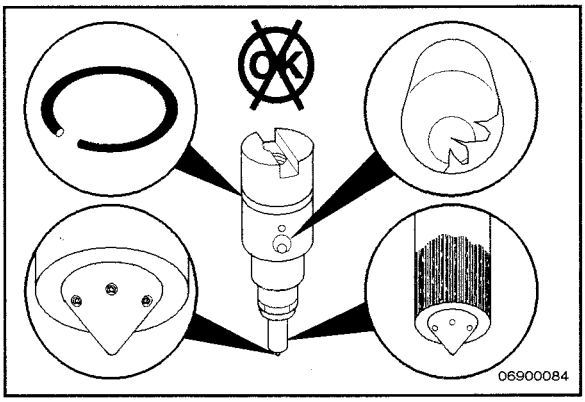


Inspect the o-ring for damage.

Look for burrs on the inlet to the injector.

Check the nozzle holes for any signs of damage such as hole erosion or hole plugging.

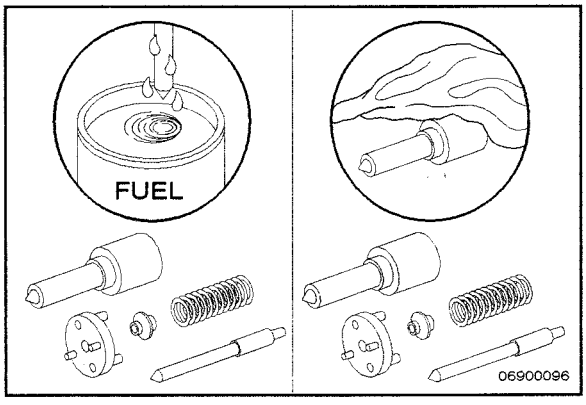
Spray safety solvent on the injector body and inspect the fuel inlet passage for small cracks which can allow high pressure fuel to leak to the injector drain passage.

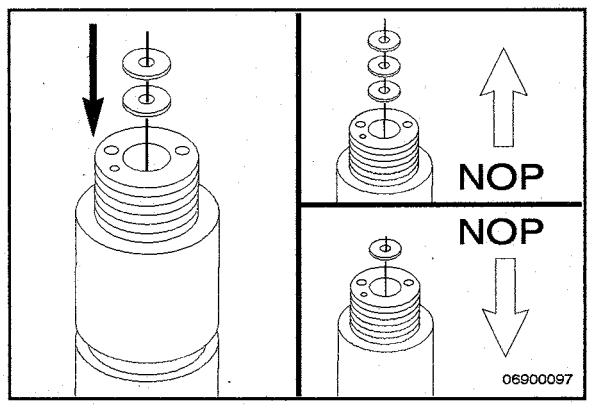


Assemble

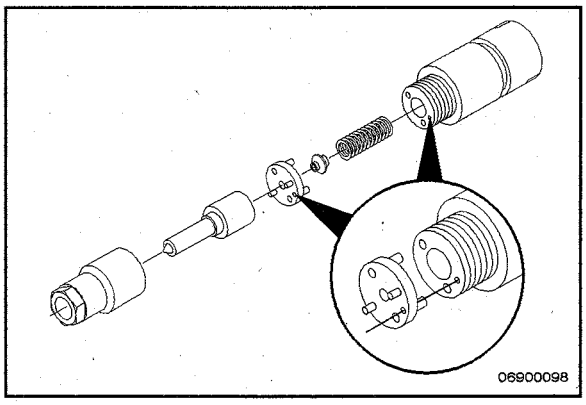
Mechanical Injectors

Clean the injector internal components with clean diesel fuel and a clean rag. Make sure there is no debris in the internal parts of the injector.



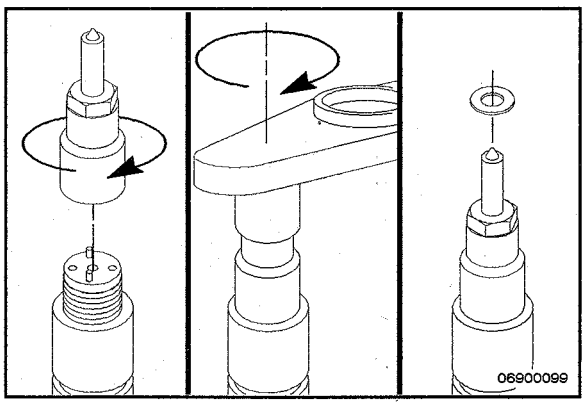


Install shims necessary to modify the nozzle opening pressure. More shims raise the nozzle opening pressure, less shims lower the nozzle opening pressure.



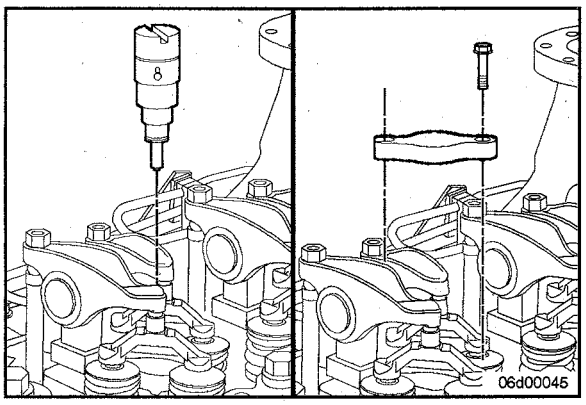
Install the spring, button, intermediate plate, and nozzle/needle.

Make sure that the intermediate plate is in the correct orientation with the supply hole on the plate lining up with the supply hole on the holder.



Install the retaining nut finger tight. Place the injector in the injector clamp and tighten the retaining nut. Install the sealing washer and body o-ring.

Torque Value: 47 N•m [35 ft-lb]



Install

CAPS Fuel System

Make sure that the injector bore is clean and that **only** one (1) sealing washer is installed on the injector nozzle.

Lubricate the injector o-ring with clean engine oil.

Place the injector in the head in the proper orientation.

Place the injector hold-down clamp on top of the injector and make sure that the injector is fully seated in the injector bore.

Install the injector hold-down and tighten.

Torque Value: 10 N•m [89 in-lb]

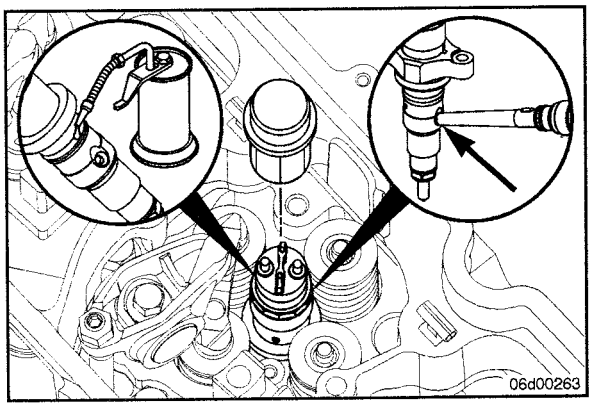
Cummins Common Rail Fuel System

Make sure that the injector bore is clean and that **only** one (1) sealing washer is installed on the injector nozzle.

Lubricate the injector o-ring with clean engine oil.

Place the injector in the cylinder head in the proper orientation (fuel inlet toward the high-pressure fuel connector).

Using the injector shipping sleeve, make sure that the injector is seated in the injector bore.



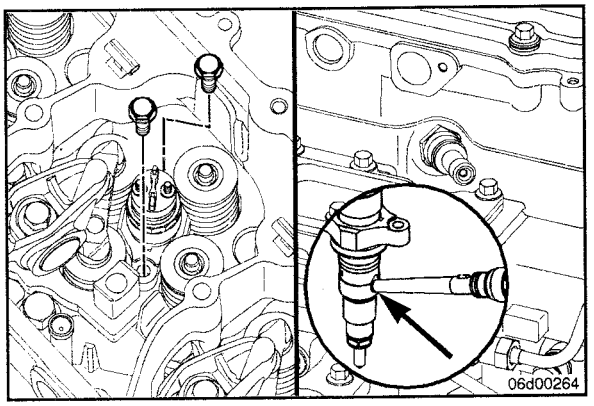
Start the injector hold-down capscrews but do **not** tighten.

Install the high-pressure fuel connector making sure that the end of the high-pressure fuel connector is in the injector inlet port.

Start the high-pressure fuel connector retaining nut and tighten partially.

Torque Value: 15 N•m [133 in-lb]

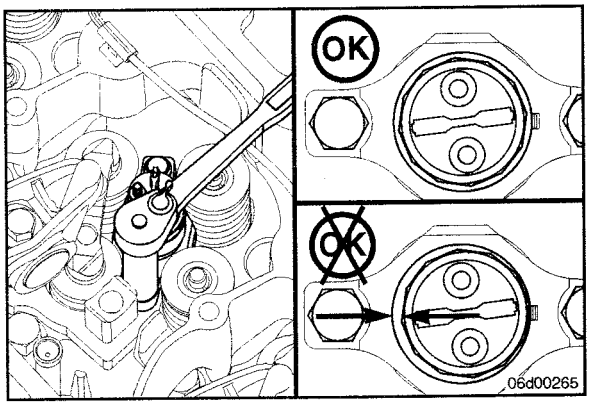
NOTE: This is not the final torque for the high-pressure fuel connector retaining nut.



Tighten the injector hold-down capscrews.

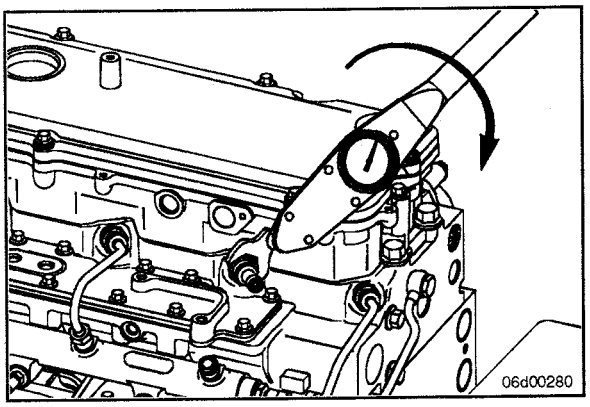
NOTE: Make sure to tighten the hold-down capscrews evenly. Check to make sure the gap between the hold-down clamp and the injector is equally spaced around the injector body.

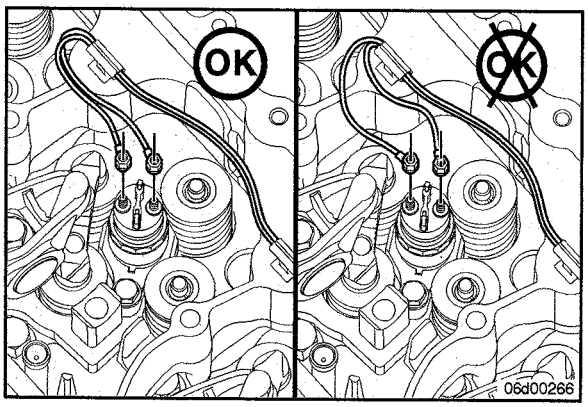
Torque Value: 10 N•m [89 in-lb]



Tighten the high-pressure fuel connector retaining nut.

Torque Value: 41 N•m [31 ft-lb]





⚠CAUTION⚠

Do not overtighten the injector harness. The injector terminals will be damaged if excessive over-torqued.

Install the exhaust rocker lever. Refer to Procedure 003-008.

Connect the wire harness to the injector. Refer to Procedure 019-063 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.

Orient the injector wires so that they will **not** interfere with a rocker lever or engine brake housing. If the rocker lever is able to come into contact with the injector harness, it will rub through the wire insulation and cause injector circuit fault codes.

Finishing Steps

CAPS Fuel System

Install the fuel connector. Refer to Procedure 006-052.

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

Install the high pressure fuel lines. Refer to Procedure 006-051.

Operate the engine and check for leaks.

Cummins Common Rail Fuel System

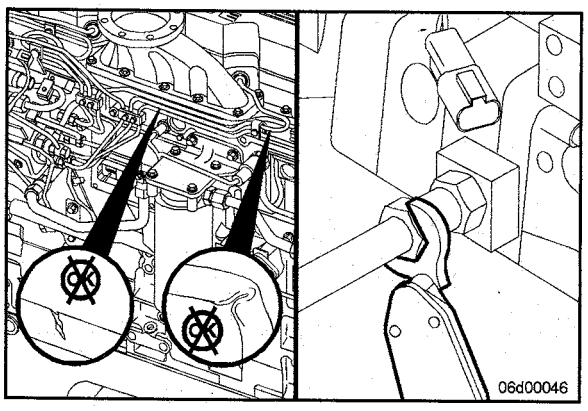
Install the exhaust rocker lever assembly. Refer to Procedure 003-008.

Install the engine brake, if equipped. Refer to Procedure 020-004.

Install the high pressure fuel lines. Refer to Procedure 006-051.

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

Operate the engine and check for leaks.



Injector Supply Lines (High Pressure) (006-051)

Initial Check

CAPS Fuel System

Inspect the lines for cracks, chafing, or leaks. Make sure that the lines are tightened to the proper specification.

Check the fuel pump connection.

Torque Value: 24 N•m [18 ft-lb]

Check the cylinder head connection.

Torque Value: 38 N•m [28 ft-lb]

Cummins Common Rail Fuel System

Check the fuel pump connection.

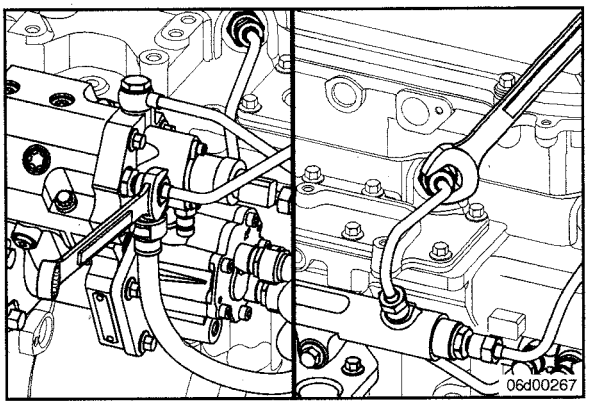
Torque Value: 38 N•m [28 ft-lb]

Check the cylinder head connection.

Torque Value: 38 N•m [28 ft-lb]

Check thr fuel rail connection.

Torque Value: 38 N•m [28 ft-lb]



Remove

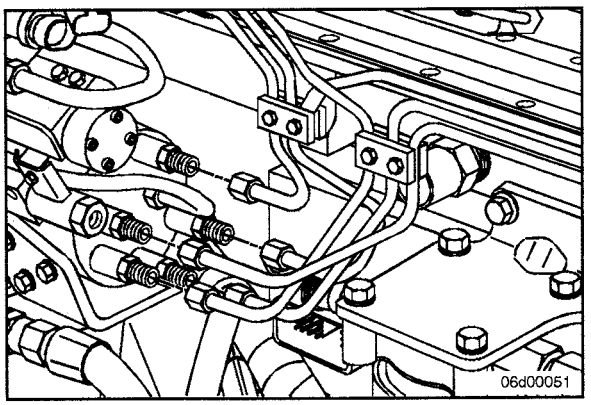
CAPS Fuel System

Remove the fuel line from the injection pump.

NOTE: Use two (2) wrenches to prevent the outlet fitting from turning.

Remove the fuel line clamp capscrews from the intake cover. This **must** be done before injection lines can be pulled loose from cylinder head.

Remove the fuel line from the cylinder head.

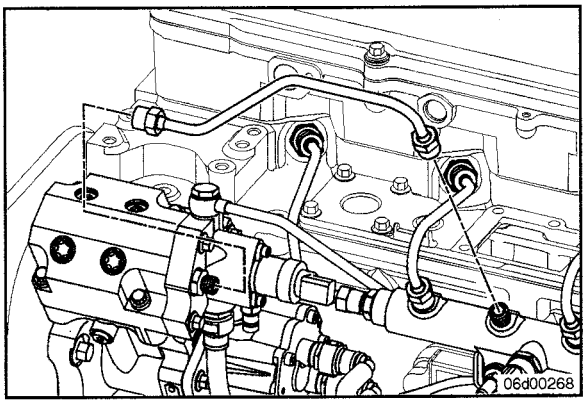


Cummins Common Rail Fuel System

If necessary, remove the air intake connection or turbo control actuator.

Loosen the fuel line at the fuel rail and the fuel connector or high-pressure pump outlet fitting.

Remove the high-pressure fuel line.

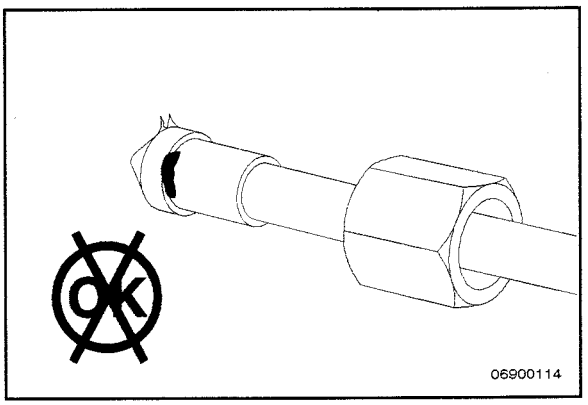


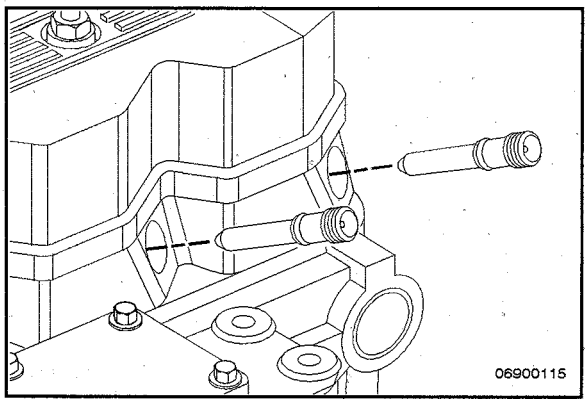
Clean and Inspect for Reuse

Check the ferrules of the lines for any signs of burrs or foreign material.

Inspect the sealing surface on the cone for severe deformation that would prohibit reuse.

Check for cracks and deformation.

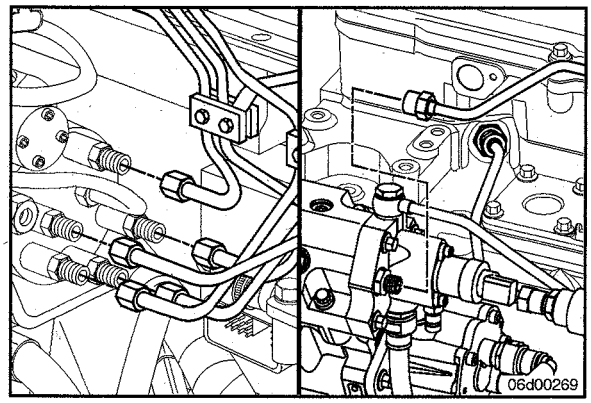




Install

CAPS Fuel System

Before installing the injector supply lines, make sure that the fuel connector is fully and properly seated against the injector. Refer to Procedure 006-052.



Install the fuel lines in the reverse order of removal.

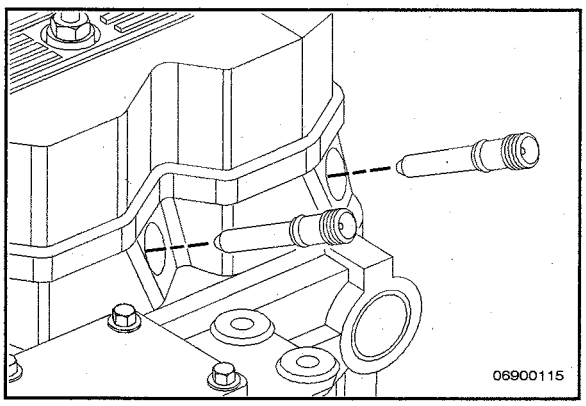
Check the fuel pump connection.

Torque Value: 24 N•m [18 ft-lb]

Check the cylinder head connection.

Torque Value: 38 N•m [28 ft-lb]

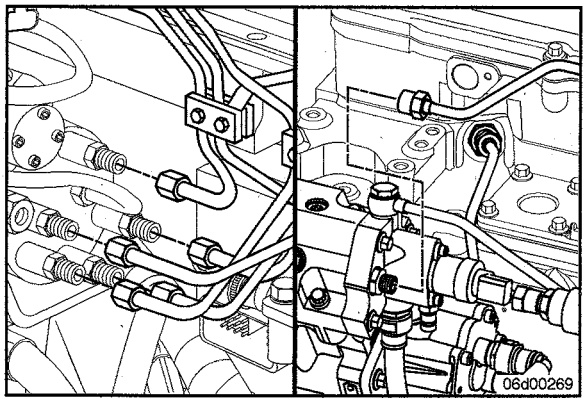
Operate the engine and check for leaks.



Cummins Common Rail Fuel System

Before installing the injector supply lines, make sure that the fuel connector is fully and properly seated against the injector. Refer to Procedure 006-052.

For Cummins Common Rail Fuel Systems, be certain that the high-pressure connector retaining nut is tightened. Refer to Procedure 006-052.



Install the fuel lines in the reverse order of removal.

Check the fuel pump connection.

Torque Value: 38 N•m [28 ft-lb]

Check the cylinder head connection.

Torque Value: 38 N•m [28 ft-lb]

Check thr fuel rail connection.

Torque Value: 38 N•m [28 ft-lb]

Operate the engine and check for leaks.

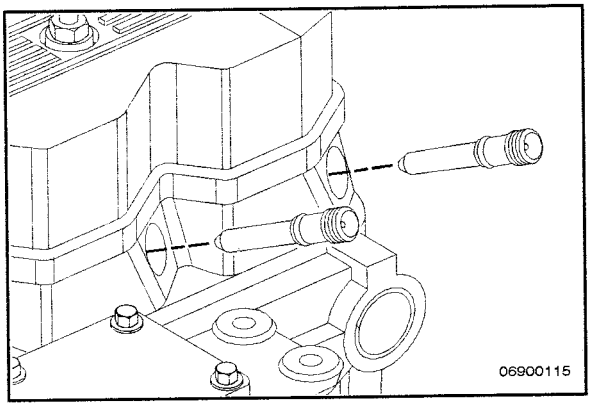
Fuel Connector (Head Mounted) (006-052)

Remove

CAPS Fuel System

Remove injector supply line. Refer to Procedure 006-051.

Use fuel connector puller, Part Number 3825157, to remove the fuel connector from the cylinder head.

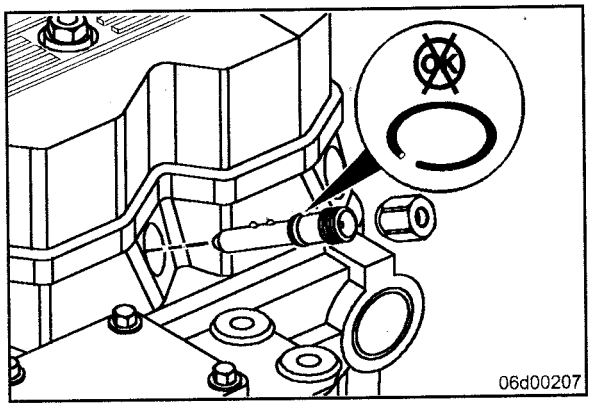


Cummins Common Rail Fuel System

Remove the injector supply line. Refer to Procedure 006-051.

Remove the fuel connector retaining nut.

Use fuel connector puller, Part Number 3164025 to remove the fuel connector from the cylinder head.



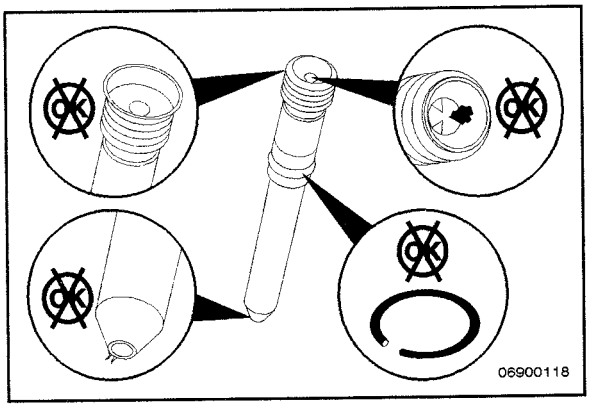
Inspect for Reuse

A new high-pressure connector **must** be installed if a new injector is being installed.

Inspect the fuel connector. Look for burrs or deformation around the inlet and outlet sides of the connector.

Check the edge filter for signs of plugging or material contamination. Do **not** reuse a high-pressure fuel connector debris is present.

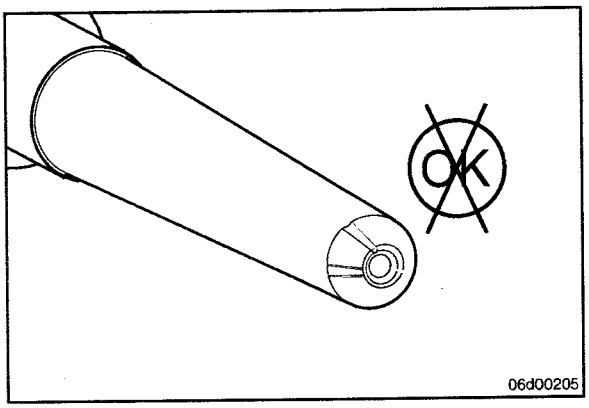
Check the o-ring for tearing or deterioration.

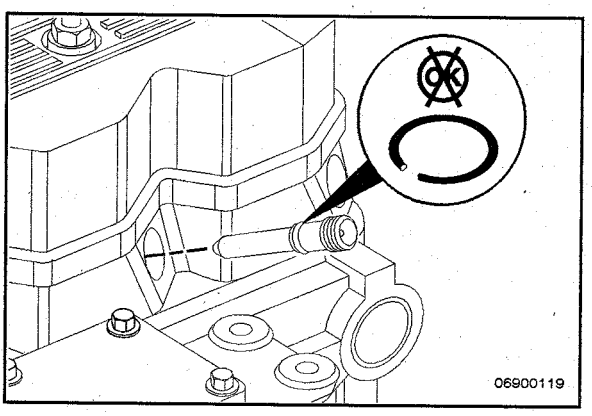


Inspect the outlet sealing surface of the high-pressure connector for wear, an uneven seating surface, or signs of leakage.

When a high-pressure fuel leak is present, small lines or cuts in the connector will be eroded into the seating surface.

The high-pressure connector and injector **must** be replaced when this failure is observed.





Install

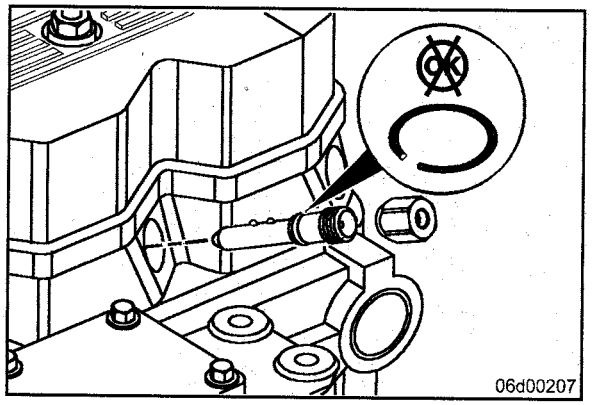
CAPS Fuel System

Oil the fuel connector o-ring with clean engine oil.

Carefully push the fuel connector into the head until it stops against the injector. Be certain the injector is fully seated in the injector bore before installing the fuel connector. Refer to Procedure 006-026.

Install the high-pressure fuel lines. Refer to Procedure 006-051.

Operate the engine and check for leaks.



Cummins Common Rail Fuel System

A new fuel connector **must** be used when replacing the injector.

Lubricate the fuel connector o-ring and the threads on the fuel connector retaining nut.

Carefully insert the fuel connector, aligning the guide pin with the slot in the cylinder head at the 12-o'clock position.

NOTE: If the injector was removed along with the high-pressure fuel connector, the installation steps outlined in Procedure 006-026 **must** be followed.

Tighten the fuel connector retaining nut.

Torque Value: 41 N•m [31 ft-lb]

Install the high-pressure fuel lines. Refer to Procedure 006-051.

Operate the engine and check for leaks.

Fuel Pump Air Bleed Line (006-056)

Preparatory Steps

⚠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.

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△

Do not use the air bleed line as a handle or step. Doing this may result in cracks or damaged air bleed line that will cause fuel leaks. Make sure that steam does not spray directly on the electrical connections on the top of the accumulator block or fault codes will possibly occur.

Thoroughly steam-clean the entire fuel pump.

Dry the fuel pump with compressed air.

Remove

ISC and QSC8.3 With CAPS Injection Pump

⚠WARNING⚠

To reduce the possibility of an air bleed line leak due to a broken air bleed line, use two wrenches during removal and installation. Failure to do so may result in a cracked fuel line. In certain applications, with the fuel tank above the head of the engine, this will result in fuel draining from the fuel tank.

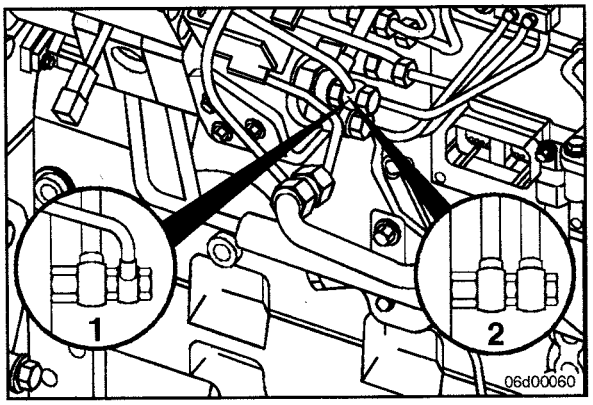
NOTE: There are three styles of air bleed lines. Identify your style and use the appropriate procedures that follow.

Style One (1):

Remove the banjo capscrew at the injection control valve drain fitting of the fuel pump. Use two wrenches to prevent the line from being bent.

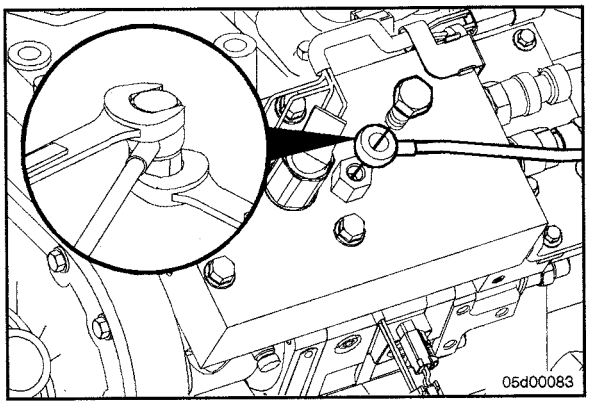
Style Two (2):

Remove the banjo capscrew at the injection control valve drain fitting of the fuel pump. Remove the hollow banjo fitting holding the air bleed line. Use two wrenches to prevent the line from being bent.



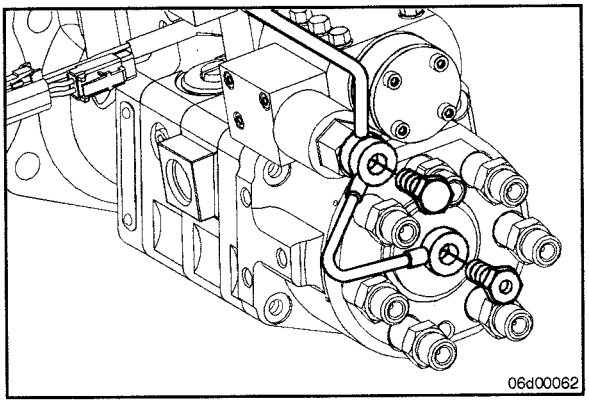
Remove the banjo capscrew at the air bleed fitting on top of the fuel pump. It is located on the accumulator module next to the two pumping control valves.

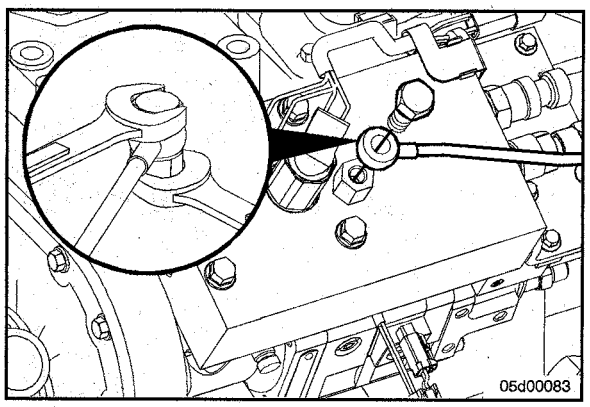
Use two wrenches to prevent the air bleed fitting from turning.



ISL and QSL9 With CAPS Injection Pump

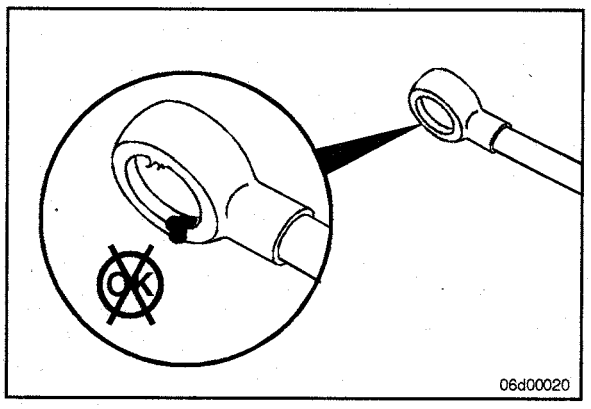
Remove the banjo bolt from the injection control valve drain fitting and the distributor plug.





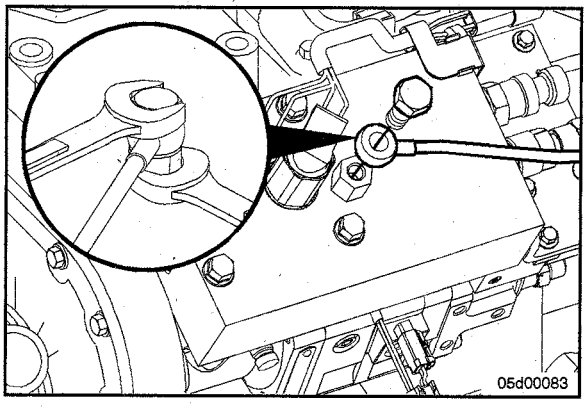
Remove the banjo capscrew at the air bleed fitting on top of the fuel pump. It is located on the accumulator module next to the two pumping control valves.

Use two wrenches to prevent the air bleed fitting from turning.



Inspect for Reuse

Inspect the lines for pinches, bends, or damaged connectors.



Install

ISC and QSC8.3 With CAPS Injection Pump

⚠WARNING⚠

To reduce the possibility of an air bleed line leak due to a broken air bleed line, use two wrenches during removal and installation. Failure to do so may result in a cracked fuel line. In certain applications, with the fuel tank above the head of the engine, this will result in fuel draining from the fuel tank.

Install the banjo capscrew at the air bleed fitting on top of the fuel pump. Use two wrenches to prevent the line from being bent.

Torque Value: 8 N•m [70 in-lb]

NOTE: Use new sealing washers.

Style One (1):

Install the banjo capscrew drain fitting on the fuel pump at the injection control valve. Use two wrenches to prevent the line from being bent.

Torque Value: 8 N•m [70 in-lb]

NOTE: Use new sealing washers.

Style Two (2):

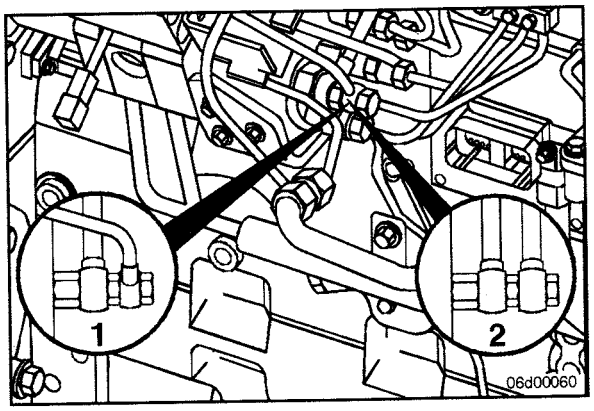
Install the hollow banjo fitting at the injection control valve drain fitting to secure the air bleed line. Use two wrenches to prevent the line from being bent.

Torque Value: 24 N•m [18 ft-lb]

Install banjo capscrew. Use two wrenches to prevent the line from being bent.

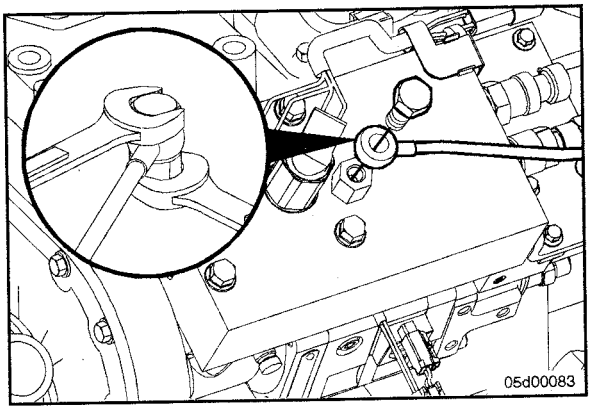
Torque Value: 24 N•m [18 ft-lb]

NOTE: Use new sealing washers.



ISL and QSL9 With CAPS Injection Pump

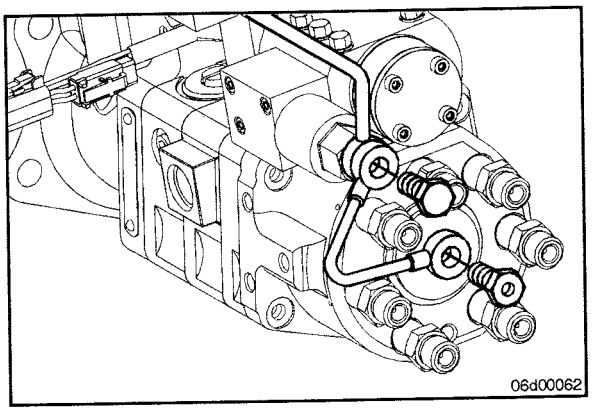
Install the banjo capscrew at the air bleed fitting on top of the fuel pump. Use two wrenches to prevent the air bleed fitting from turning.



Install the banjo capscrew in the injection control valve drain fitting and the distributor plug.

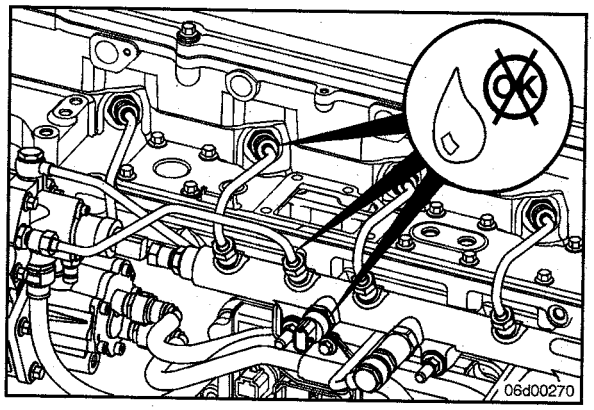
Torque Value: 8 N•m [70 in-lb]

NOTE: Use new sealing washers.



Finishing Steps

Operate the engine and check for leaks.



Fuel Rail (006-060)

Initial Check

⚠WARNING⚠

The pressure within the fuel rail is extremely high. High pressure can penetrate the skin. Stand clear of the engine while it is running.

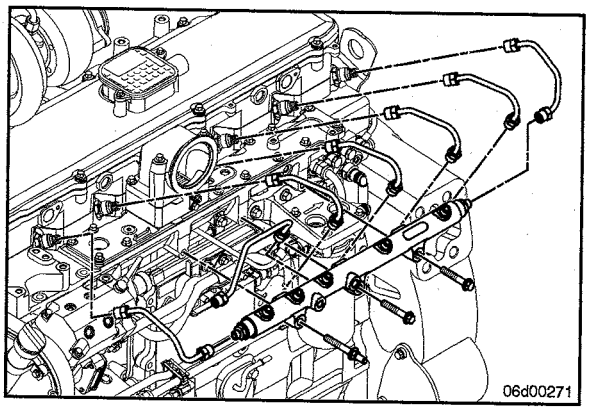
⚠WARNING⚠

The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. To avoid the possibility of personal injury and property damage, never loosen any fittings while the engine is running.

Inspect the fuel pressure sensor, high-pressure fuel line connections, and male unions for leaks.

Preparatory Steps

Disconnect the fuel pressure sensor from the engine wiring harness. Refer to Procedure 019-043 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.



Remove

Remove the high-pressure fuel lines from the fuel rail. Refer to Procedure 006-051.

Remove the fuel drain line from the fuel rail pressure relief valve. Refer to Procedure 006-013.

Remove the capscrews that secure the fuel rail to the cylinder head. Remove the fuel rail assembly.

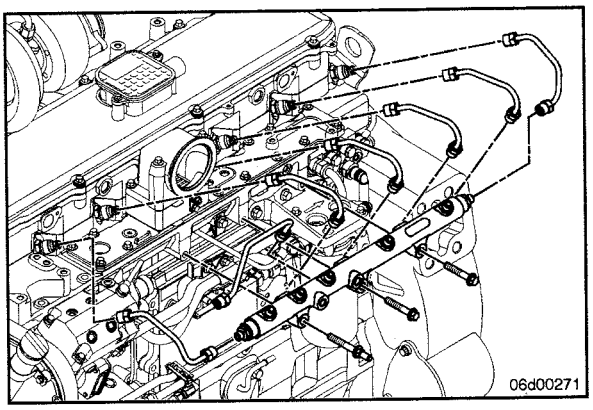
Install

Install the fuel rail assembly. Follow the proper sequence to make sure that high-pressure fuel lines are properly aligned.

1. . Install the fuel rail assembly capscrews finger-tight.
2. . Install the high-pressure fuel lines finger-tight.
3. . Tighten the fuel rail assembly capscrews.

Torque Value: 43 N•m [32 ft-lb]

4. Tighten the high-pressure fuel lines. Refer to Procedure 006-051.



Finishing Steps

Install the fuel drain line to the fuel pressure relief valve. Refer to Procedure 006-013.

Install the fuel pressure sensor to the engine wiring harness. Refer to Procedure 019-043 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.

Operate the engine and check for leaks.

Fuel Pressure Relief Valve (006-061)

Initial Check

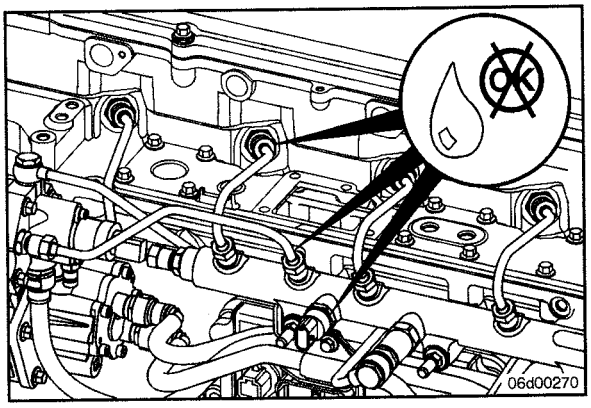
⚠WARNING⚠

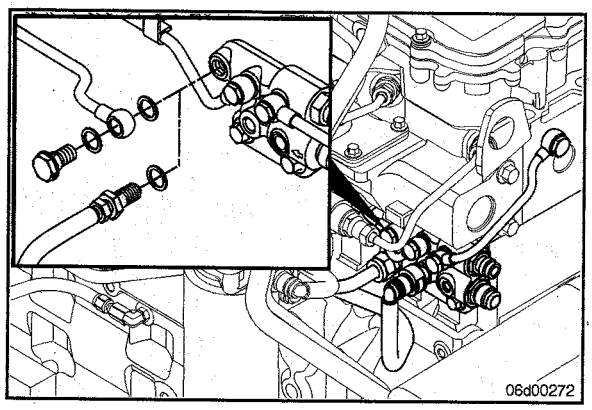
The pressure within the fuel rail is extremely high. High-pressure can penetrate the skin. Stand clear of the engine while it is running.

⚠WARNING⚠

The fuel pump high-pressure fuel lines and fuel rail contain very high pressure fuel. To avoid the possibility of personal injury, never loosen any fittings while the engine is running.

Operate the engine and check for external fuel leaks.





Check for a fuel rail pressure relief valve that leaks excessive fuel to drain.

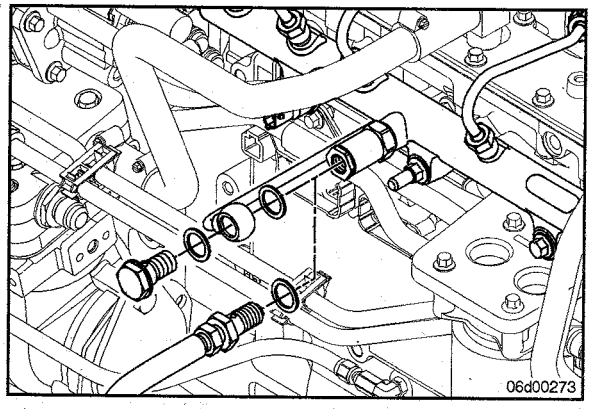
Measurement of fuel rail pressure relief valve leakage requires use of a fuel return hose, Part Number 3164618. If necessary this tool can be constructed. Refer to Procedure 006-026. The tool is used to isolate the leakage from just the fuel rail pressure relief valve so that it can be measured into a graduated cylinder.

NOTE: If Fault Code 449 or 2311 is active, do **not** replace the fuel rail pressure relief valve without first determining the cause of the fault condition. Refer to the appropriate troubleshooting tree(s).

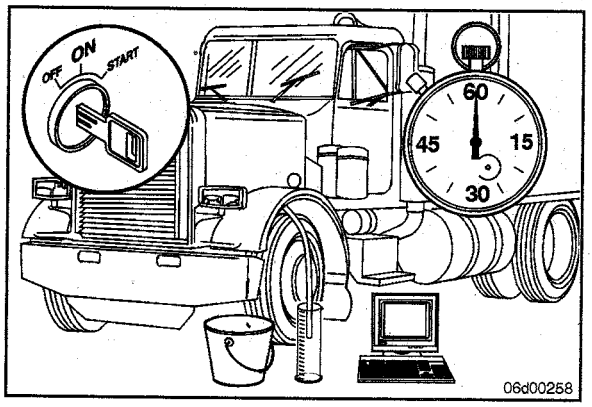
Remove the M12 banjo bolt that connects the fuel rail pressure relief valve drain line to the fuel drain manifold.

Install a fuel return hose, Part Number 3164618, at the fuel drain manifold.

Route the fuel return hose into a collection device.



Alternatively, fuel rail pressure relief valve leakage measurement tool, Part Number 4164617, can be installed at the fuel rail pressure relief valve.



Test

Start the engine and allow the engine to idle.

Measure the leakage.

Specification:

Less than 30 drops per minute **must** drain from the fuel rail pressure relief valve while the engine runs at idle.

⚠CAUTION⚠

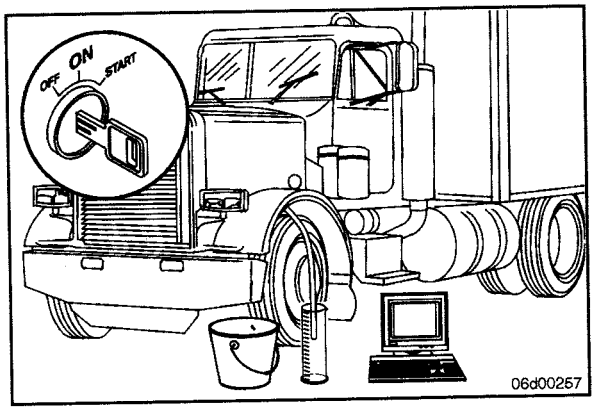
Fuel is at high pressure during this test. After connecting the test fitting, close the engine cover and stand clear of high-pressure fuel lines.

While the engine is running at idle, use the INSITE™ High Pressure Leak Test to create higher fuel rail pressure. INSITE™ will command 1500 BAR fuel rail pressure while the engine is at idle during this test.

Specification:

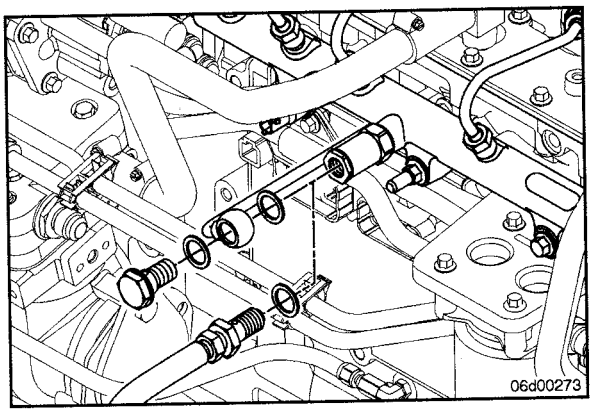
Less than 30 drops of fuel per minute **must** drain from the fuel rail pressure relief valve.

If fuel rail pressure relief valve leakage is excessive, it **must** be replaced. However, make certain that Fault Code 449 or 2311 is **not** active indicating that a system failure is causing the fuel rail pressure relief valve to open.



Remove the fuel return hose and install the fuel drain line banjo bolt. Refer to Procedure 006-013.

Operate the engine and check for leaks.

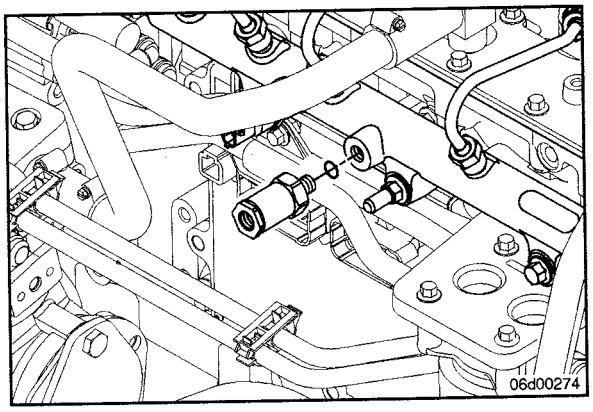


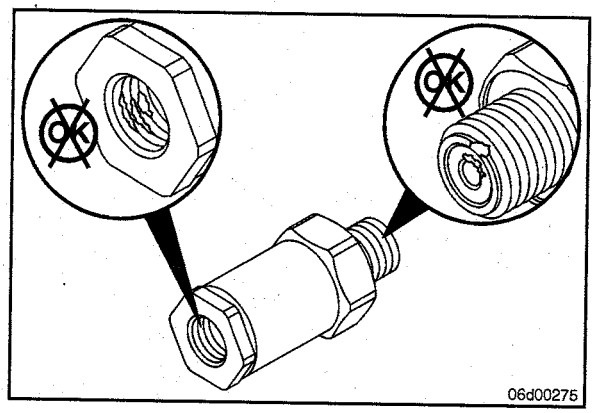
Remove

Remove the fuel drain line from the fuel rail pressure relief valve. Refer to Procedure 006-013.

Remove the fuel pressure relief valve adapter and copper seal washer.

Remove the fuel pressure relief valve.



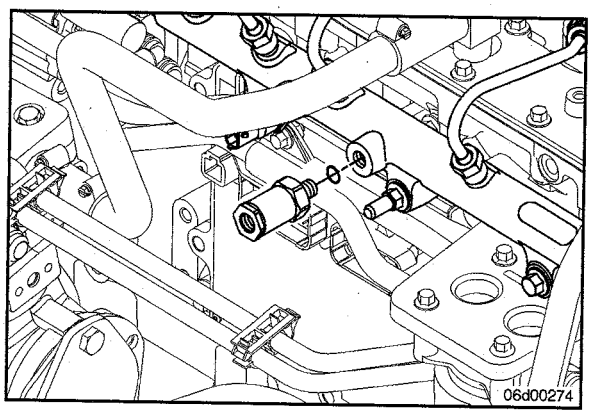


Inspect for Reuse

If the fuel pressure relief valve exhibits excessive leakage to drain, it **must not** be reused.

Inspect the high-pressure seal surface on the fuel pressure relief valve and also in the fuel rail for damage. Do **not** reuse components if the high-pressure seal joint is damaged.

Inspect the copper seal washer and adapter fitting for damage.



Install

Install the fuel pressure relief valve with Lubriplate™ on the threads.

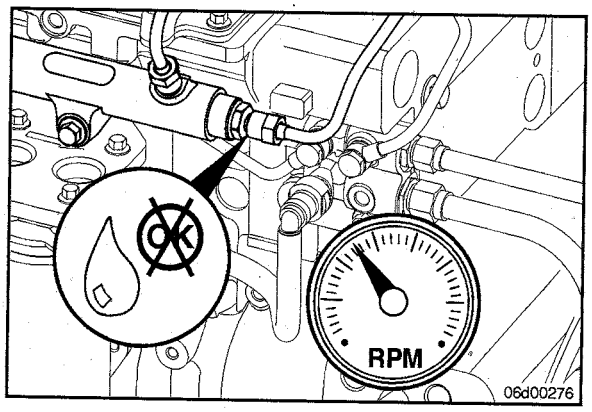
Torque Value: 100 N•m [74 ft-lb]

If the reducer has been removed from the fuel rail pressure relief valve, install the reducer with a new copper seal washer.

Torque Value: 37 N•m [27 ft-lb]

Install the fuel drain line to the fuel pressure relief valve. Refer to Procedure 006-013.

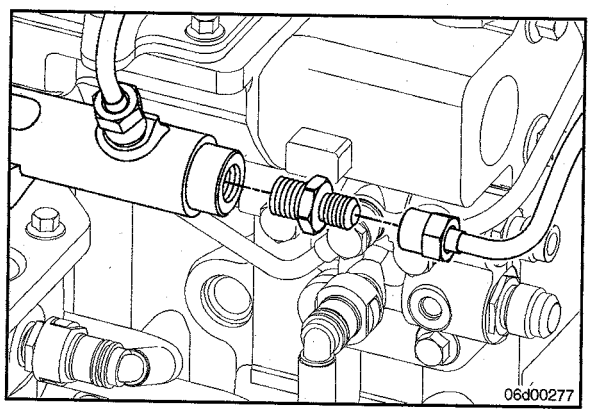
Operate the engine and check for leaks.



Fuel Rail High Pressure Fitting (006-067)

Initial Check

Operate the engine and check for external leaks.



Remove

Remove the high-pressure fitting **only** if a leak is detected.

Install

Flush the outlet fitting using contact cleaner.

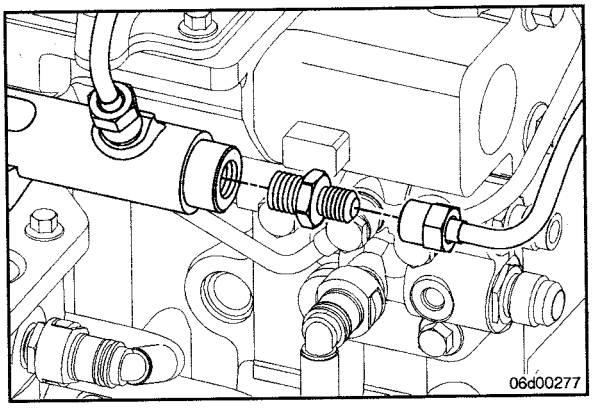
Apply Lubriplate™ to the high-pressure fitting threads.

Install the high-pressure fitting.

Torque Value: 100 N•m [74 ft-lb]

Reinstall the high-pressure fuel line. Refer to Procedure 006-051.

Operate the engine and check for leaks. If a leak occurs after replacing the fitting, replace the rail.



Notes

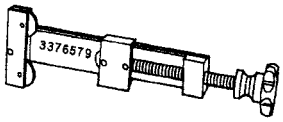
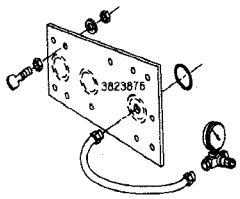
Section 7 - Lubricating Oil System - Group 07

Section Contents

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
3376579	**Tube (Filter) Cutter** Used to cut open the filter to permit inspection of the filter element.	 3376579
3823876	**Lubricating Oil Cooler Pressure Test Kit** Used to seal and pressurize the lube oil cooler to test for leaks.	

Engine Oil Heater (007-001)

Preparatory Steps

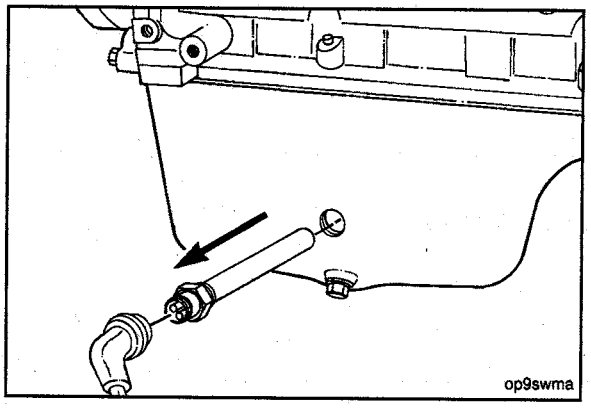
⚠WARNING⚠

Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

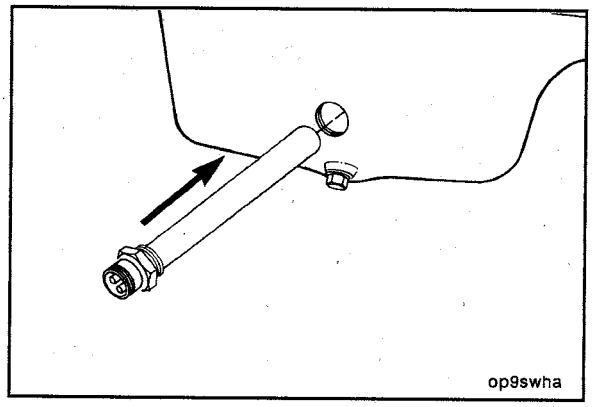
Drain the lubricating oil. Refer to Procedure 007-037.



Remove

Disconnect the oil heater electrical cord.

Remove the heater element.



Install

Install the heater element.

Torque Value: 120 N•m [89 ft-lb]

Finishing Steps

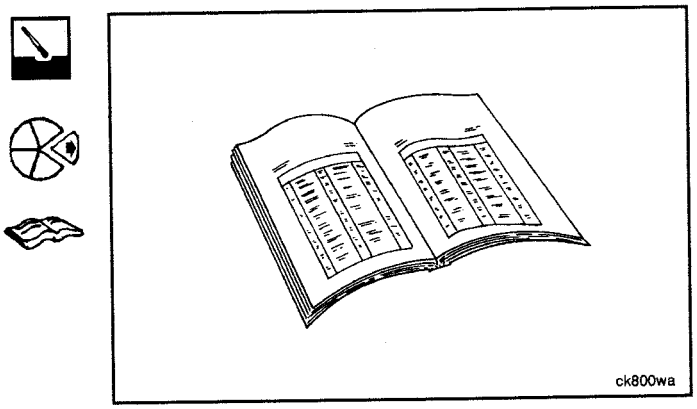
Connect the oil heater electrical cord.

Fill the engine to the correct oil level. Refer to Procedure 007-037.

Operate the engine and check for leaks.

Lubricating Oil Cooler (007-003)

Preparatory Steps



⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠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.

⚠WARNING⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

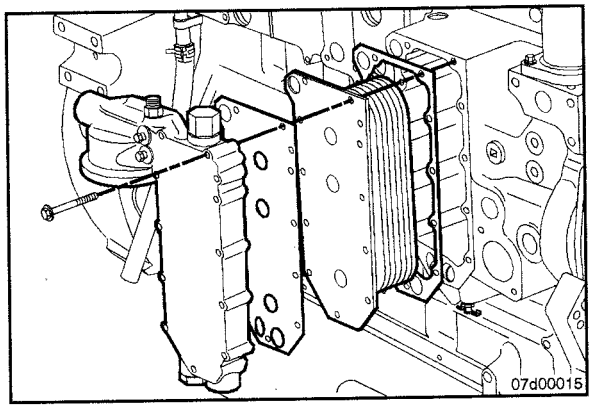
⚠WARNING⚠

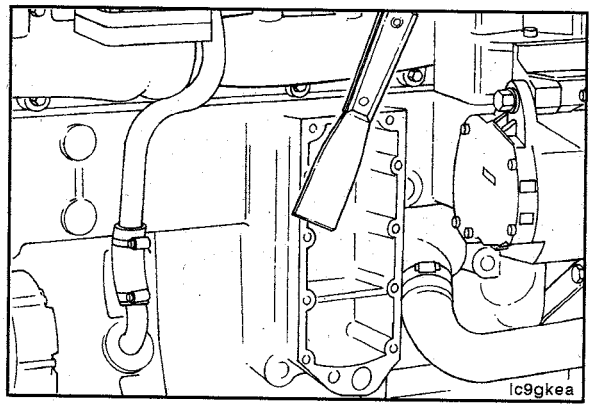
State and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

- Drain the coolant. Refer to Procedure 008-018.
- Clean the area around the lubricating oil cooler cover.
- Remove the lubricating oil filter. Refer to Procedure 007-013.
- Remove the turbocharger oil supply line. Refer to Procedure 010-046.

Remove

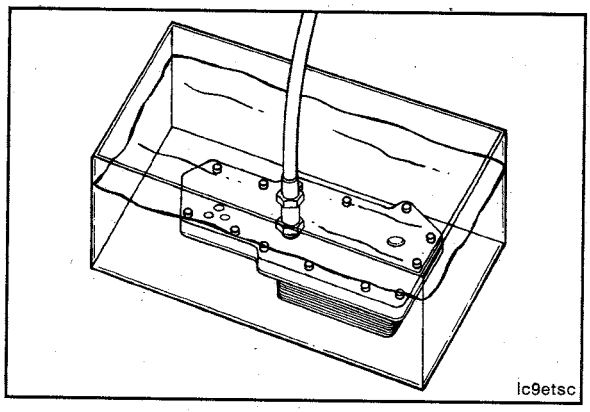
Remove the lubricating oil cooler cover, gaskets and cooler element.





Clean

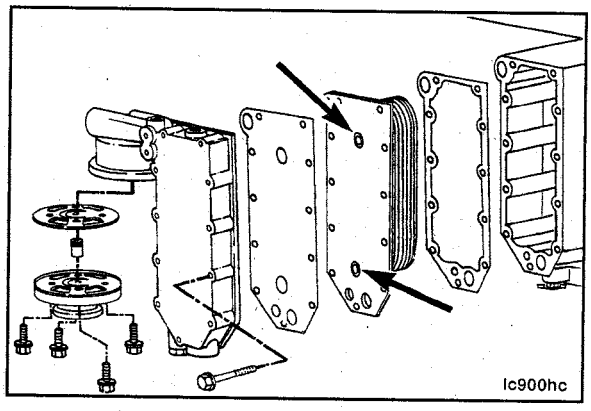
Clean the sealing surfaces of the cylinder block and the oil cooler cover.



Leak Test

Pressure-test the lubricating oil cooler element using leak test kit, Part Number 3823876.

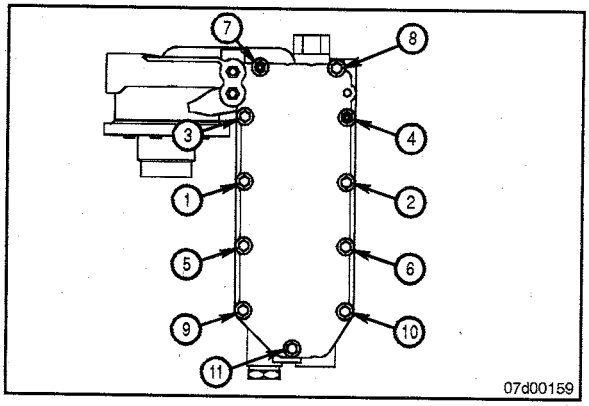
Air Pressure Test		
kPa		psi
449	MIN	65
518	MAX	75



Install

NOTE: Be sure to remove the shipping plugs from a new element.

Assemble the lubricating oil cooler gaskets, element, and cooler cover.



Tighten the capscrews in the sequence shown in the illustration.

Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

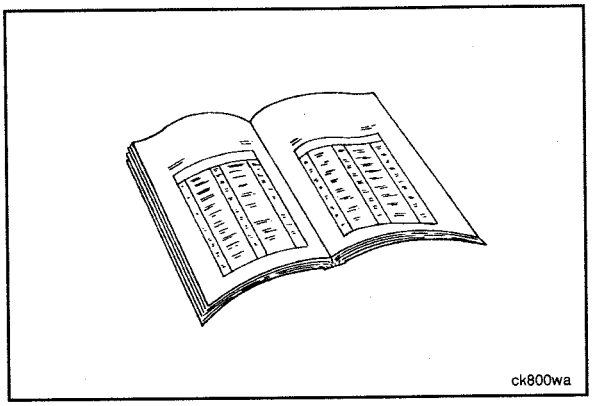
⚠WARNING⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠

State and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

- Install the turbocharger oil supply line. Refer to Procedure 010-046.
- Install the lubricating oil filter. Refer to Procedure 007-013.
- Fill the engine with coolant. Refer to Procedure 008-018.
- Operate the engine and check for leaks.
- Stop the engine and check the coolant and lubricating oil level.



Lubricating Oil Dipstick (007-009)

Calibrate

⚠WARNING⚠

Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

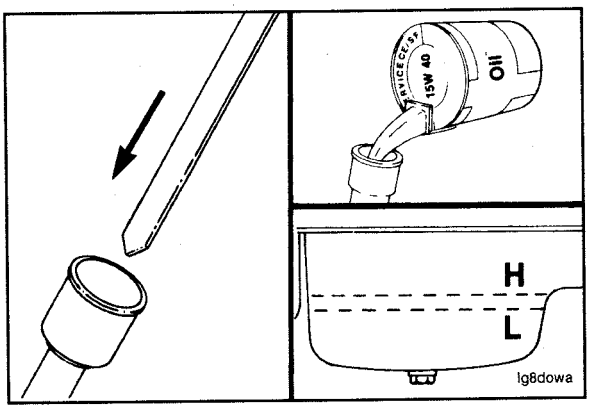
⚠WARNING⚠

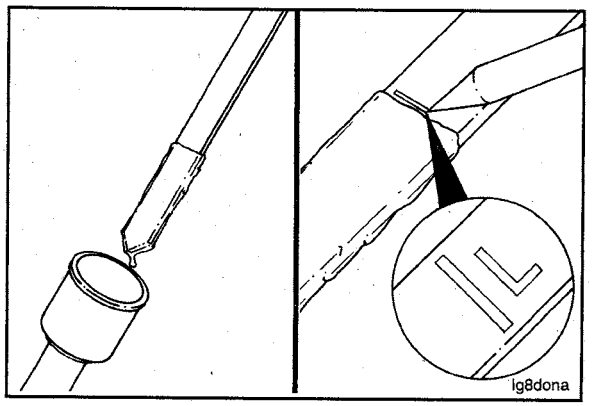
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

Drain the lubricating oil. Refer to Procedure 007-037.

Install the dipstick in the dipstick tube housing.

Use clean 15W-40 oil to fill the oil pan to the specified LOW oil level. Refer to Lubricating Oil System Specifications in Procedure 018-017 of this manual for the correct engine oil capacity.

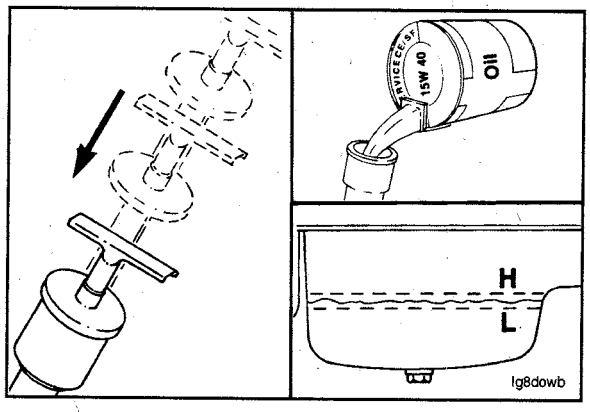




⚠CAUTION⚠
Use care when marking the dipstick. The dipstick will break if the scribe mark is too deep.

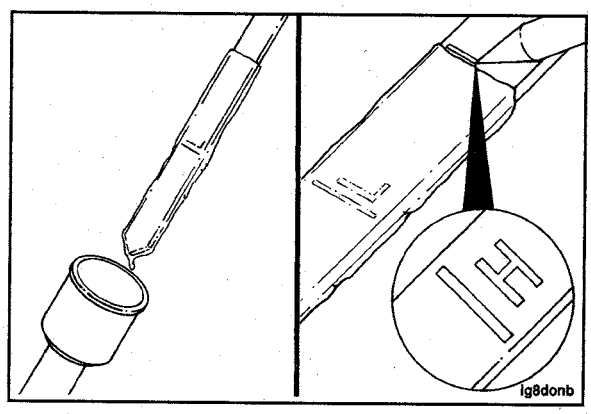
Remove the dipstick and scribe a mark across the stick at the oil level. Label the mark with an L to indicate the "LOW" oil level.

NOTE: 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.

Fill the oil pan to the specified HIGH oil level. Refer to Lubricating Oil System Specifications in Procedure 018-017 of this manual for the correct engine oil capacity.



⚠CAUTION⚠
Use care when marking the dipstick. 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 H to indicate the HIGH oil level.

Lubricating Oil Dipstick Tube (007-011)

Preparatory Steps

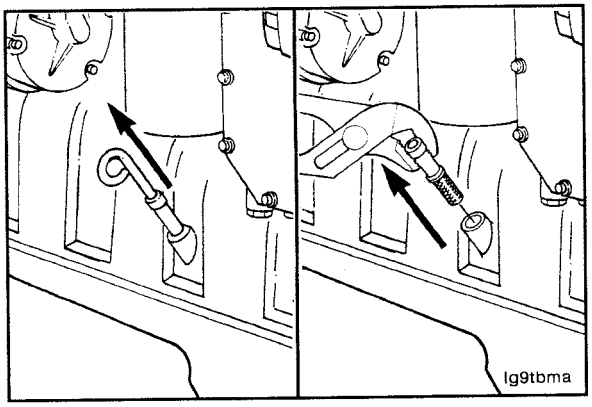
Clean the area around the dipstick tube before removing to prevent debris from entering the oil system.

Remove

Remove dipstick from the dipstick tube.

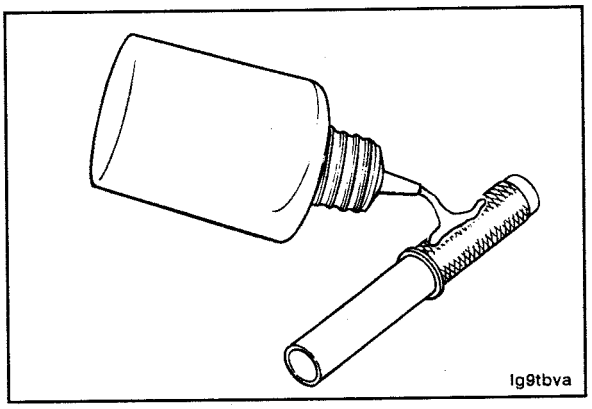
Remove dipstick tube from the cylinder block.

Service Tip: Use a dent puller and a M8 x 1.25 x 21-mm self-tapping capscrew. Thread the capscrew into the dipstick tube and remove the tube.



Install

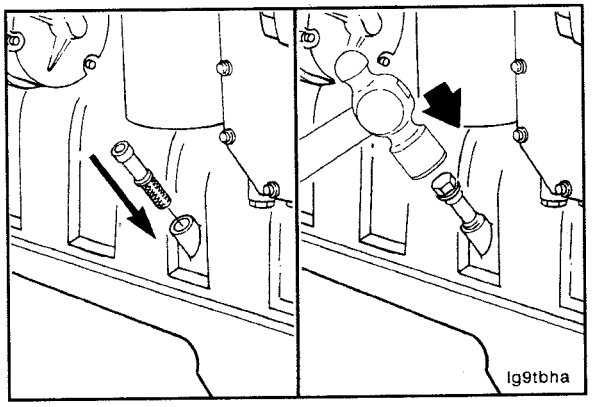
Apply a thin bead of Loctite™ 609, part number 3823718 or equivalent, around the bottom of the knurled end of the tube.



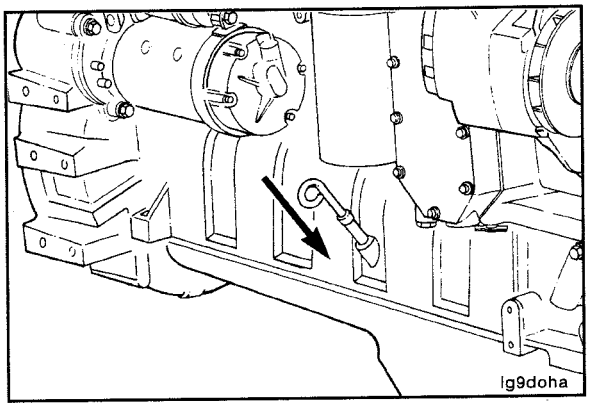
Place the knurled end of the tube into the dipstick tube bore in the cylinder block.

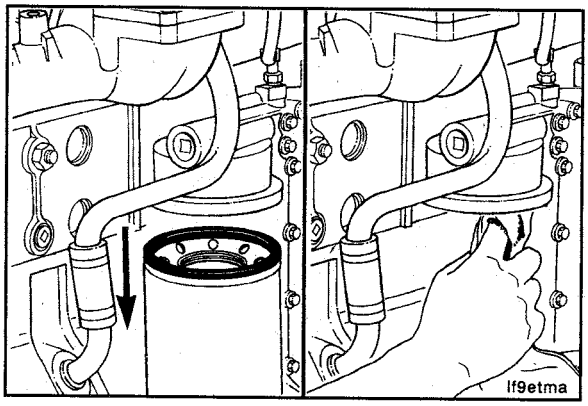
Use a flat washer and hex head capscrew to drive the tube into the cylinder block.

Lightly drive the dipstick tube until it seats against the block casting.



Install the dipstick into the dipstick tube.





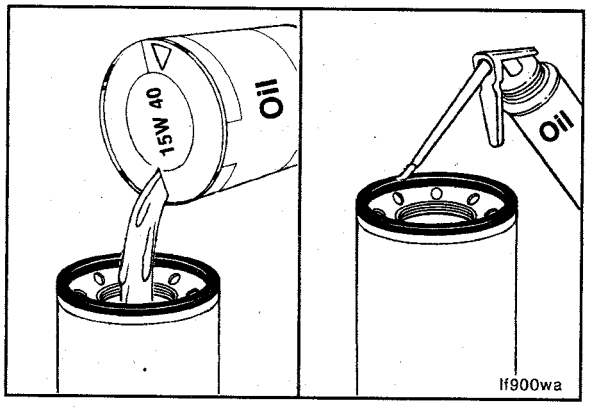
Lubricating Oil Filter (Spin-On) (007-013)

Remove

Clean the area around the lubricating oil filter head.

Remove the oil filter with oil filter wrench, Part Number 3375049.

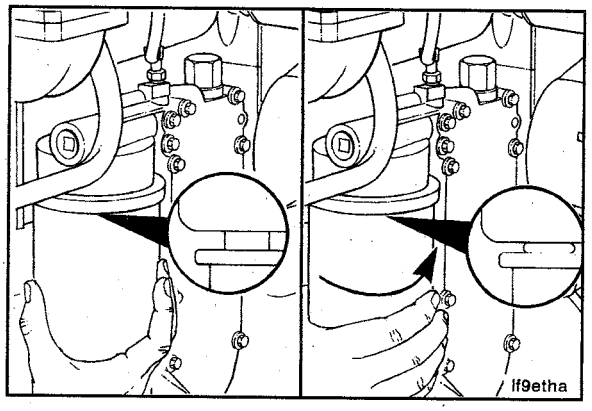
Clean the gasket surface of the filter head.



Install

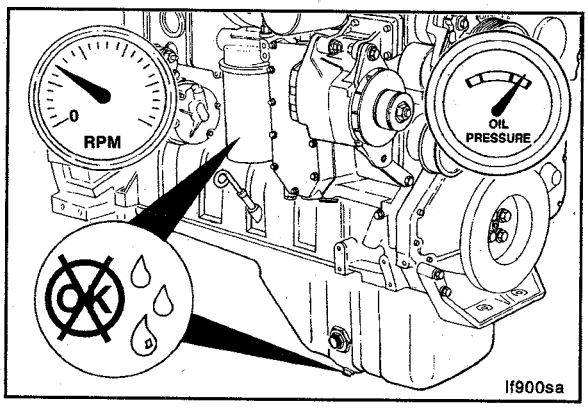
Lubricate the oil filter gasket with clean engine oil.

Fill the oil filter with clean engine oil.



Install the filter on the oil filter head. Tighten the filter until the gasket contacts the filter head surface.

Use oil filter wrench, Part Number 3375049, to tighten the filter an additional ½ to ¾ of a turn, or follow the instructions supplied with the oil filter.



Operate the engine and check for leaks.

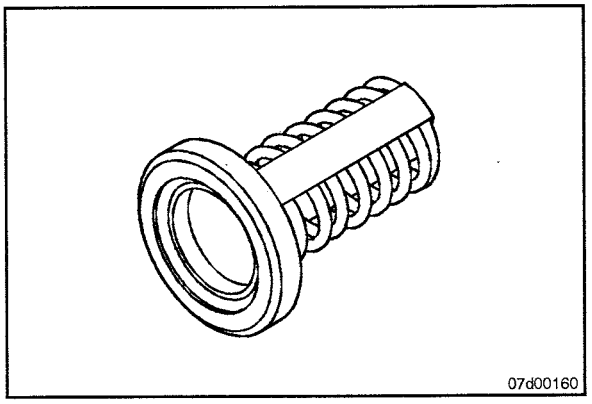
Lubricating Oil Filter Bypass Valve (007-014)

General Information

Whenever the pressure drop across the lubricating oil filter exceeds a predetermined set point, the oil filter bypass valve opens and allows lubricating oil to bypass the lubricating oil filter.

This condition can occur during cold ambient (cold lubricating oil) engine start-ups.

The purpose of the bypass valve is to maintain lubricating oil flow to the engine and prevent an oil filter collapse.



Preparatory Steps

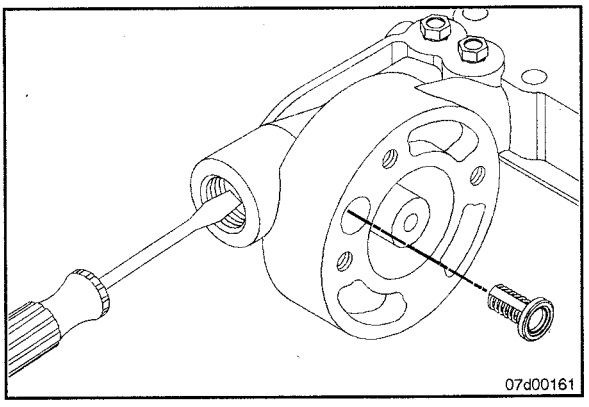
Remove the lubricating oil filter. Refer to Procedure 007-013.

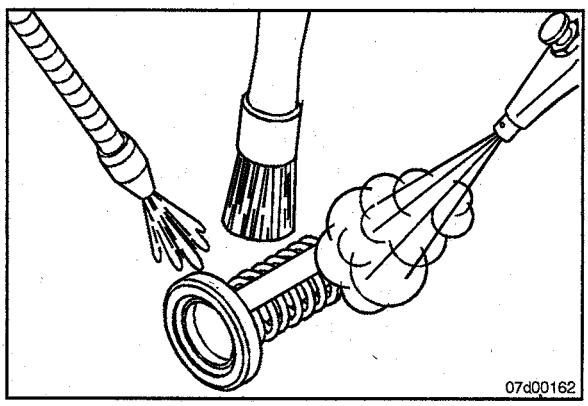
Remove the lubricating oil filter head. Refer to Procedure 007-015.

Remove the 3/4-inch pipe plug from the end of the oil filter head.

Remove

Using a screwdriver, gently push down on the top of the bypass valve to remove it from the bore.





Clean and Inspect for Reuse

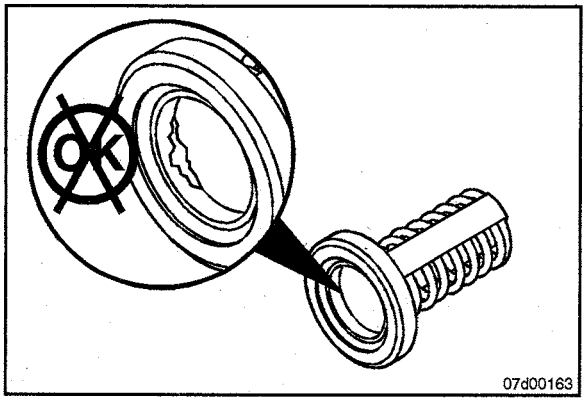
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

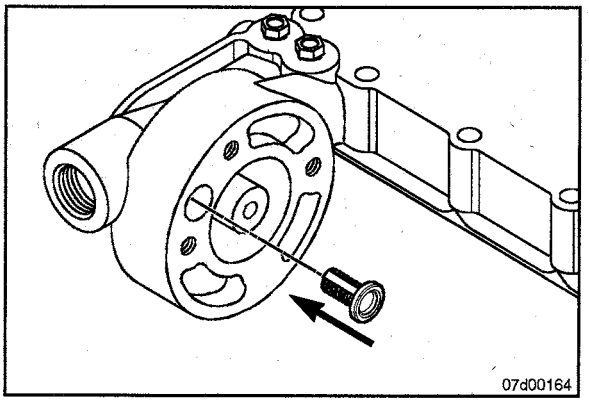
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the bypass valve with solvent.

Dry with compressed air.



Inspect the bypass valve seat for damage. Make sure the valve fully closes.



Install

Insert the bypass valve into the bore. The spring should be pointing upward into the bore.

Gently seat the bypass valve into the bore until it seats.

Finishing Steps

Install the 3/4-inch pipe plug into the end of the oil filter head.

Torque Value: 45 N•m [33 ft-lb]

Install the lubricating oil filter head. Refer to Procedure 007-015.

Install the lubricating oil filter. Refer to Procedure 007-013.

Lubricating Oil Filter Head (007-015)

Preparatory Steps

⚠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.

⚠WARNING⚠

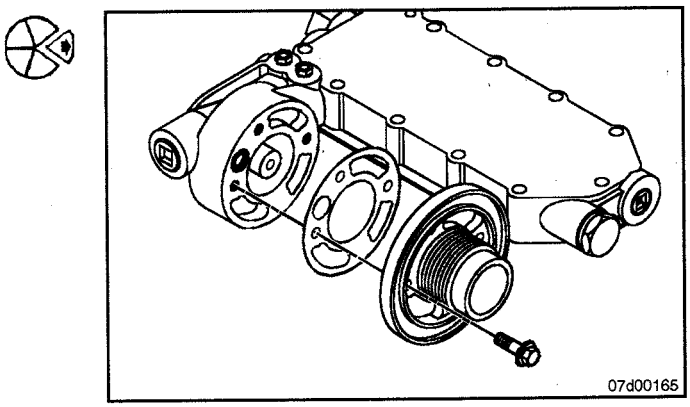
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

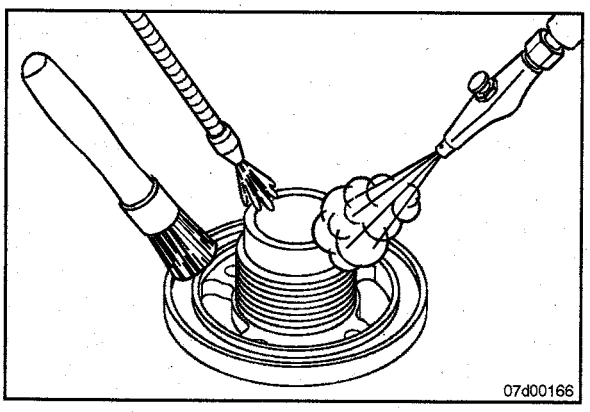
Drain the coolant. Refer to Procedure 008-018.

Remove the lubricating oil cooler. Refer to Procedure 007-003.

Remove

Remove the lubricating oil filter head capscrews, filter head, and gasket.



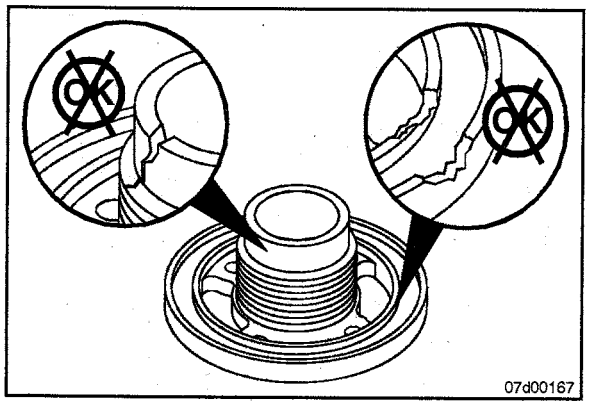


Clean and Inspect for Reuse

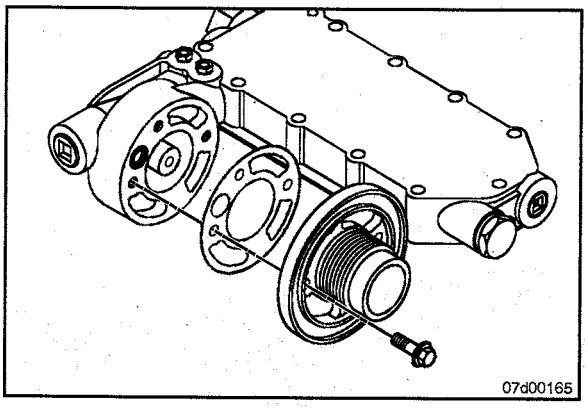
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Use solvent to clean the adapter.



Inspect the adapter for cracks and other damage.



Install

Install the oil filter head, gasket, and capscrews.

Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

Install the lubricating oil cooler. Refer to Procedure 007-003.

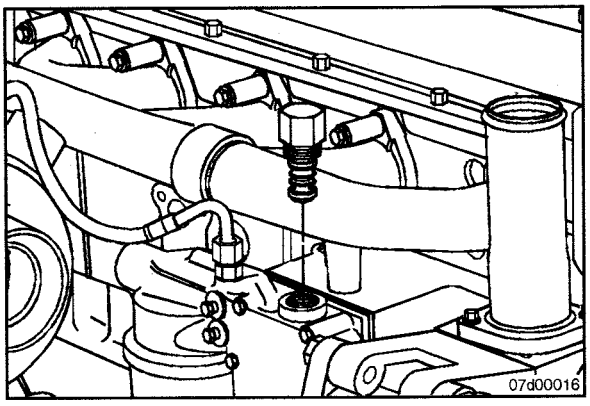
Fill the cooling system. Refer to Procedure 008-018.

Operate engine and check for leaks.

Lubricating Oil High Pressure Relief Valve (007-021)

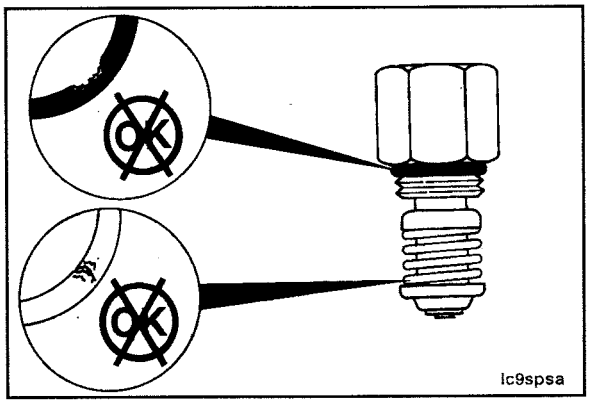
Remove

Remove the oil cooler bypass valve.



Inspect for Reuse

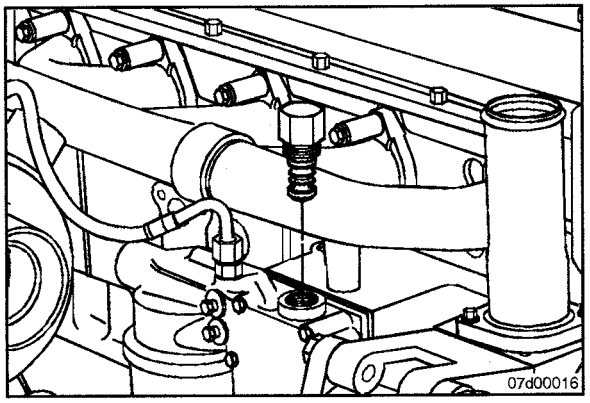
Inspect for a damaged o-ring, broken spring or other damage.



Install

Install the oil cooler bypass valve.

Torque Value: 50 N•m [37 ft-lb]



Lubricating Oil Pan (007-025)

Preparatory Steps

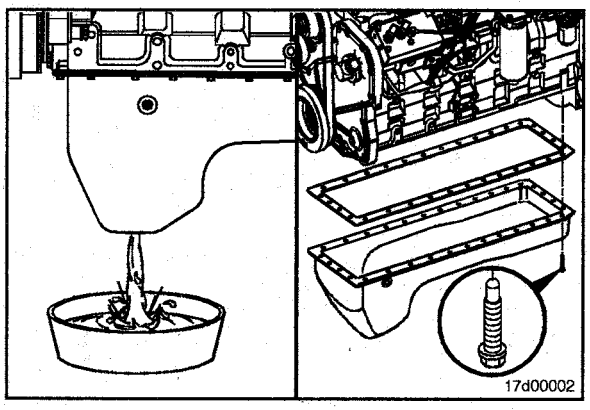
⚠WARNING⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠

Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

Drain the lubricating oil. Refer to Procedure 007-037.

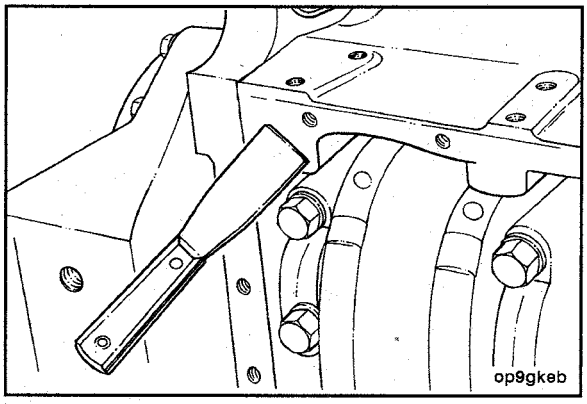


Remove

Remove the lubricating oil pan and gasket.

If suction tube **must** be removed, refer to Procedure 007-035.

If the engine is equipped with a block stiffener plate, refer to Procedure 001-089.



Clean and Inspect for Reuse

⚠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.

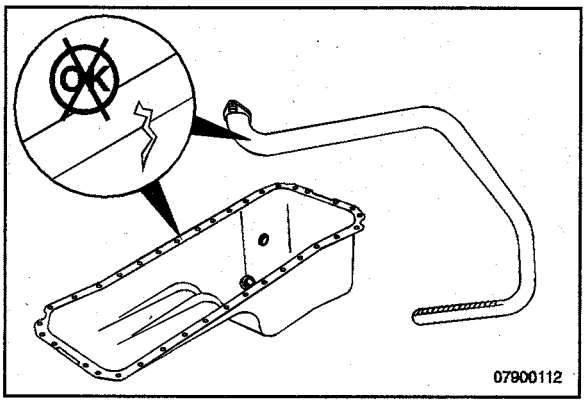
⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Remove all gasket material from the cylinder block and oil pan surface.

Steam-clean the oil pan.

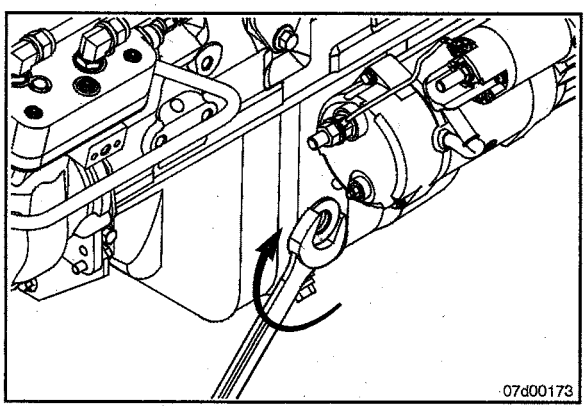
Dry with compressed air.



Inspect the oil pan, suction tube, and tube braces for damage.

NOTE: If cracks are found, replace the damaged part. Do **not** attempt to repair the oil pan by welding.

If the suction tube **must** be replaced; refer to Procedure 007-035.



Composite Oil Pan **Only**

Make sure the bulkhead fitting is tight. If it is found to be loose, replace the o-ring and tighten the bulkhead.

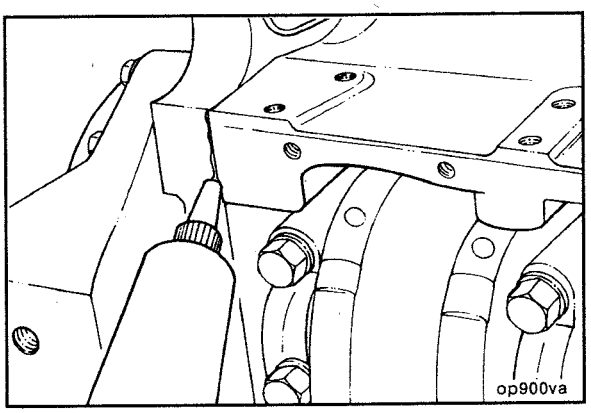
Torque Value: 24 N•m [20 ft-lb]

Install

Use Three-Bond™ RTV sealant, or equivalent, to fill the joints between the lubricating oil pan rail, gear housing, and rear seal housing.

If the suction tube has been removed; refer to Procedure 007-035 for installation instructions.

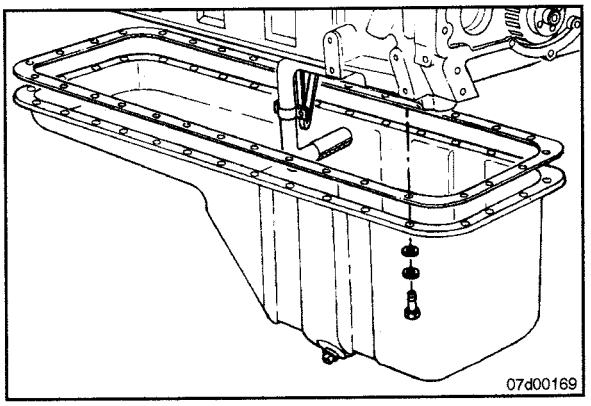
If the engine is equipped with a block stiffener plate, refer to Procedure 001-089.



Install the gasket and lubricating oil pan.

Install the oil pan corner braces, if equipped.

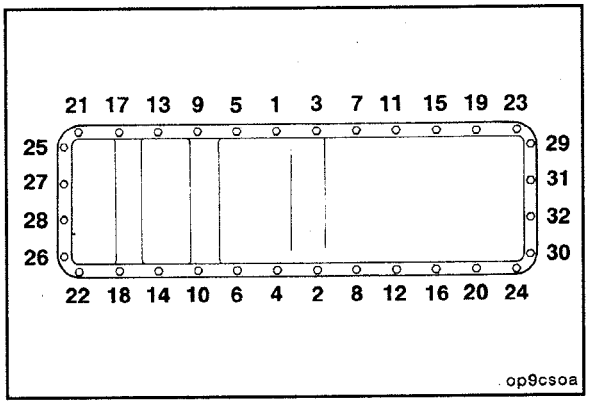
NOTE: New noise isolators **must** be used with oil pans using the isolated gasket system.



Assemble the washers and capscrews to secure the lubricating oil pan as illustrated.

Tighten all capscrews in the sequence shown in the accompanying chart.

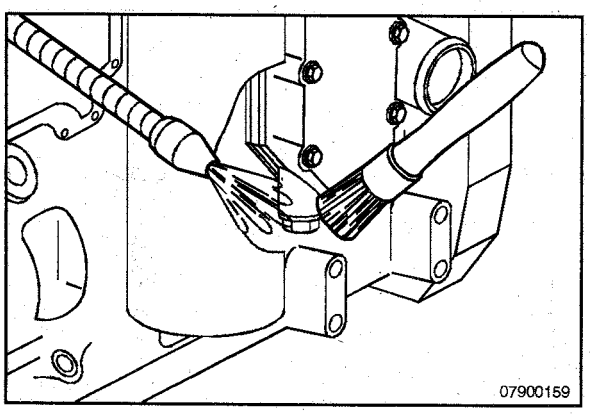
Torque Value: 28 N•m [21 ft-lb]



Finishing Steps

Fill the lubricating oil system. Refer to Procedure 007-037.

Operate the engine and check for leaks.



Lubricating Oil Pressure Regulator (Main Rifle) (007-029)

Remove

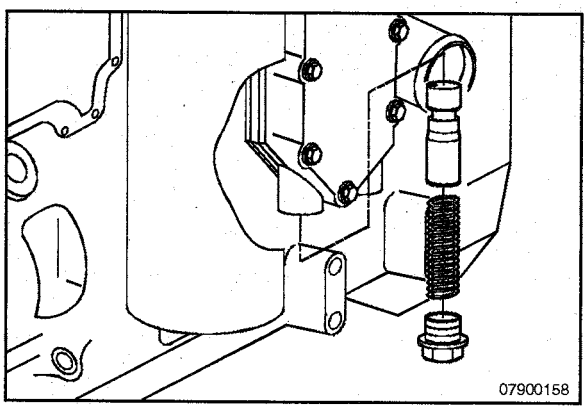
⚠WARNING⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠

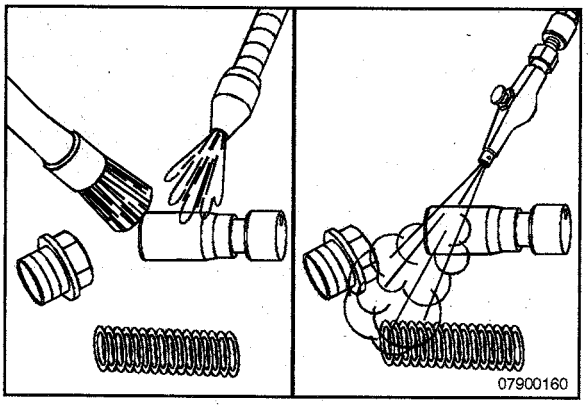
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Thoroughly clean the area around the pressure regulator plug with clean solvent to prevent debris from falling into the plunger bore when the plug is removed.



Remove the threaded plug, spring, and plunger.

Service Tip: The plunger normally can be removed by inserting one finger into the plunger bore until snug and pulling down. If the plunger can **not** be removed in this manner, the plunger is probably stuck and will require removal of the housing for cleaning the plunger.



Clean and Inspect for Reuse

⚠WARNING⚠

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⚠WARNING⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠

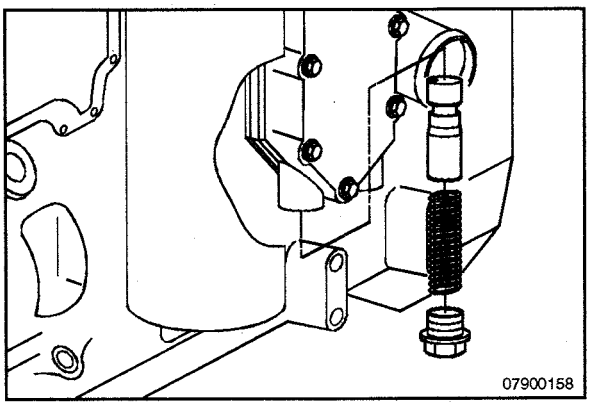
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: If the plunger bore requires cleaning, remove the housing to avoid flushing debris into the engine.

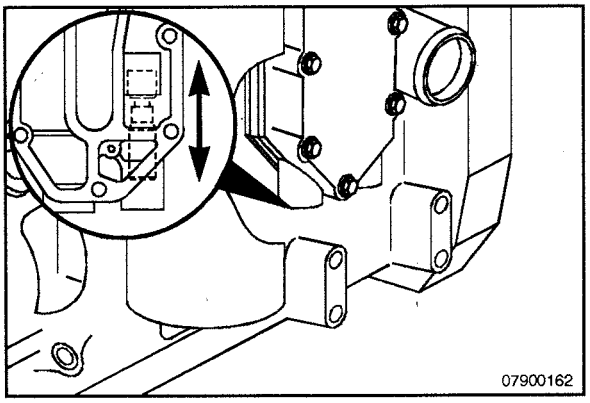
Thoroughly clean all components with clean solvent.

Dry with compressed air.

Inspect the plunger and plunger bore. Polished areas on the plunger and bore are acceptable.



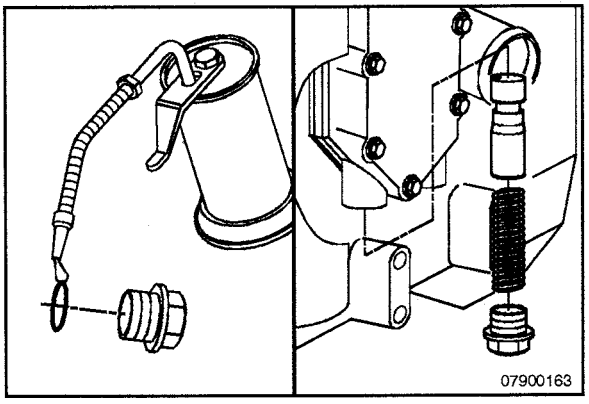
Verify that the plunger moves freely in the bore.



Install

Install a new sealing o-ring on the threaded plug and lubricate with clean engine oil. Install the pressure regulator assembly.

Torque Value: 80 N•m [59 ft-lb]



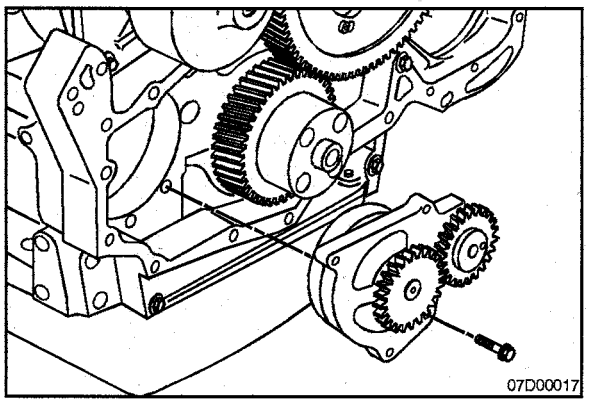
Lubricating Oil Pump (007-031)

Preparatory Steps

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

Remove the vibration damper. Refer to Procedure 001-052.

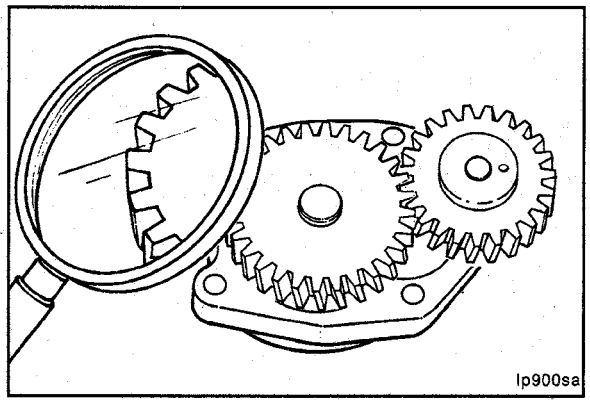
Remove the front cover. Refer to Procedure 001-031.



Remove

Remove the four mounting capscrews.

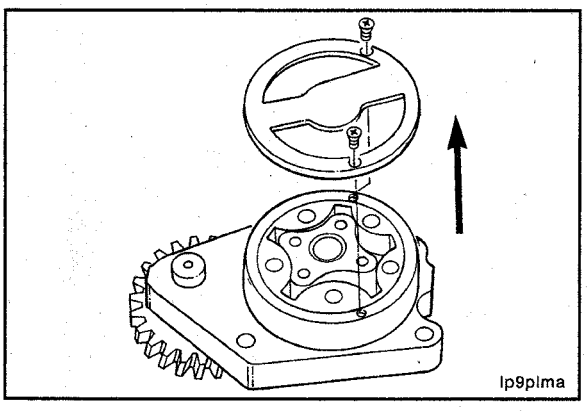
Remove the pump from the bore in the cylinder block.



Disassemble

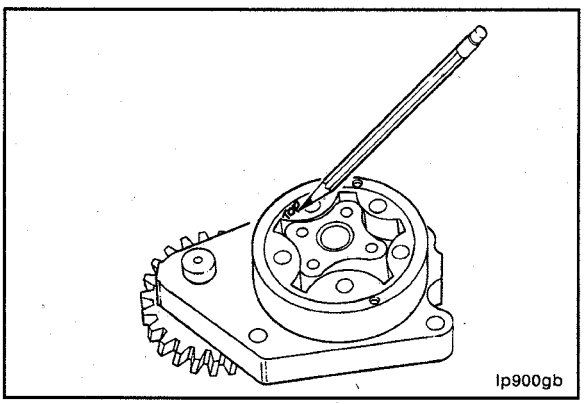
If the lubricating oil pump is to be inspected for reuse, follow these steps.

Inspect the lubricating oil pump gears for chips, cracks, or excessive wear.



Remove the back plate.

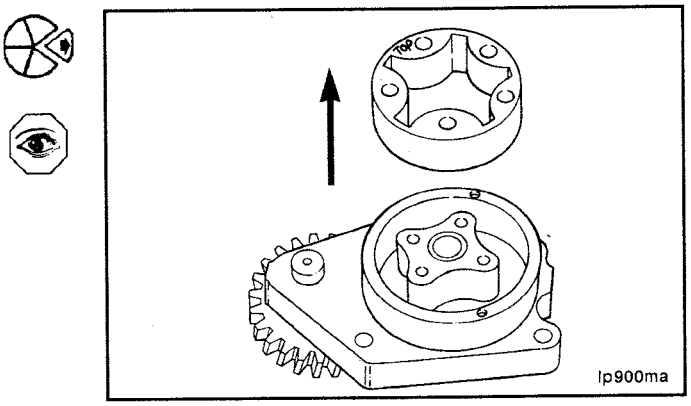
NOTE: The ISC, QSC8.3, ISL, and QSL9 lubricating oil pump uses a large diameter 5/6 rotor set. The graphics in this manual illustrate a 4/5 rotor set.



Mark TOP on the gerotor planetary.

Remove the gerotor planetary.

Inspect for excessive wear or damage.



Clean and Inspect for Reuse

⚠WARNING⚠

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⚠WARNING⚠

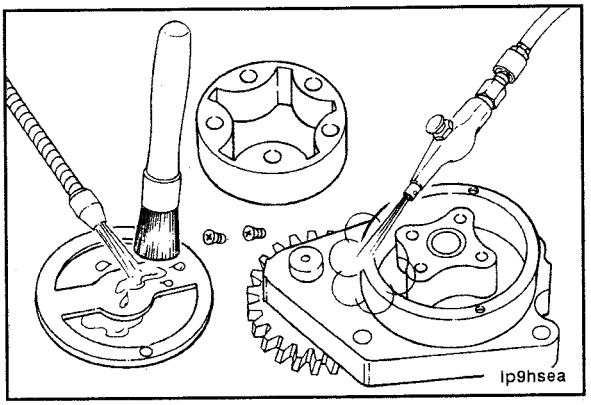
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠

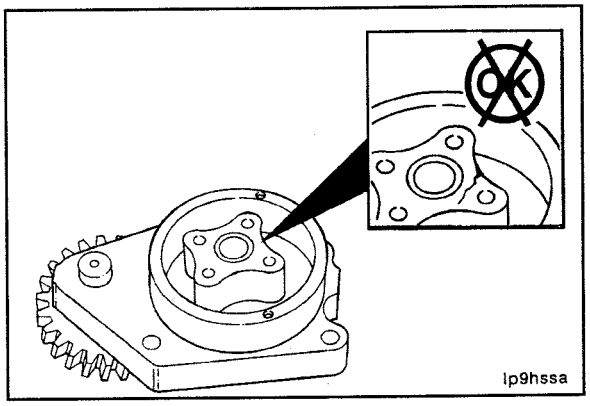
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

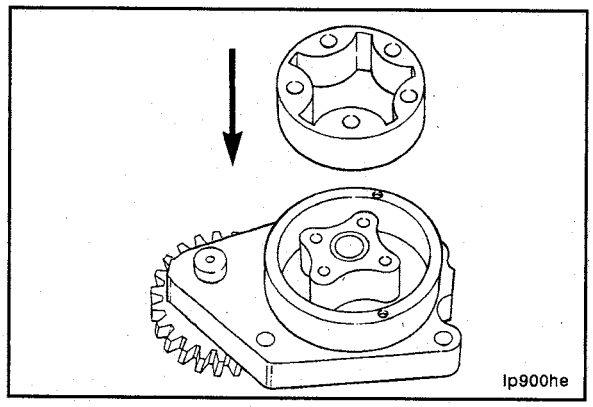
Clean all parts in solvent.

Dry with compressed air.



Inspect the lubricating oil pump housing and gerotor drive for damage and excessive wear.



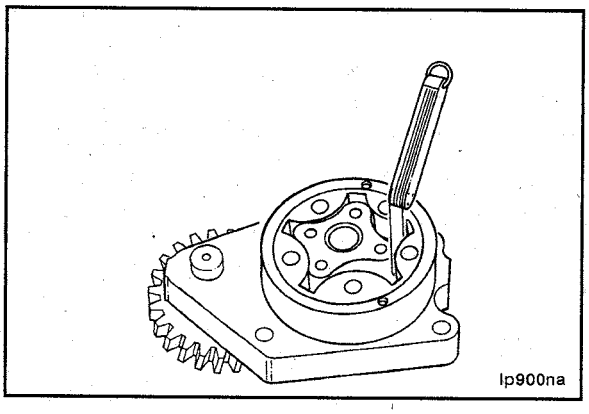


Assemble

⚠CAUTION⚠

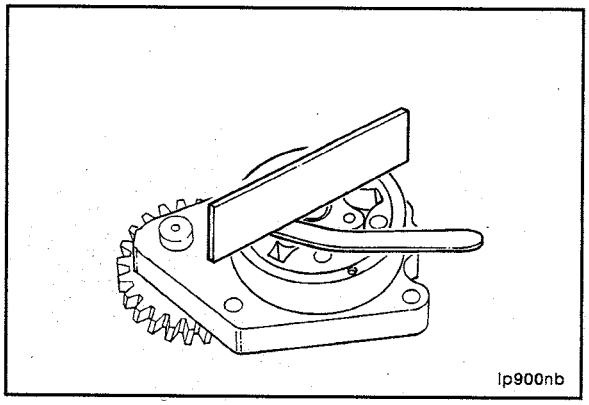
Make sure that the gerotor planetary is installed in the original position.

Install the gerotor planetary.



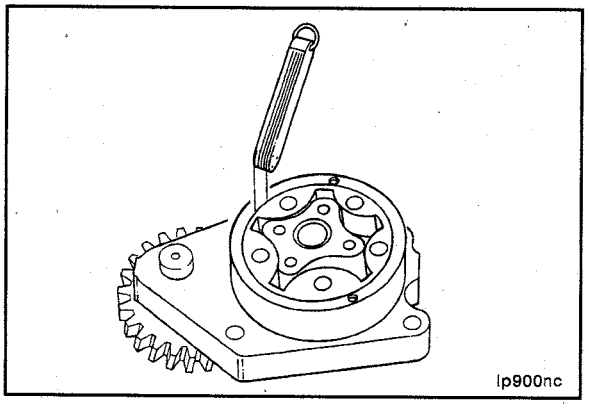
Measure the tip clearance.

Tip Clearance		
mm		in
0.025	MIN	0.001
0.1778	MAX	0.007



Measure the clearance of the gerotor drive/gerotor planetary to port plate.

Gerotor Drive/Gerotor Planetary to Port Plate Clearance		
mm		in
0.025	MIN	0.001
0.127	MAX	0.005

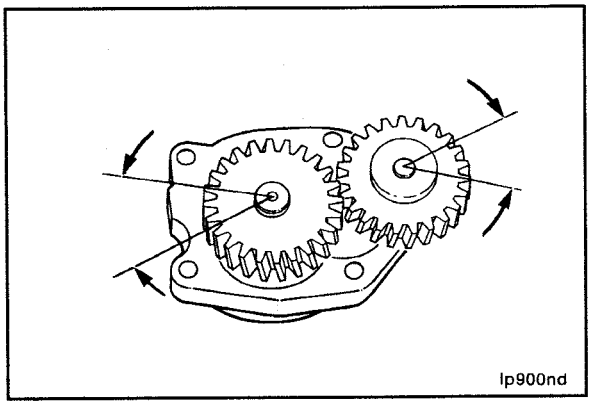


Measure the clearance of the gerotor planetary to the body bore.

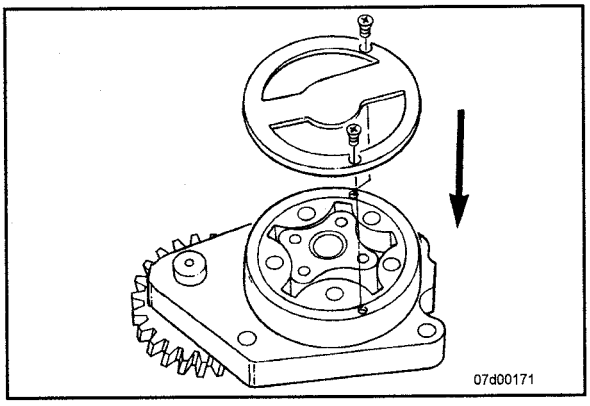
Gerotor Planetary to Body Bore Clearance		
mm		in
0.1778	MIN	0.007
0.381	MAX	0.015

Measure the backlash.

Lubricating Oil Pump Gears Backlash Limits (Used Pump)		
mm		in
0.076	MIN	0.003
0.330	MAX	0.013



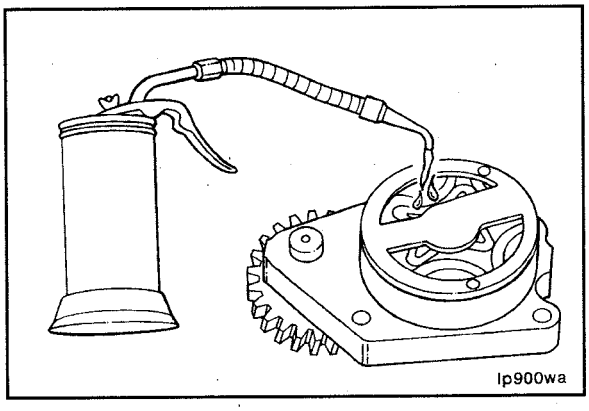
Install the back plate.



Install

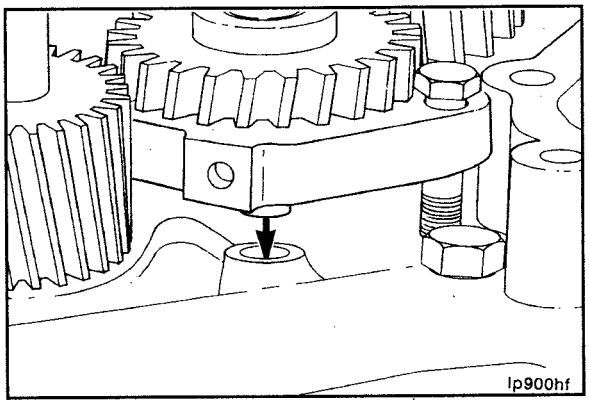
⚠CAUTION⚠
Failure to fill the pump with oil during installation can result in a failure of the lubricating oil pump to prime at initial engine start-up, resulting in severe engine damage.

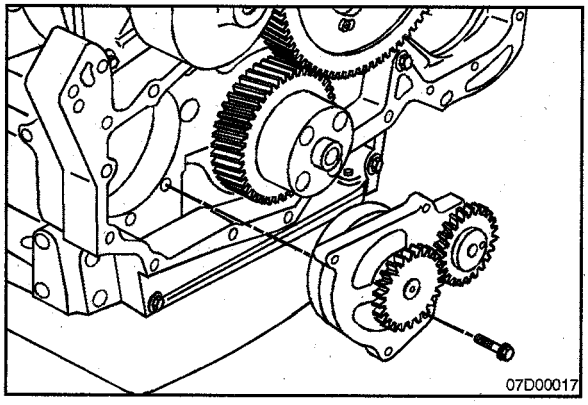
Lubricate the lubricating oil pump with clean 15W-40 engine oil.



⚠CAUTION⚠
Make sure the idler gear pin is installed in the locating bore in the cylinder block.

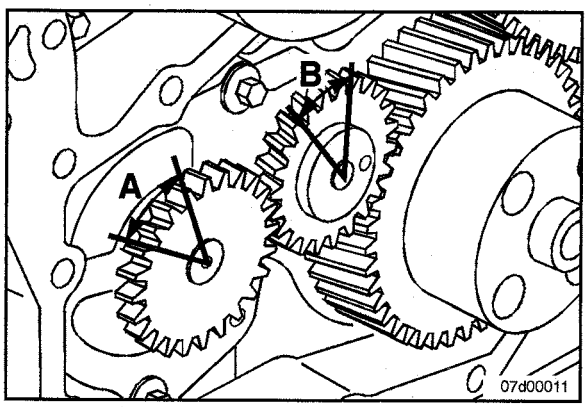
Install the lubricating oil pump.





Tighten capscrews in an X pattern, starting with the upper right capscrew.

Torque Value: 24 N•m [18 ft-lb]



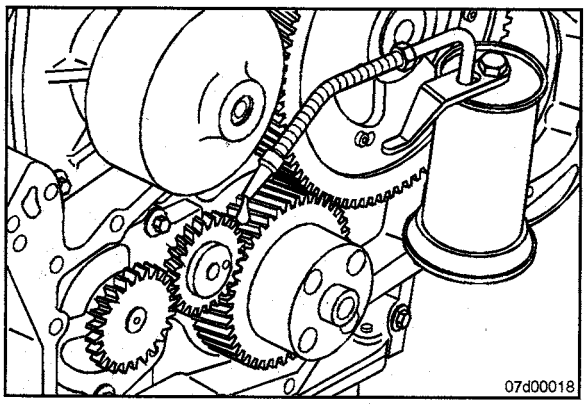
NOTE: Be sure the gear backlash is correct if installing a new lubricating oil pump.

Measure the gear backlash.

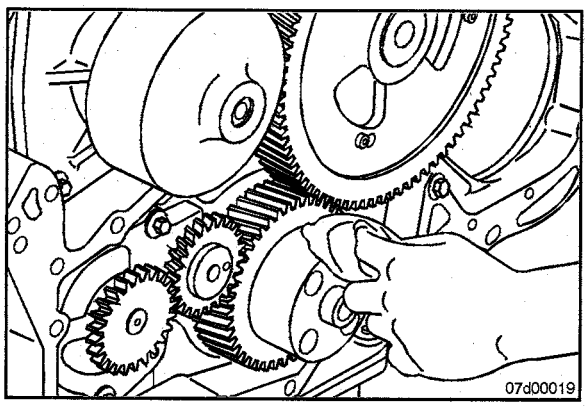
Lubricating Oil Pump Gears Backlash Limits (Installed)

	mm		in
A	0.076	MIN	0.003
	0.330	MAX	0.013
B	0.076	MIN	0.003
	0.330	MAX	0.013

NOTE: If the adjoining gear moves when you measure the backlash, the reading will be incorrect.



Lubricate the front gear train with clean 15W-40 engine oil.



⚠CAUTION⚠

The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Thoroughly clean the front seal area of the crankshaft.

NOTE: Always replace the front seal when removing and installing the front cover. Refer to Procedure 001-031.

Finishing Steps

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

Install the vibration damper. Refer to Procedure 001-052.

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

Lubricating Oil Suction Tube (Block-Mounted) (007-035)

Preparatory Steps

⚠WARNING⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠

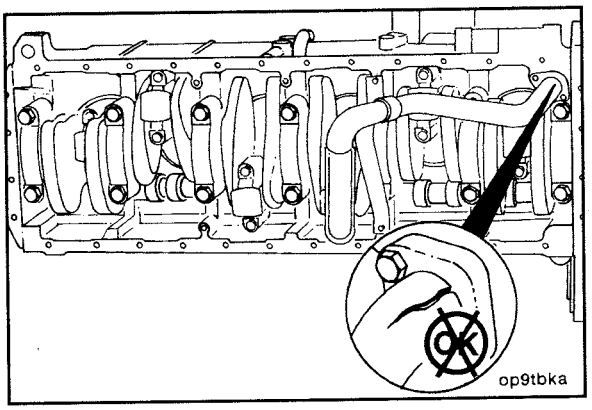
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

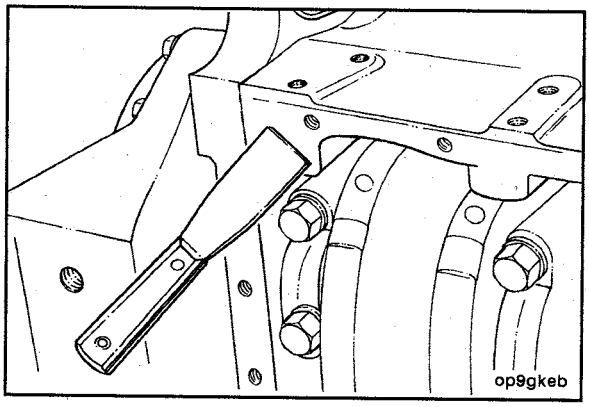
Drain the lubricating oil. Refer to Procedure 007-037.

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

Remove

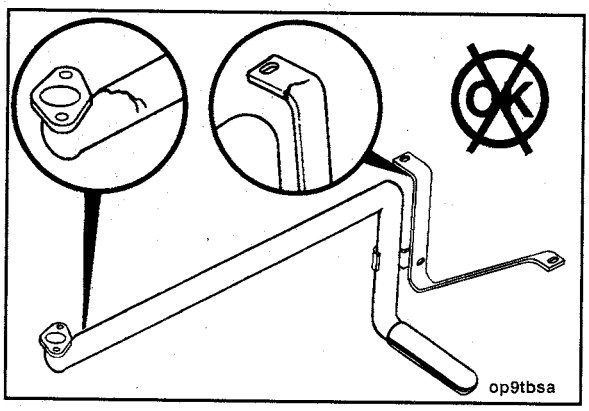
Remove the lubricating oil suction tube.



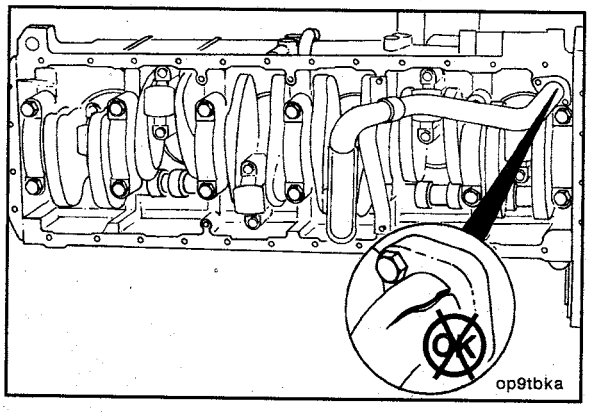


Clean and Inspect for Reuse

Clean the gasket surfaces.



Inspect the suction tube for cracks.



Install

Install the lubricating oil suction tube and new gasket.

1. . Install all capscrews finger tight and check for correct alignment.
2. . Torque the lubricating oil suction tube to the block.

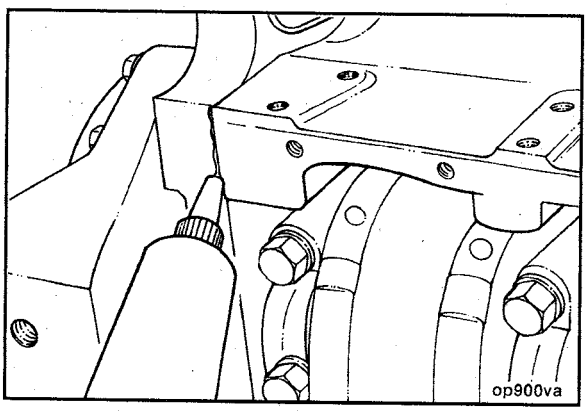
Torque Value: 10 N•m [89 in-lb]

3. Torque the lubricating oil suction tube brace to the engine block.

Torque Value: 10 N•m [89 in-lb]

4. Torque the lubricating oil suction tube to the brace.

Torque Value: 10 N•m [89 in-lb]



Use Three-Bond™ 1207-C, or equivalent, to fill the joints between the lubricating oil pan rail, gear housing, and rear seal housing.

Finishing Steps

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

Operate the engine and check for leaks.

Lubricating Oil System (007-037)

Drain

⚠WARNING⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠

Some state and federal agencies 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. If not reused, dispose of in accordance with local environmental regulations.

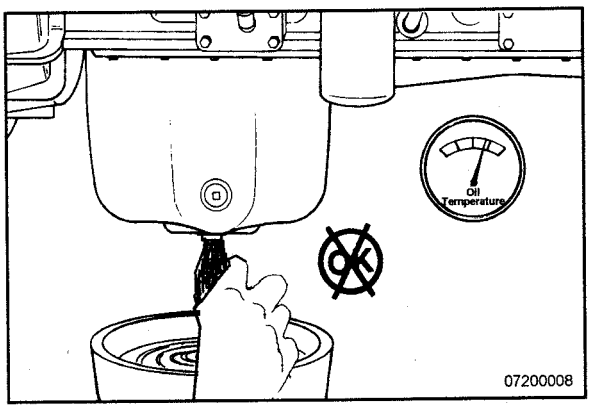
NOTE: Use a container that can hold at least 23.6 liters [25 qt] of lubricating oil.

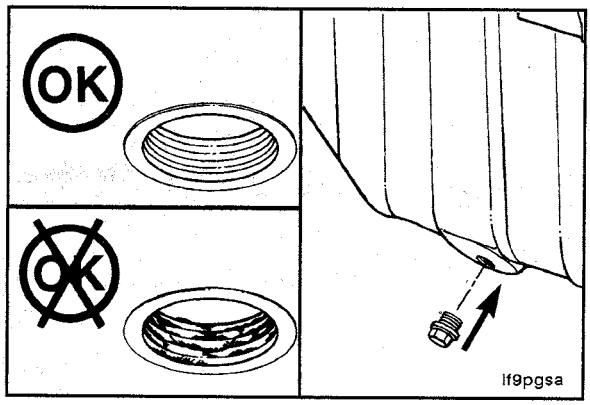
NOTE: For composite oil pans, hold the external locking nut in position with a separate wrench while removing the drain plug. This will prevent the bulkhead from loosening during drain plug removal.

Operate the engine until the coolant temperature reaches 60°C [140°F]. Shut off the engine.

Remove the oil drain plug.

Drain the oil immediately to make sure all the oil and suspended contaminants are removed from the engine.





Fill

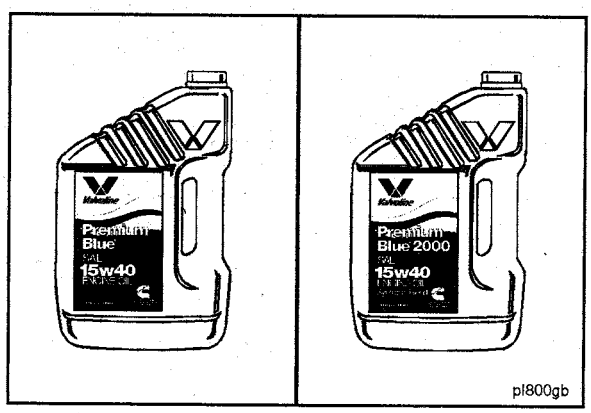
⚠CAUTION⚠

For composite oil pans, always use a new sealing washer on the oil drain plug. Hold the external locking nut in place while tightening the oil drain plug.

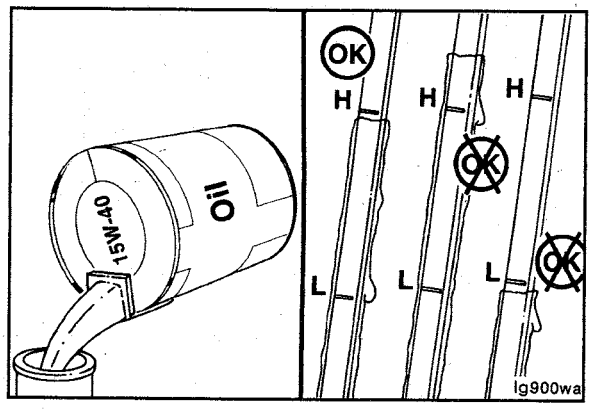
Clean and check the lubricating oil drain plug threads and sealing surface.

Install the lubricating oil pan drain plug.

Torque Value		
	N•m	[ft-lb]
Steel Oil Pan	80	59
Cast Aluminum Oil Pan	60	45
Composite Oil Pan	60	45



NOTE: Use a high quality 15W-40 multiviscosity oil, such as Cummins Premium Blue®, or equivalent, in Cummins engines. Choose the correct oil for your operating climate as outlined in the Operation and Maintenance Manual.



Fill the engine with clean lubricating oil to the proper level.

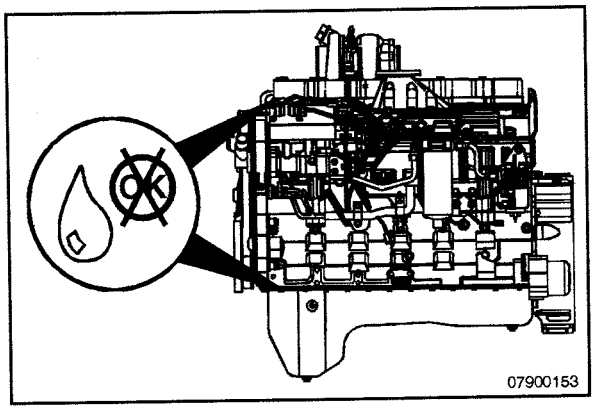
NOTE: When filling the oil pan, use the fill tube on the side of the engine rather than on top of the rocker lever cover.

Refer to Section V for lubricating oil pan capacities.

⚠WARNING⚠

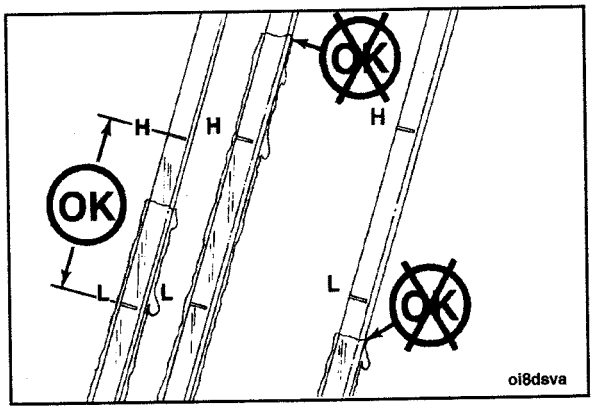
If no oil pressure is noted within 15 seconds after the engine is started, shut down the engine to reduce the possibility of internal damage.

Idle the engine to inspect for leaks at the drain plug.



Shut off the engine. Wait approximately 10 minutes to let the oil drain from the upper parts of the engine. Check the level again.

Add oil as necessary to bring the oil level to the "H" (high) mark on the dipstick.

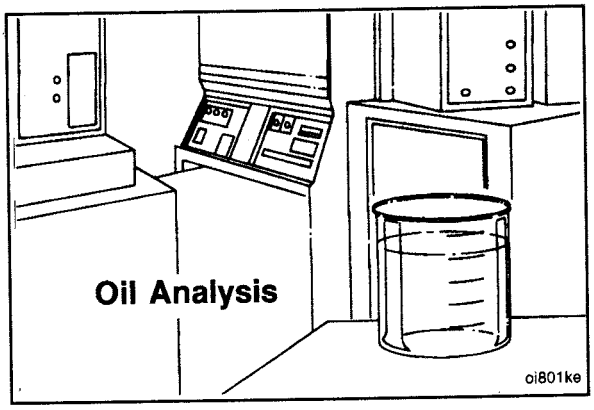


Lubricating Oil and Filter Analysis (007-083)

Inspect

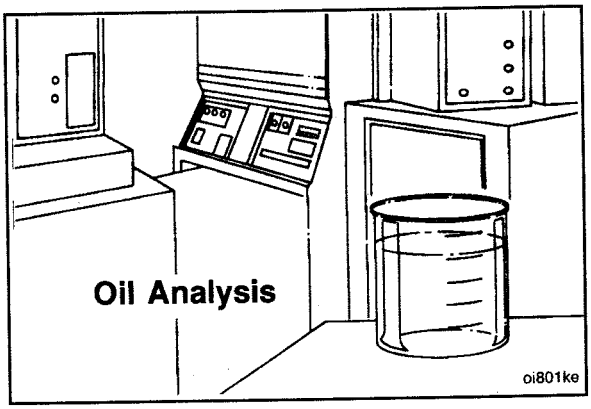
An analysis of used oil can help diagnose internal engine damage and determine if it was caused by one of the following:

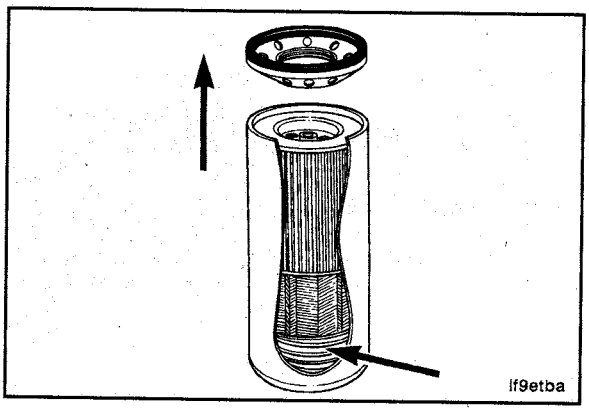
- Intake air filter malfunction
- Coolant leaks
- Oil diluted with fuel
- Metal particles causing wear.



For additional oil analysis information, Refer to Cummins Engine Oil Recommendations, Bulletin 3810340.

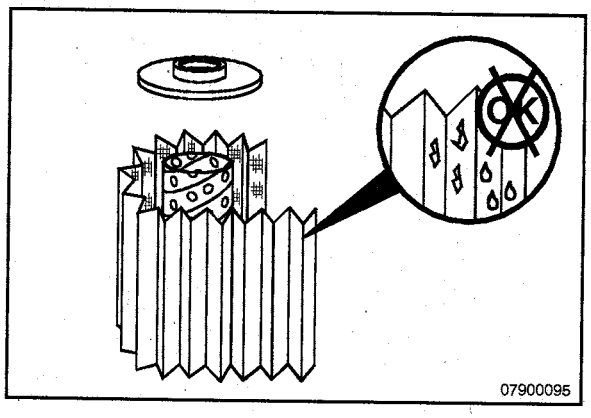
NOTE: Do **not** take apart an engine for repair based solely on the results of an oil analysis. Inspect the oil filters. If the oil filter shows evidence of internal damage, find the source of the problem, and repair the damage. Refer to the appropriate procedure(s) based on the following oil filter inspection.





⚠WARNING⚠

Restrain the full flow lubricating oil filter, and carefully cut the filter (upper section of combination filter) open. The filter element spring is under compression and can cause personal injury.



Use the tube cutter, Part No. 3376579, to open the full-flow oil filter (upper section of the bypass 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
Lead	Bearing Overlay Material
Aluminum	Piston Wear or Scuffing

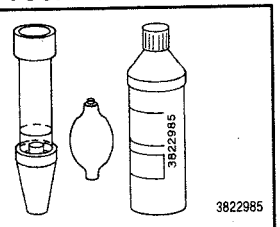
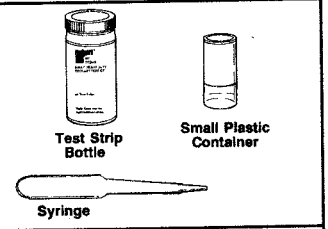
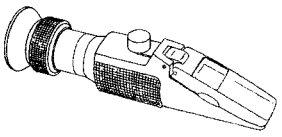
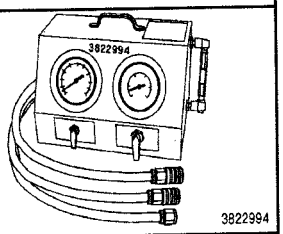
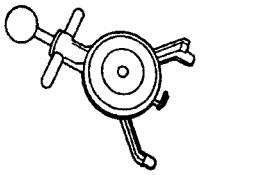
Section 8 - Cooling System - Group 08

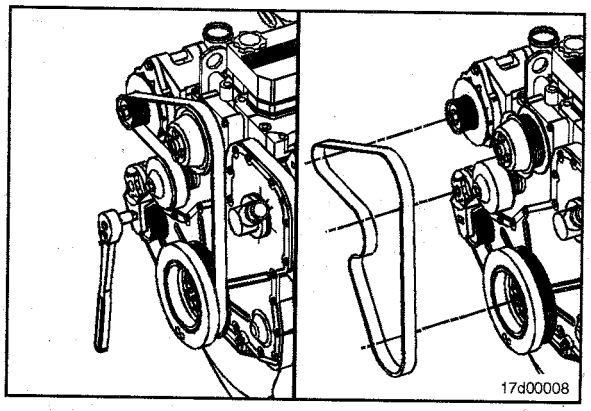
Section Contents

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
3822985	**Combustion Gas Leak Test Kit** Used to detect leaks. Includes part number 3822986 test fluid, part number 3822987 adapter, and part number 3877612 instructions.	
CC-2626	**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.	
3822994	**Engine Coolant Analyzer** The Engine Coolant Analyzer is used to troubleshoot pressure loss, restriction, and improper temperature control.	
ST 1293	**Belt Tension Gauge** Use to measure the tension in the drive belt.	

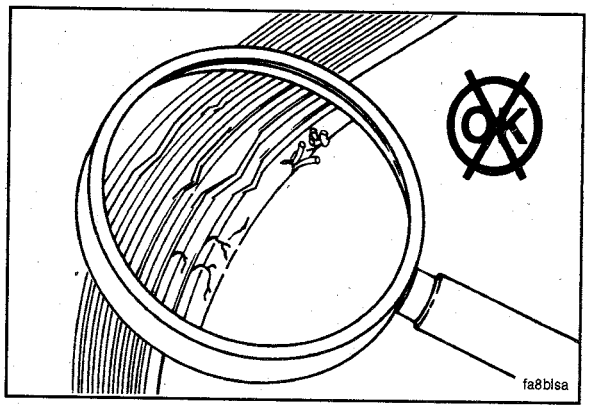


Drive Belt, Cooling Fan (008-002)

Remove

Lift the tensioner to remove the drive belt.

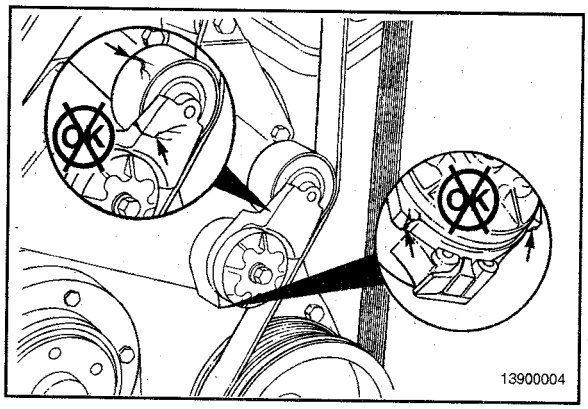
NOTE: The belt tensioner is spring-loaded and **must** be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.



Inspect for Reuse

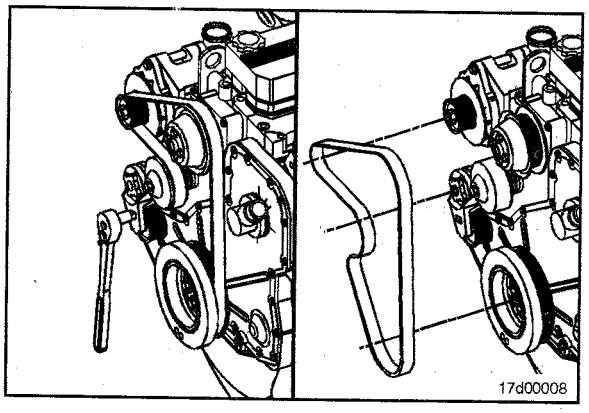
Inspect the belt for:

- Cracks
- Glazing
- Tears or cuts
- Excessive wear.



Inspect the drive belt pulleys and idlers for cracked or broken grooves. Refer to the following sections if a pulley or idler is damaged:

- Inspect the fan pulley.
- Inspect the crankshaft pulley. Refer to Procedure 001-052.
- Inspect the alternator drive belt. Refer to Procedure 013-005.
- Inspect the water pump idler. Refer to Procedure 008-062.
- Inspect the belt tensioner idler. Refer to Procedure 008-080.



Install

Lift and hold the belt tensioner. Install the drive belt and release the tensioner.

NOTE: The belt tensioner is spring-loaded and **must** be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

Service Tip: If difficulty is experienced installing the drive belt (i.e., the belt seems too short), position the belt over the grooved pulleys first then while holding the tensioner up, slide the belt over the water pump pulley.

Coolant Filter (008-006)

Remove

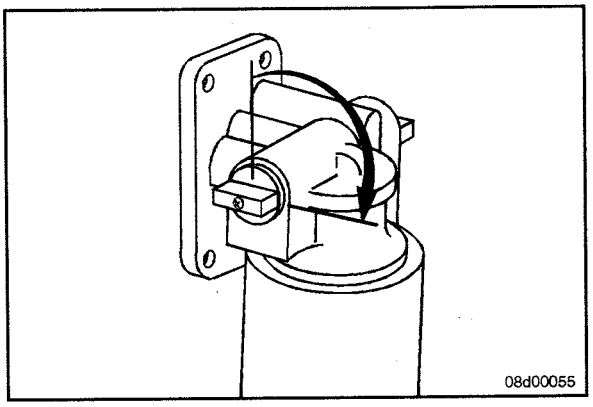
⚠WARNING⚠

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.

NOTE: Some engine models do **not** require coolant filters.

Remove the coolant system pressure cap.

Turn the shutoff valve to the OFF position by rotating the knob from vertical to horizontal in the direction shown.



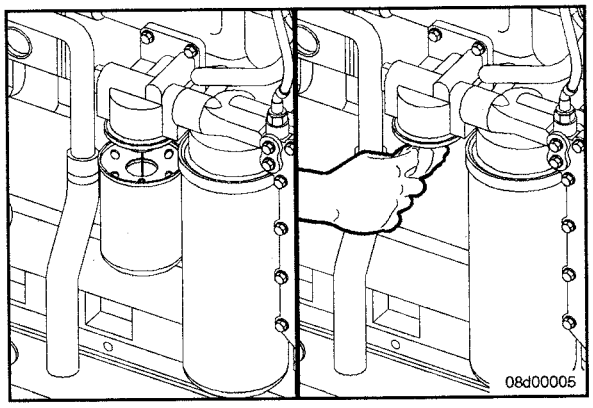
⚠WARNING⚠

A small amount of coolant can leak when servicing the coolant filter with the shutoff valve in the OFF position. To reduce the possibility of personal injury, avoid contact with hot coolant.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Remove and discard the coolant filter.



Install

⚠CAUTION⚠

Do not allow oil to get into the filter. Oil will damage the DCA.

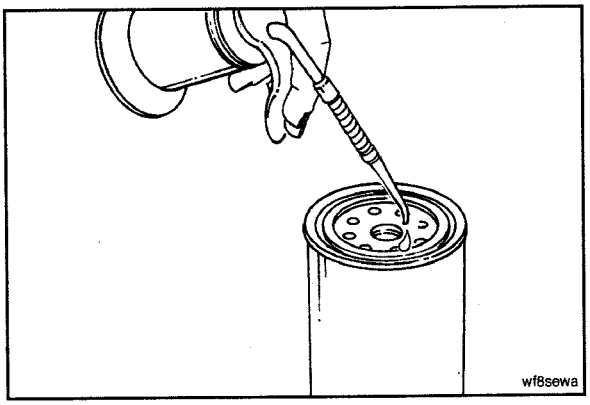
⚠CAUTION⚠

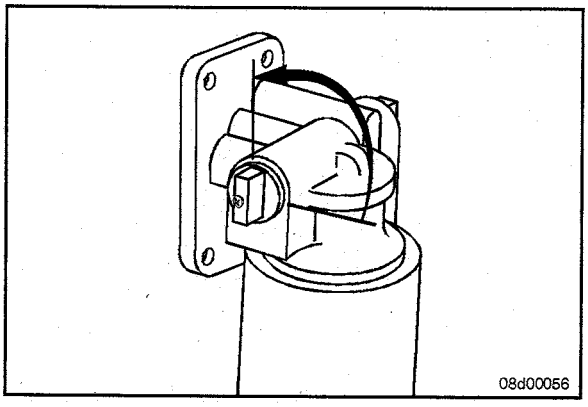
Mechanical overtightening can distort the threads or damage the filter head.

Apply a thin film of lubricating oil to the gasket sealing surface before installing the new coolant filter.

Install the coolant filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten the coolant filter an additional 1/2 to 3/4 of a turn, or as specified by the filter manufacturer.

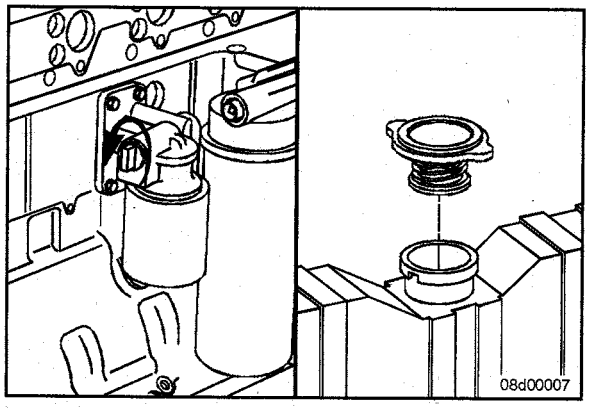




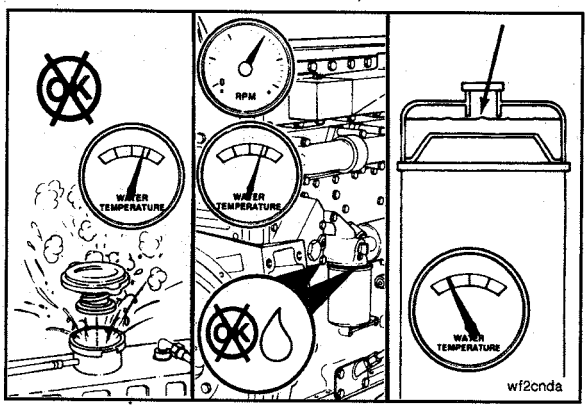
⚠CAUTION⚠

The valve must be in the ON position to prevent engine damage.

Turn the shutoff to the ON position by rotating the knob from horizontal to vertical in the direction shown.



Install the coolant system pressure cap.



⚠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.

Operate the engine and check for coolant leaks.

After the air has been purged from the system, check the coolant level again.

Coolant Filter Head (008-007)

Preparatory Steps

⚠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.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

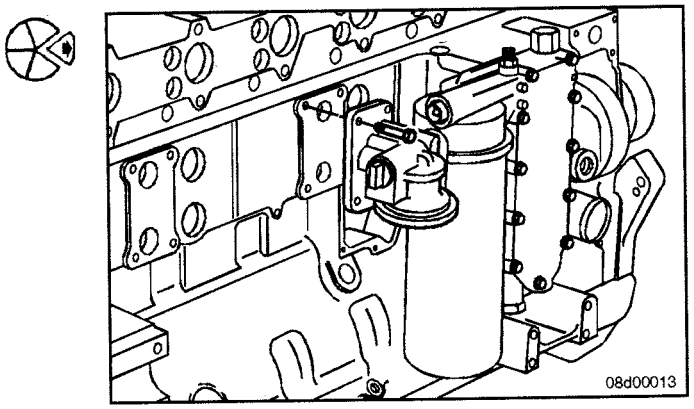
Drain at least 11.3 liters [three (3) gal] of coolant from the cooling system. Refer to Procedure 008-018.

Remove the coolant filter. Refer to Procedure 008-006.

Remove

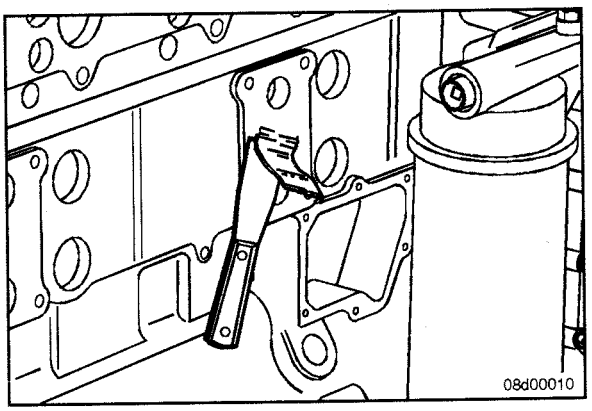
Loosen the four filter head capscrews.

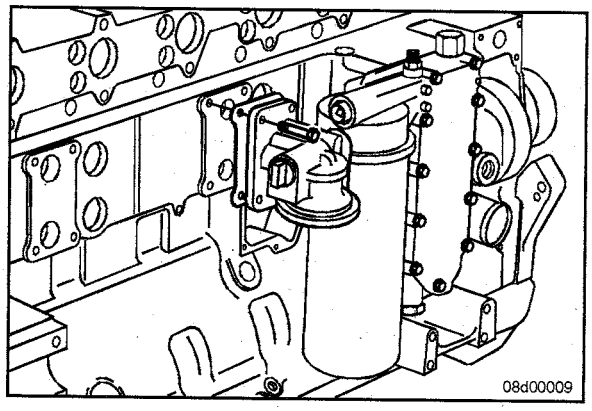
Remove the filter head and gasket.



Clean

Clean the mating surfaces.





Install

Install a new gasket and the filter head.

Tighten the four capscrews.

Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

Install the coolant filter. Refer to Procedure 008-006.

Fill the cooling system with either a 50/50 mixture of good-quality water and fully formulated antifreeze or fully formulated coolant. The fully formulated antifreeze or coolant **must** meet ASTM D6210 (EG) and ASTM D6211 (PG) specifications.

Operate the engine and check for leaks.

Coolant Filter Valve (008-009)

Preparatory Steps

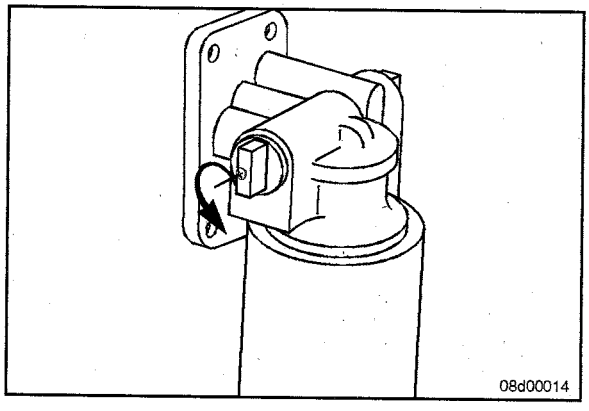
⚠WARNING⚠

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.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

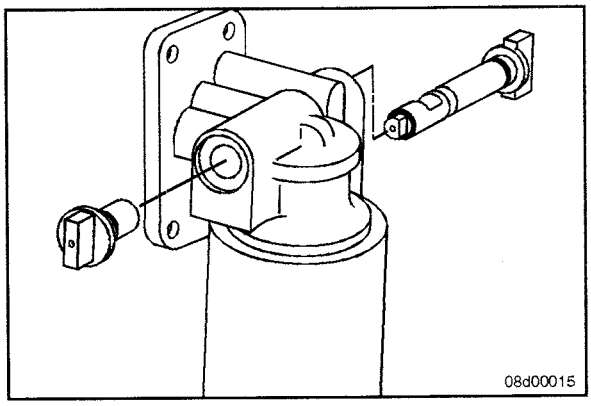
Remove the coolant filter head. Refer to Procedure 008-007.



Remove

Loosen the shutoff valve screw from the end of the valve.

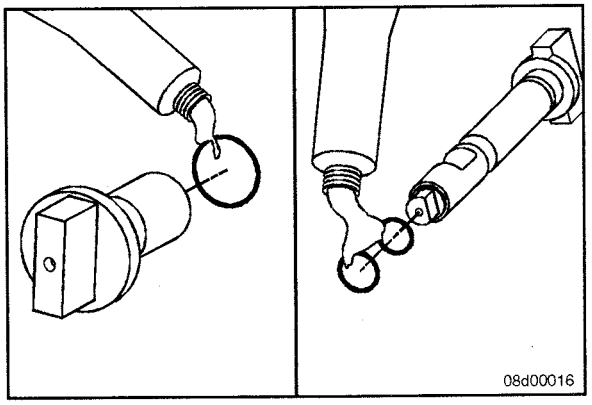
Remove the two pieces of the shutoff valve from both sides of the valve bore.



Install

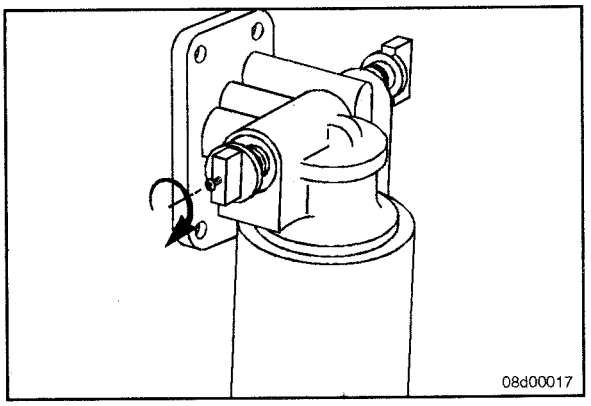
Replace the shutoff valve o-rings.

Lubricate the o-rings before installing the valve pieces back into the bore.



Tighten the shutoff valve screw to tighten the two pieces of the valve together.

Torque Value: 1.5 N•m [12 in-lb]



Finishing Steps

Install the coolant filter head on the engine. Refer to Procedure 008-007.

Install the coolant filter. Refer to Procedure 008-006.

Fill the cooling system with either a 50/50 mixture of good-quality water and fully formulated antifreeze or fully formulated coolant. The fully formulated antifreeze or coolant must meet TMC RP329 or TMC RP330 specifications.

Operate the engine and check for leaks.

Coolant Heater (008-011)

Preparatory Steps

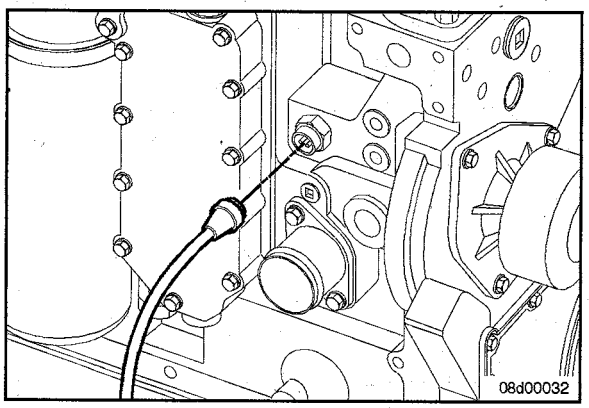
⚠WARNING⚠

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.

⚠WARNING⚠

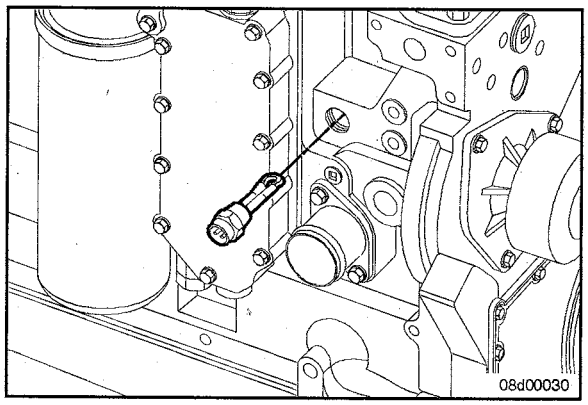
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain at least 19 liters [5 U.S. gal] of coolant. Refer to Procedure 008-018.

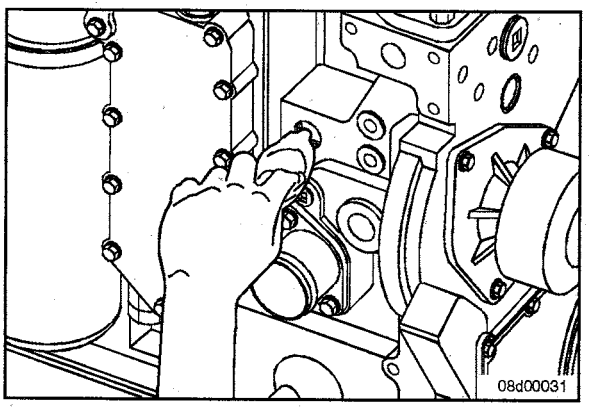


Remove

Disconnect the block heater electrical cord.



Loosen the block heater, and remove it from the block.

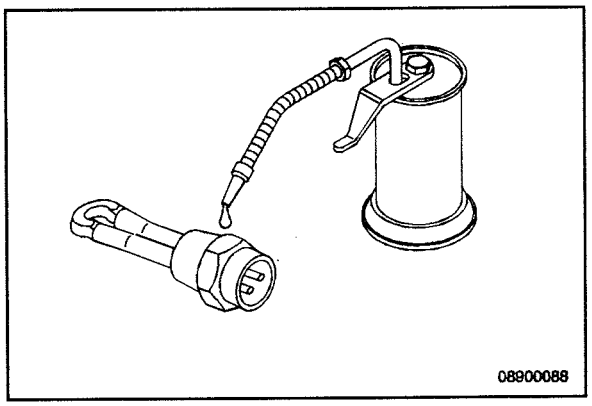


Clean

Clean the heater threads thoroughly.

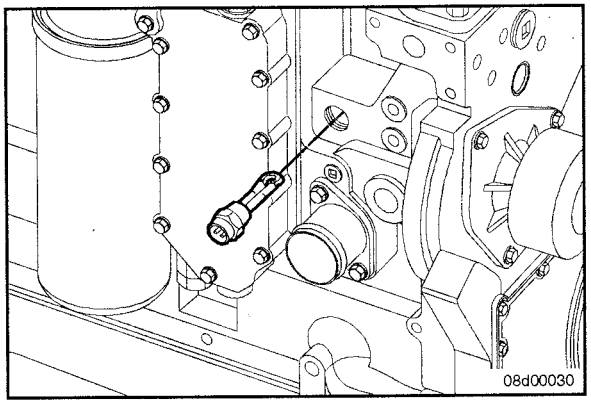
Install

Lubricate the new heater with clean engine oil.

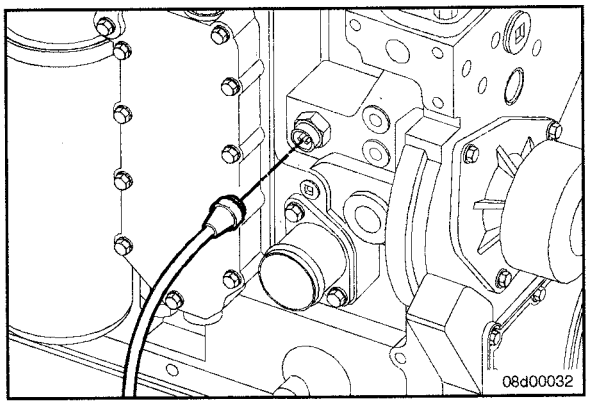


Install the heater.

Torque Value: 75 N•m [55 ft-lb]



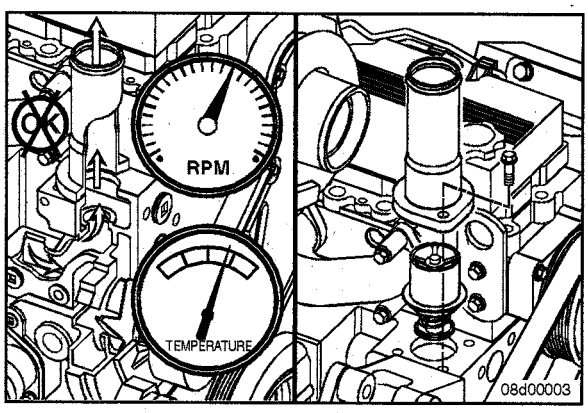
Attach the heater electrical cord.



Finishing Steps

Fill the cooling system. Refer to Procedure 008-018.

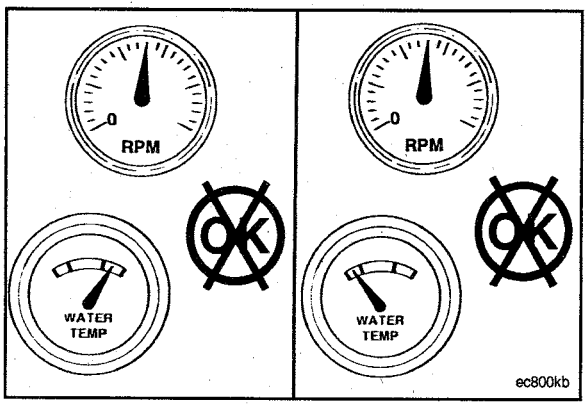
Operate the engine and check for leaks.



Coolant Thermostat (008-013)

General Information

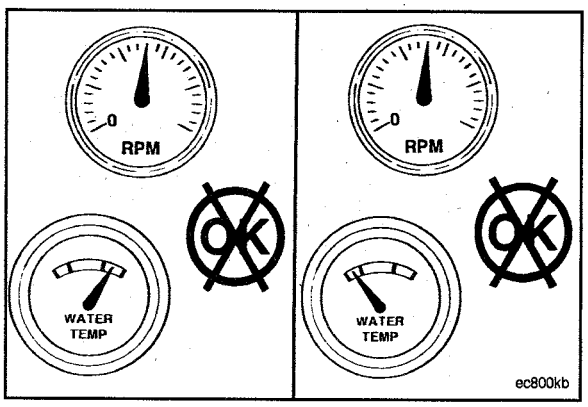
The thermostat controls the coolant temperature. When the coolant temperature is below operating temperature, coolant is bypassed to the inlet of the water pump. When the coolant temperature reaches the operating range, the thermostat opens, sealing off the bypass, and forcing coolant to flow to the radiator. The thermostat begins opening at 82°C [180°F].



⚠CAUTION⚠

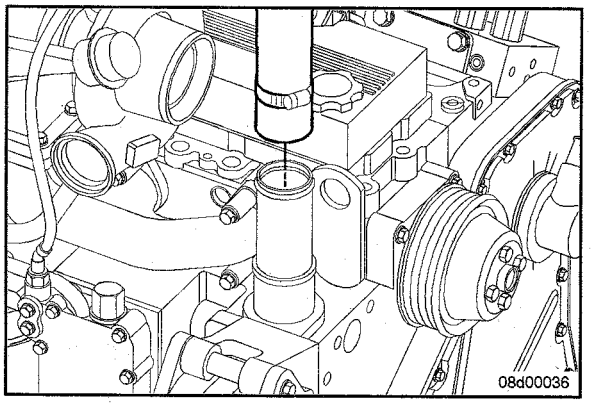
Never operate the engine without a thermostat. Without a thermostat, the path of least resistance for the coolant is through the bypass to the pump inlet. This will cause the engine to overheat.

An incorrect or malfunctioning thermostat can cause the engine to run too hot or too cold.



Leak Test

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.



⚠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.

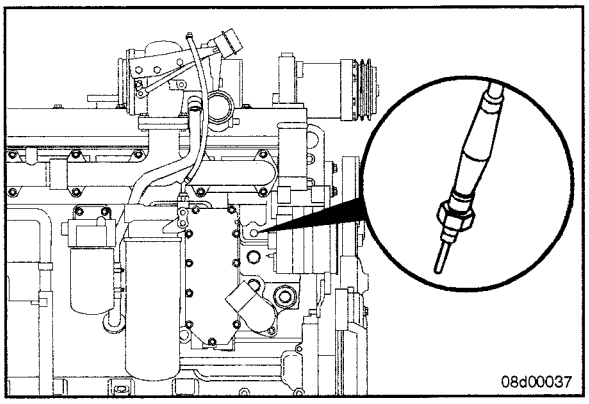
⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain the coolant. Refer to Procedure 008-018.

Remove the radiator hose from the water outlet connection.

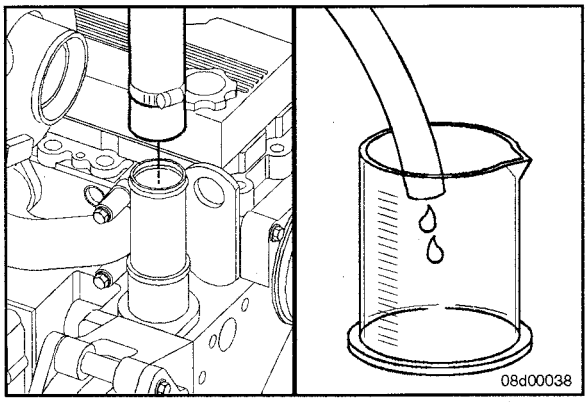
Use INSITE™ to monitor the coolant temperature. Install a thermocouple or temperature gauge that is known to be accurate, in the cylinder block on the engine side of the thermostat.



Install a hose of the same size on the water outlet connection long enough to reach a remote, dry container used to collect coolant.

Install and tighten a hose clamp on the housing outlet.

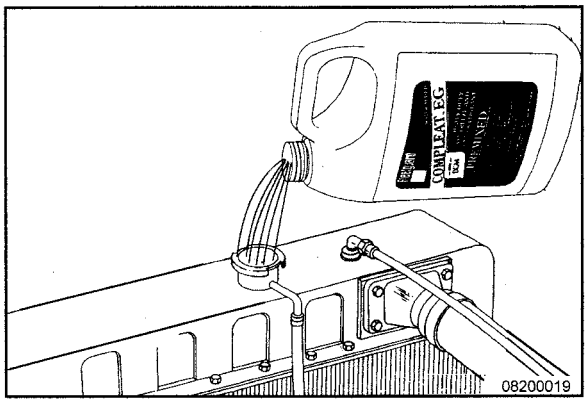
Place the other end of the hose in a dry container.



⚠CAUTION⚠

Always vent the engine and aftercooler during filling to remove air from the coolant system, or overheating will result.

Fill the cooling system. Refer to Procedure 008-018.

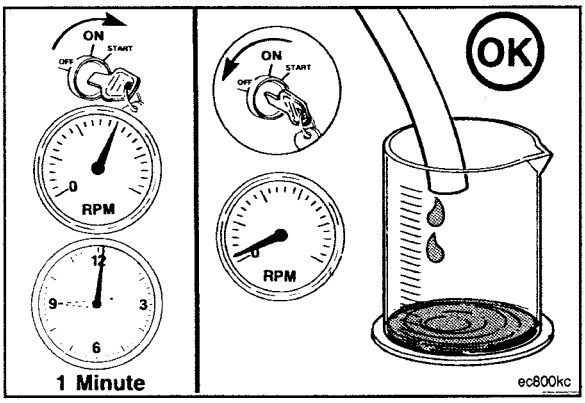


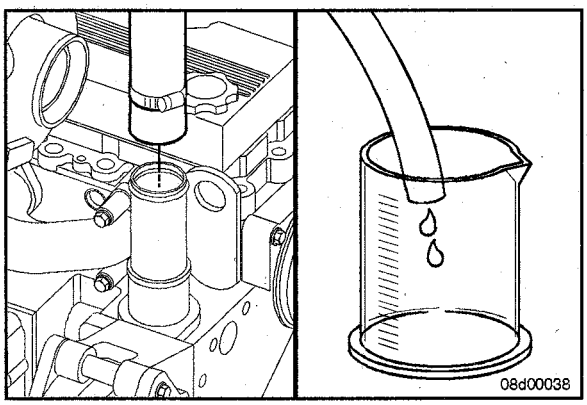
NOTE: The engine coolant temperature **must** be below the thermostat opening temperature to perform this test.

Operate the engine at rated speed for 1 minute.

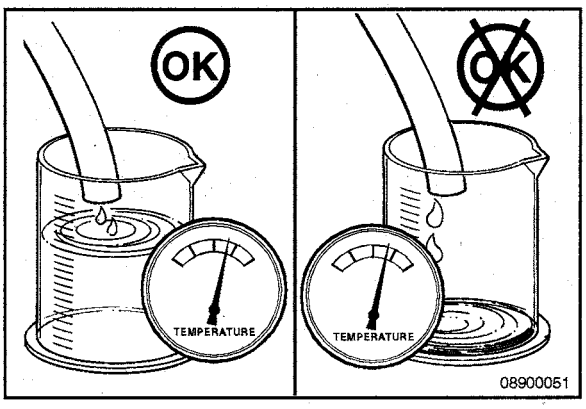
Shut off the engine and measure the amount of coolant collected in the container.

The amount of coolant collected **must not** be more than 100 cc [3.3 fl oz].





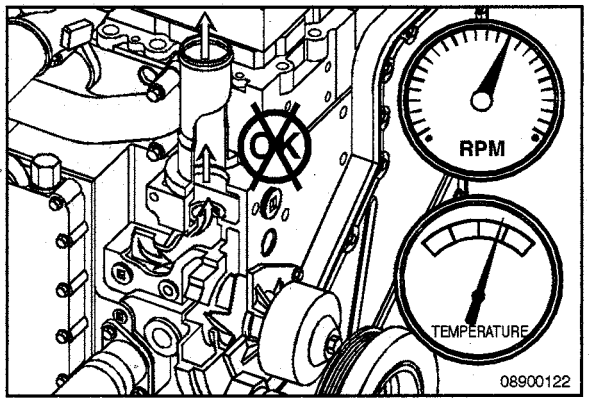
If more than 100 cc [3.3 fl oz] of coolant is collected, the thermostat is leaking and **must** be replaced.



Complete the following test in-chassis to determine the thermostat opening temperature.

Start the engine and monitor the water temperature with INSITE™ or a gauge. Keep the engine speed below 1500 rpm during the test.

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.

Preparatory Steps

⚠ 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.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

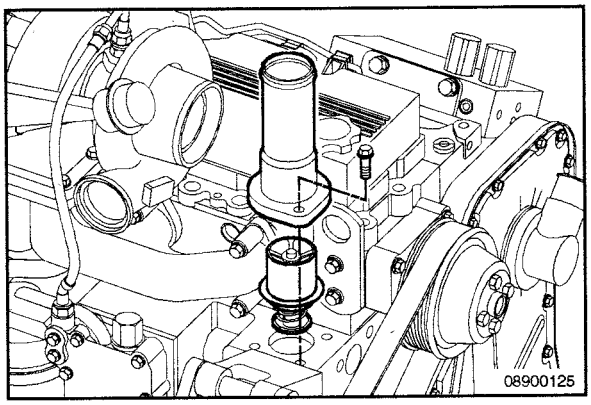
Drain the coolant. Refer to Procedure 008-018.

Remove the radiator hose from the water outlet connection.

Remove

Remove the water outlet connection capscrews and water outlet connection.

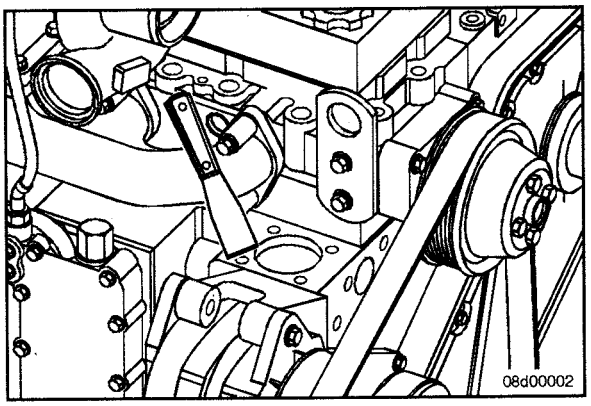
Remove the thermostat.



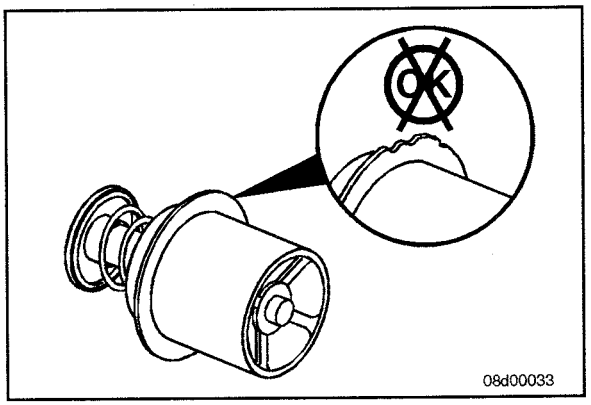
Clean and Inspect for Reuse

Clean all the mating surfaces.

NOTE: Do **not** let any debris fall into the thermostat cavity when cleaning the surfaces.



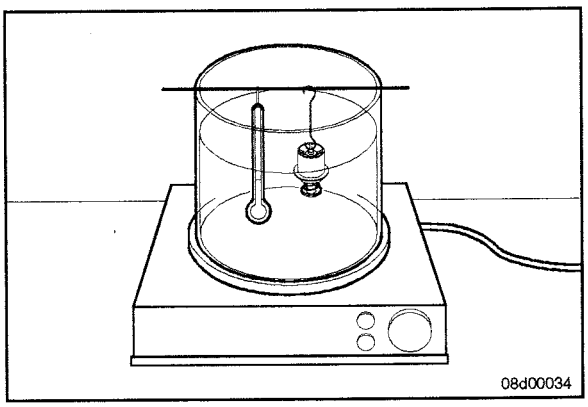
Inspect the thermostat for damage.

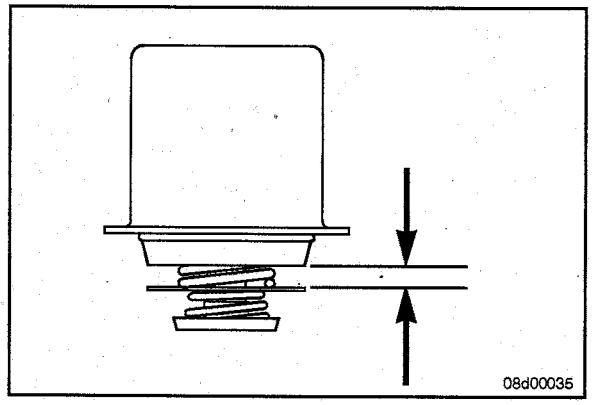


NOTE: Do **not** allow the thermostat or thermometer to touch the container.

Heat the water and check the thermostat as follows:

Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.

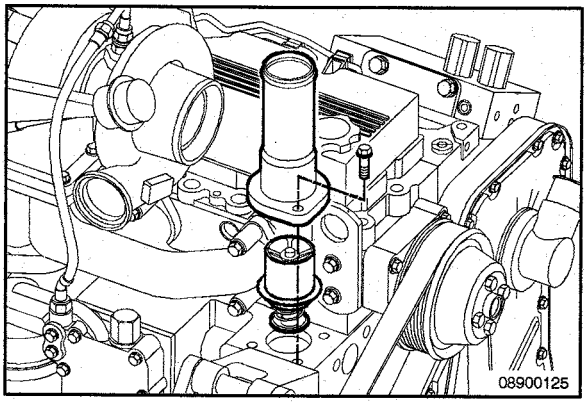




The nominal operating temperature is stamped on the thermostat. The thermostat **must** meet the following criteria:

- The thermostat **must** begin to open within 1°C [2°F] of this nominal temperature.
- The thermostat **must** be fully open within 12°C [22° F] of this nominal temperature.

The fully open distance between the thermostat flange and housing is 9.4 mm [0.370 in].



Install

Install the new thermostat into the water outlet connection. Make sure that the top and bottom o-rings are in place.

Install the water outlet connection and mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

⚠CAUTION⚠

Always vent the engine and aftercooler during filling to remove air from the coolant system, or overheating will result.

Install the water outlet connection. Refer to Procedure 008-082.

Fill the cooling system. Refer to Procedure 008-018.

Operate the engine, and check for leaks.

Cooling System (008-018)

Drain

Marine Applications

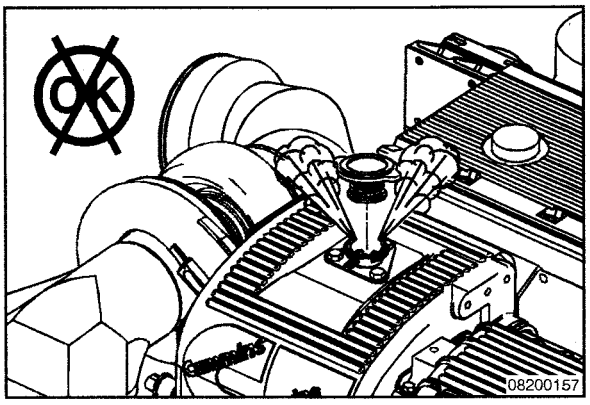
⚠WARNING⚠

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.

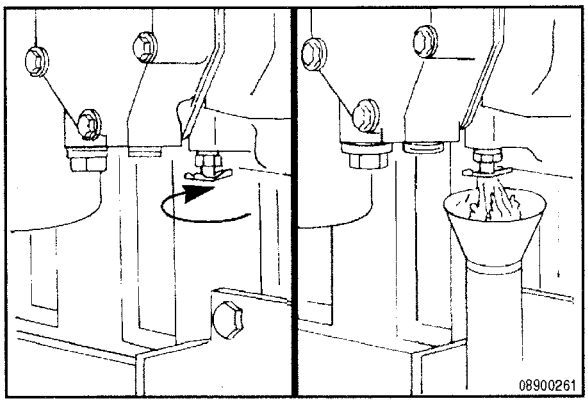
⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Avoid excessive contact, and wash thoroughly after contact.
- Keep out of reach of children.



Drain the engine cooling system by opening the drain valve on the engine oil cooler (exhaust side of engine). A drain pan with a capacity of 31.7 liters (8 gal) will be adequate in most installations. Remove the pressure cap to allow the coolant to drain properly. After the cooling system is completely drained, close the drain valve.



Industrial Applications

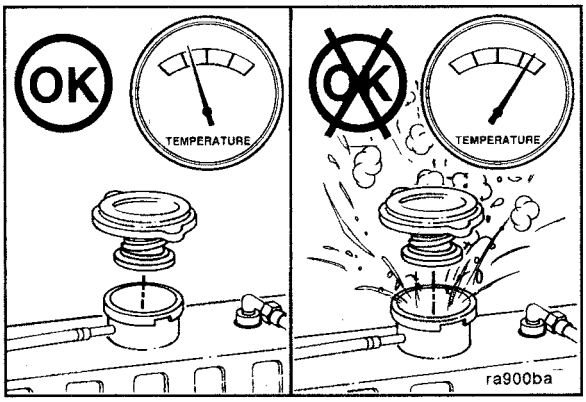
⚠WARNING⚠

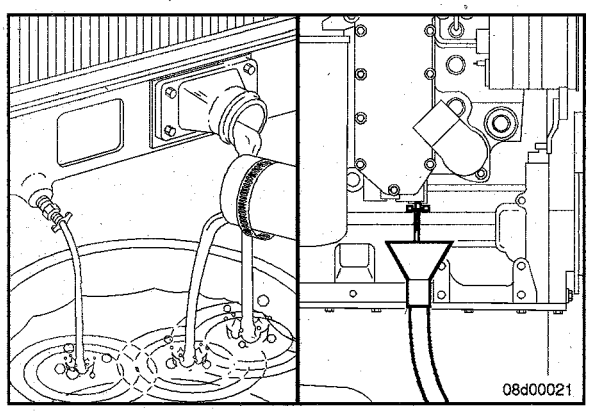
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠

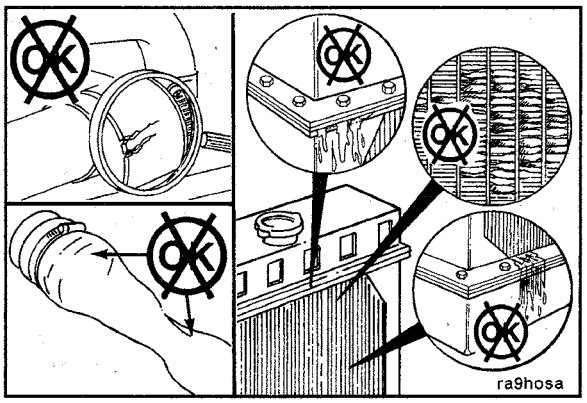
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Avoid excessive contact, and wash thoroughly after contact.
- Keep out of reach of children.





Drain the cooling system by opening the drain valve on the radiator and removing the plug in the bottom of the water inlet hose. A drain pan with a capacity of 19 liters [5 gal] will be adequate for most applications.



Check for damaged hoses and loose or damaged hose clamps. Replace as required.

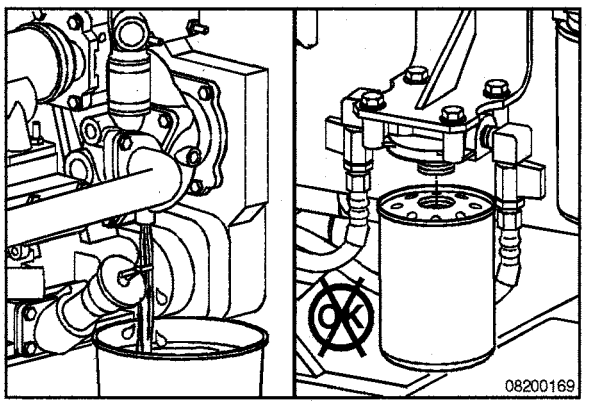
Check the radiator for leaks, damage, and buildup of dirt.

Clean and replace as required.

Flush

Marine Applications

RESTORE™ is a heavy-duty cooling system cleaner that removes corrosion products, 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⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

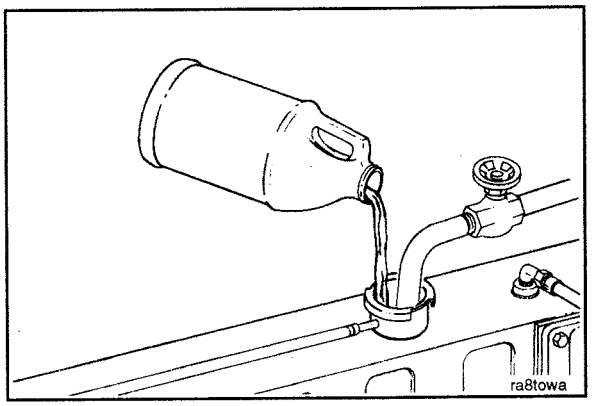
If not previously done, drain the cooling system. Refer to Cooling System - Drain. Do **not** allow the cooling system to dry out.

Do **not** remove the coolant filter.

⚠CAUTION⚠

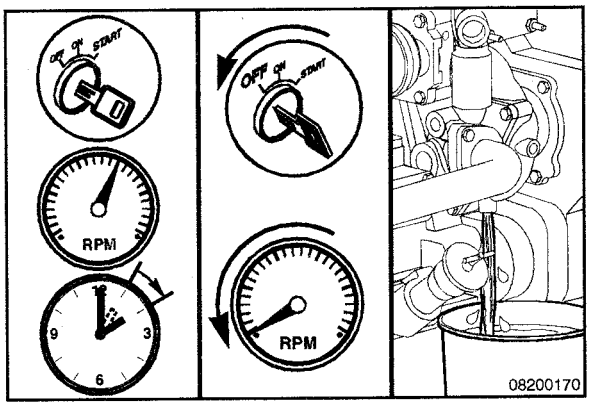
Fleetguard® RESTORE™ contains no antifreeze. Do not allow the cooling system to freeze during the cleaning operations.

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. Fill the system with clean water.

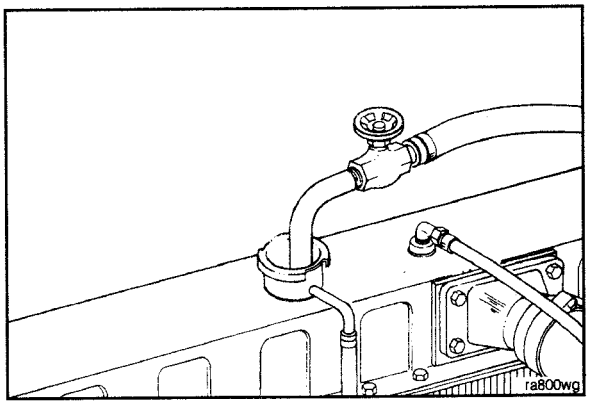


Operate the engine at normal operating temperatures, at least 85°C [185°F], for 1 to 1½ hours.

Shut off the engine, allow to cool to 50°C [122°F] and drain the cooling system.



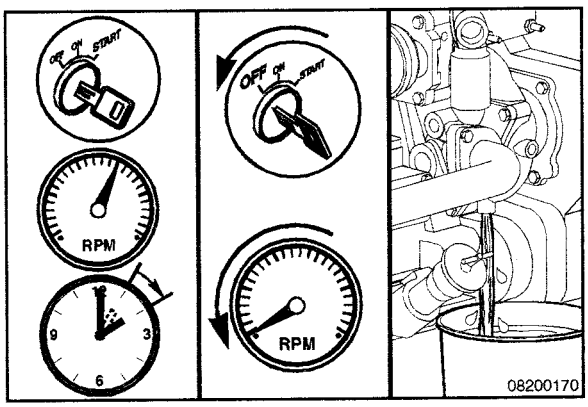
Fill the cooling system with clean water.

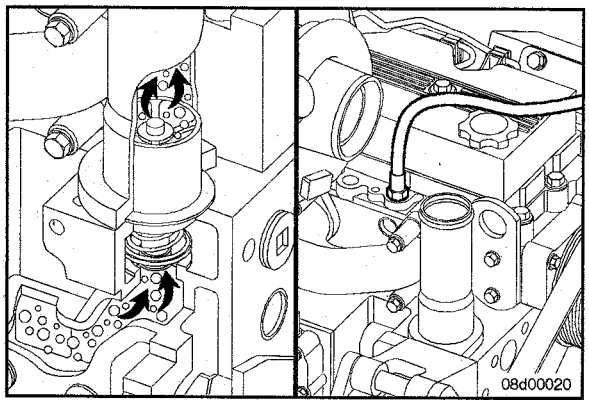


Operate the engine for 5 minutes with the coolant temperature above 85°C [185°F].

Shut off the engine, allow to cool to 50°C [122°F], and drain the cooling system.

If the water being drained is still dirty, the system **must** be flushed again until the water is clean.



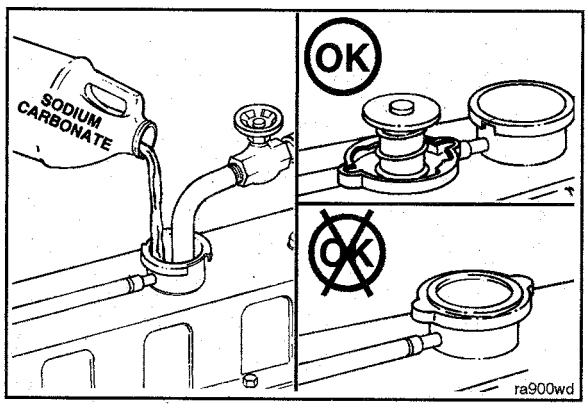


Industrial Applications

⚠CAUTION⚠

The system must be filled properly to prevent air locks. During filling, air must be purged from the engine coolant passages. Be sure to open the petcock on the aftercooler for aftercooled engines. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

NOTE: Adequate venting is provided for a fill rate of 19 liters [5 gal] per minute.

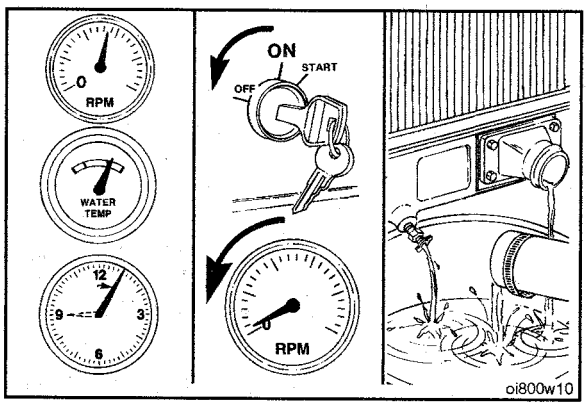


⚠CAUTION⚠

Do not install the radiator cap. The engine is to be operated without the cap for this process.

Fill the system with a mixture of sodium carbonate and water (or a commercially available equivalent).

NOTE: Use 0.5 kg [1 lb] of sodium carbonate for every 23 liters [6 gal] of water.

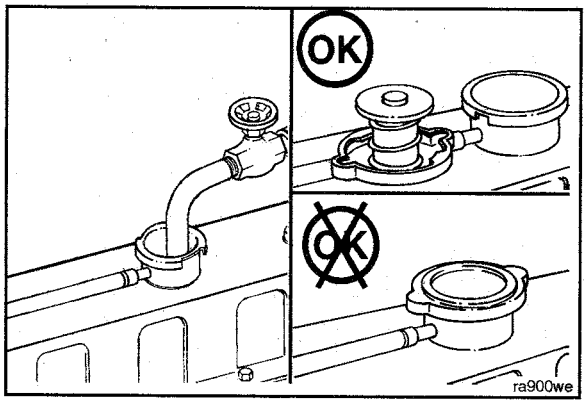


⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Operate the engine for 5 minutes with the coolant temperature above 80°C [176°F].

Shut the engine off, and drain the cooling system.



Fill the cooling system with high-quality water.

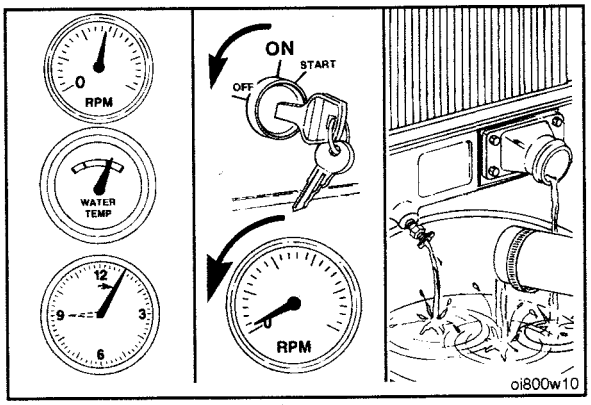
NOTE: Be sure to vent the engine and aftercooler for complete filling.

NOTE: Do **not** install the radiator cap or the new coolant filter.

Operate the engine for 5 minutes with the coolant temperature above 80°C [176°F].

Shut the engine off, and drain the cooling system.

NOTE: If the water being drained is still dirty, the system **must** be flushed again until the water is clean.

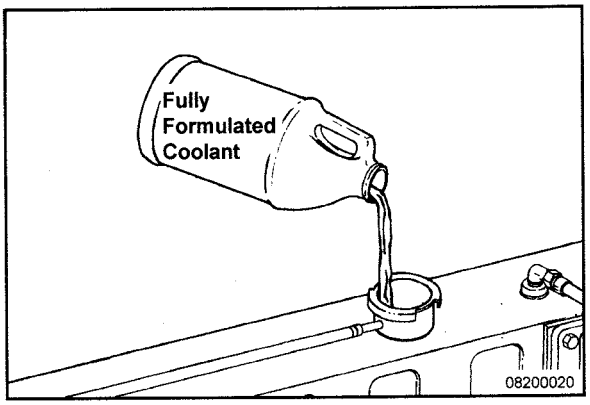


Fill

Marine Applications

Fill the cooling system with fully formulated coolant or a 50/50 mixture of recommended antifreeze, and clean, good-quality water. (Refer to the Coolant Specifications in Section V.)

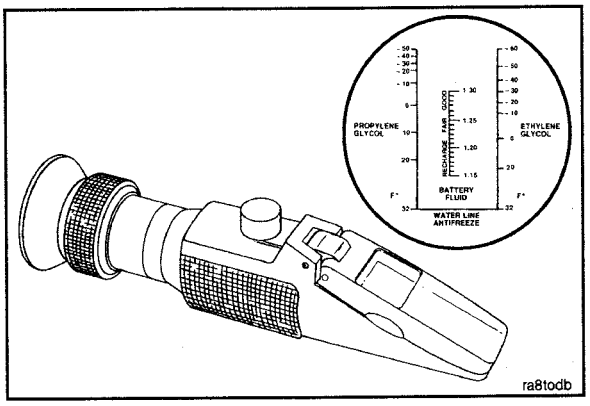
Install the pressure cap. Operate the engine to 50°C [122° F], and check for coolant leaks.



The freeze point protection **must** be checked after coolant is added to the cooling system.

The Fleetguard® refractometer, Part Number C2800, provides a reliable, easy-to-read, and accurate measurement of freeze point protection and antifreeze concentration.

Refer to the OEM's instructions for the correct operation instructions for the Fleetguard® refractometer, Part Number C2800.



Industrial Applications

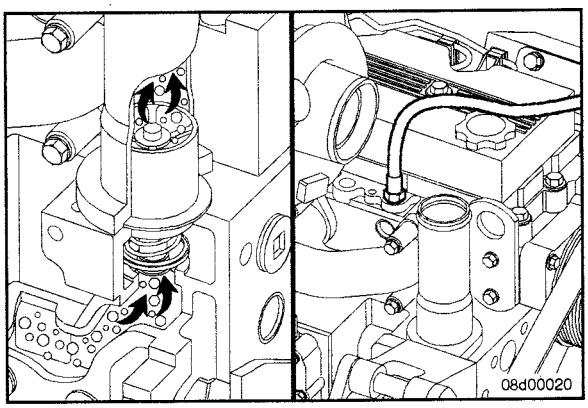
⚠CAUTION⚠

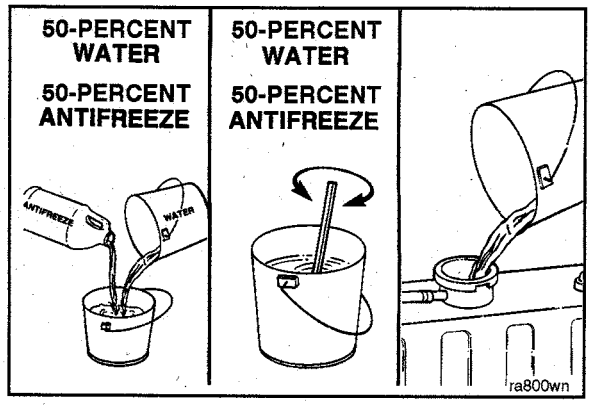
The system must be filled properly to prevent air locks. During filling, air must be purged from the engine coolant passages. Be sure to open the petcock on the aftercooler for aftercooled engines. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

The system is designed to use a specific quantity of coolant. If the coolant level is low, the engine will run hot.

If frequent addition of coolant is necessary, the engine or system has a leak. Find and repair the leak.

The system has a designed fill rate of 19 liters [5 gal] per minute.

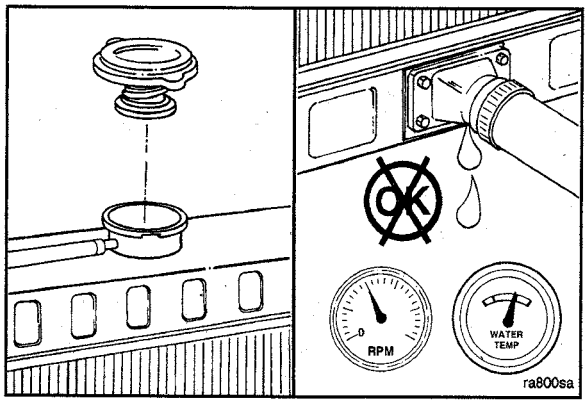




⚠CAUTION⚠

Never use water alone for coolant. This can result in damage from corrosion.

Use a mixture of 50-percent water and 50-percent ethylene glycol or propylene glycol antifreeze to fill the cooling system.

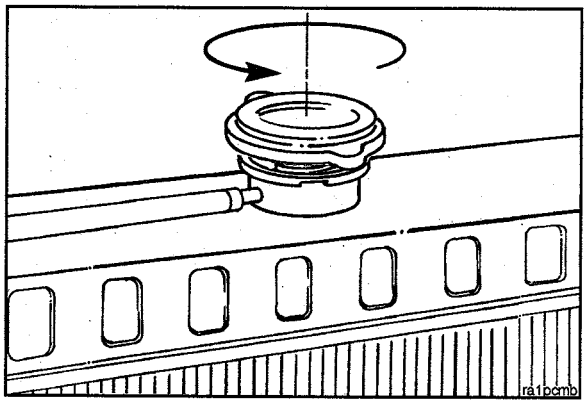


⚠WARNING⚠

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.

Install the pressure cap. Operate the engine until the coolant reaches a temperature of 80°C [180°F], and check for coolant leaks.

Check the coolant level again to make sure the system is full of coolant or that the coolant level has risen to the hot level in the recovery bottle on the system, if so equipped.



Cooling System Diagnostics (008-020)

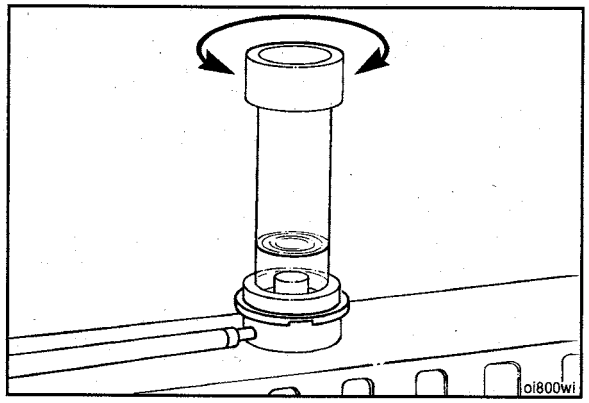
Setup

⚠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 radiator cap, and leave it off for the following test.

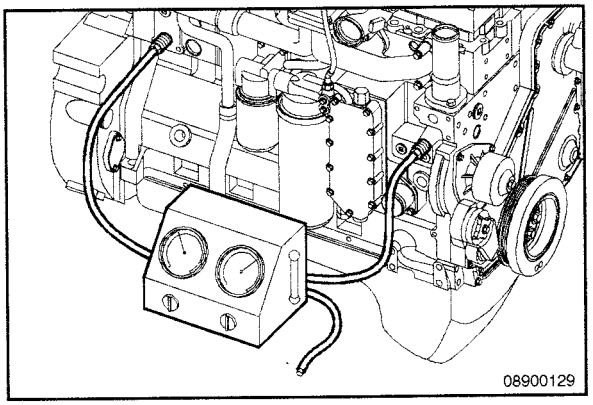
NOTE: All cab heaters and air conditioners **must** be turned to the OFF position, and the engine fan control **must** be turned to the AUTOMATIC position, if applicable.



Install the combustion gas leak test instrument, Part Number 3822985, into the radiator cap opening.

Install the analyzer kit, Part No. 3822994.

- Red line - plugged
- Yellow line - cylinder block pressure
- Black line - water pump inlet.



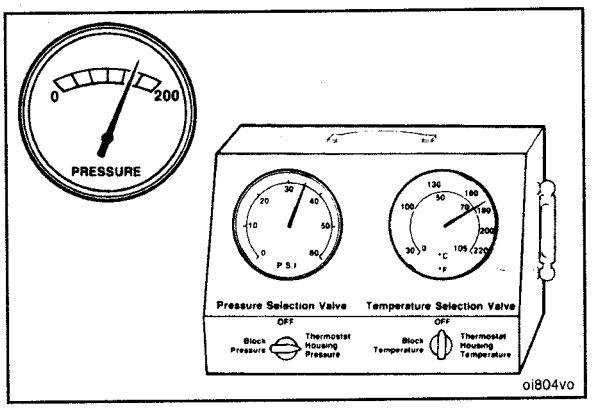
Test

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.

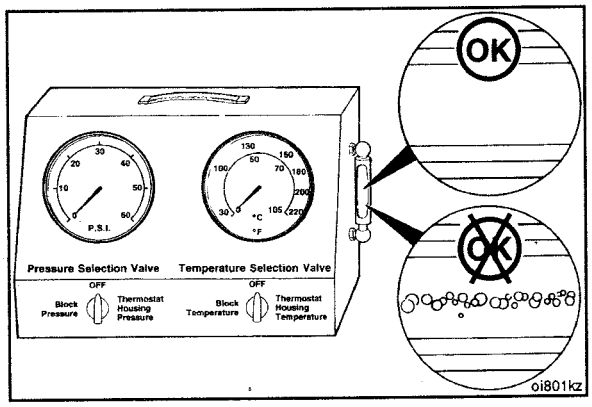
Start the engine and run at high idle.



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.

Temperature Readings:

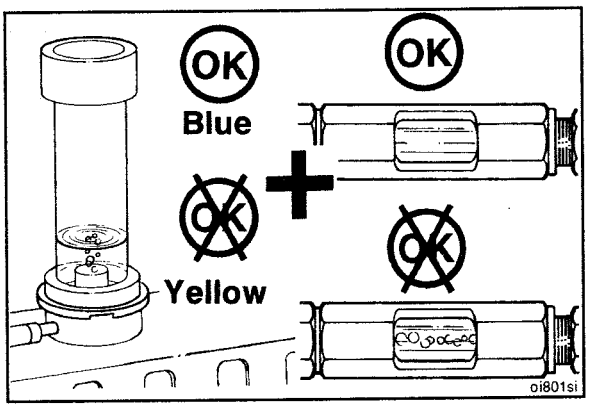
There will be temperature fluctuations when switching the temperature selection valve. This fluctuation is normal and is caused by temperature loss in the line. The temperature will stabilize after a few seconds.

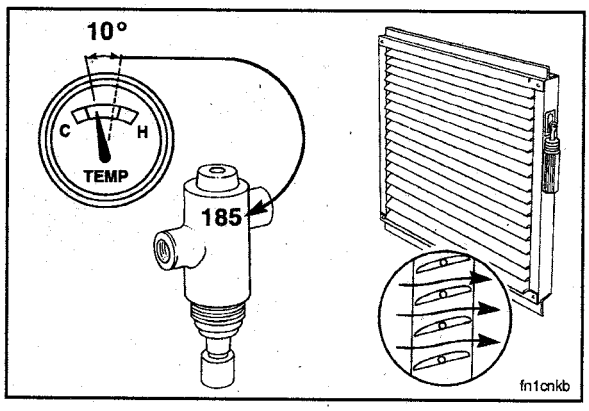


Analyzing the Data

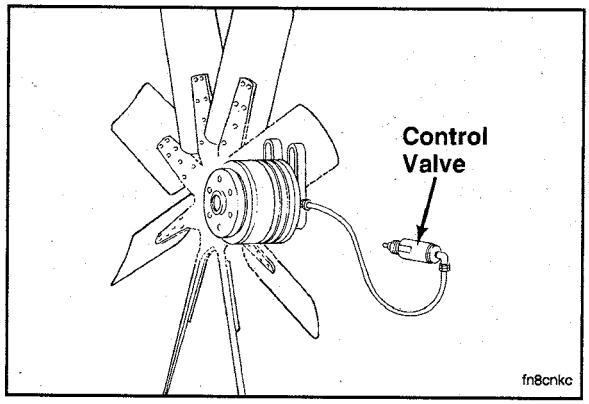
Check the color of fluid in the combustion gas leak tester. This information, along with the sight glass observations, will help isolate the source of air in the cooling system, if any.

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.

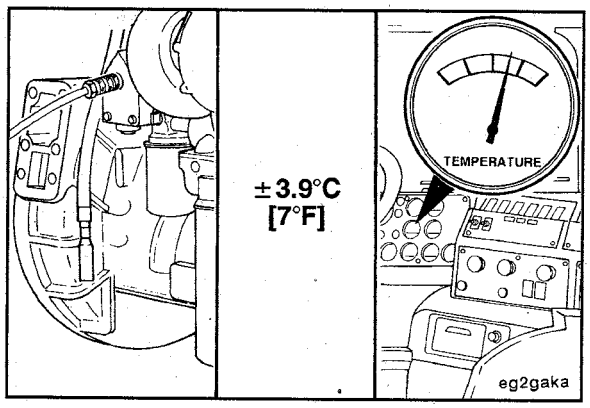




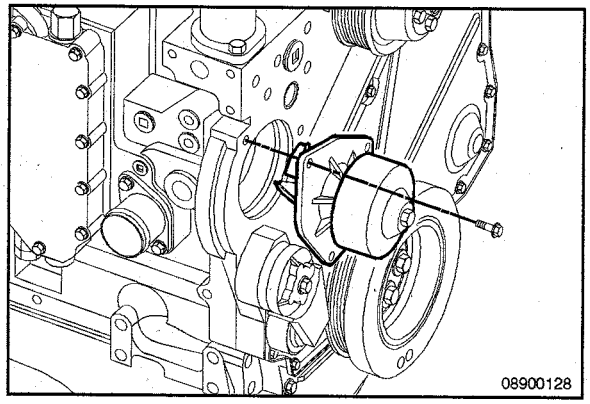
Check the recorded coolant temperature when the shutters are opened. Compare this value to the stamp on the shutter control. Cummins Inc. recommends that the shutters open at 85°C [185°F].



Check the recorded coolant temperature when the fan is engaged. Cummins 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 for the correct reading. If no manufacturer's specifications are available, replace the gauge if it is **not** within ±3.9°C [7° F] of the correct reading.

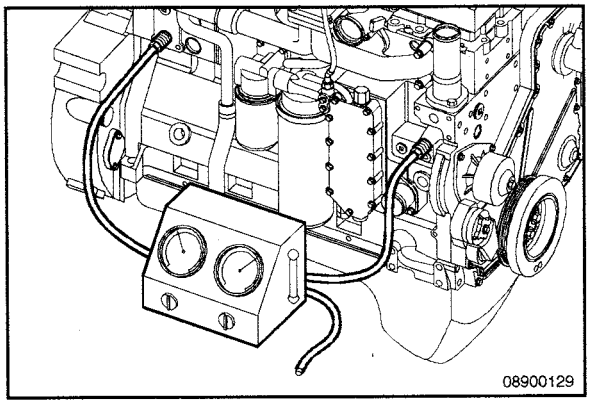


Read the recorded block pressure at 60°C [140°F]. If the block pressure is less than 138 kPa [20 psi] at high idle and without a pressure cap, check the following:

- Remove the water pump
- Inspect the impeller's integrity, and for slippage on the shaft
- Check the belt tension and condition.

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
- Incorrect initial cooling system fill
- Less than 50/50 antifreeze mixture, or the engine is at high altitude.

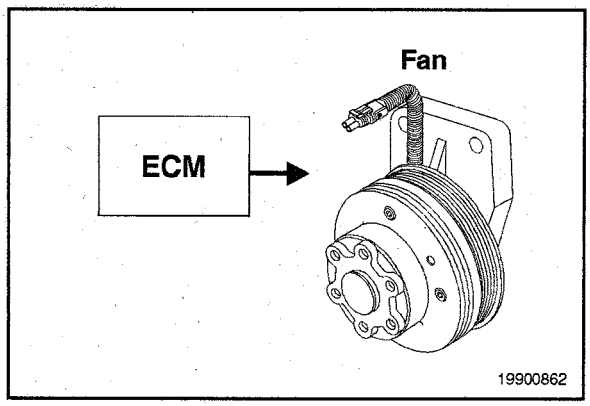


Worksheet

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.

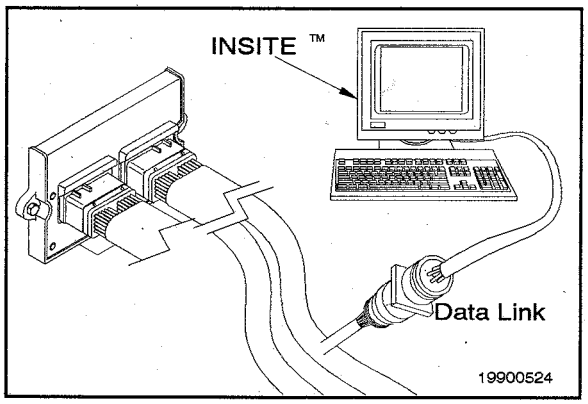
Temperature			Pressure		Fan Starts Operating	Shutters Open	Notes
Thermostat Housing	Cylinder Block	Cab Gauge	Cylinder Block	Radiator "In-Line" Starts Getting Hot			
140							Engine at high idle throughout test
145							Monitor for air throughout test
150							
155							Start monitoring radiator "in-line"
160							
165							Check water filter
170							
175							
180							
185							
190							
195							
200							
205							Cool engine down



Fan Clutch, On-Off (008-027)

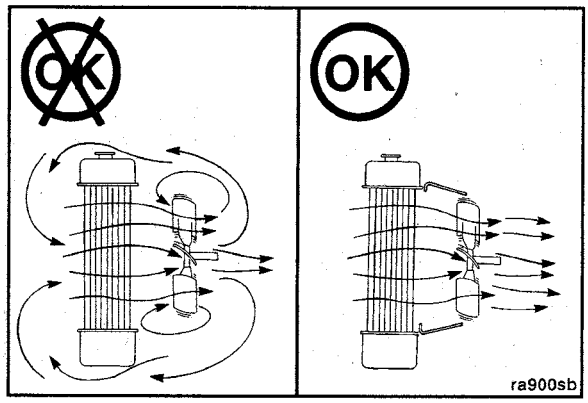
General Information

Many fan clutches can be controlled by the engine's electronic control module (ECM). The ECM monitors coolant temperature and intake manifold temperature to determine when to engage the cooling fan. Some applications have additional sensors monitored by the ECM for fan control (for example, air conditioner pressure and transmission temperature). These are various fan clutch types, such as air-engaged, air-disengaged, electric, viscous, and on/off. Refer to the equipment manufacturer's service manual to determine fan clutch type.



The ECM is capable of using either a 0-VDC or 12-VDC signal to engage the fan clutch. The enable logic is contained in the ECM calibration and can be programmed using INSITE™.

Refer to the equipment manufacturer's service manual for fan clutch troubleshooting and repair information.



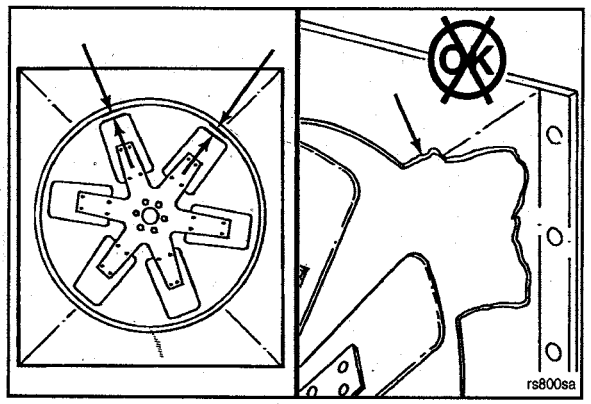
Fan Shroud Assembly (008-038)

General Information

The radiator or fan shroud is used to direct all air-flow across the radiator fins rather than around the edges of the radiator.

An incorrect fan shroud or obstructions can reduce air-flow and cause the engine to run hot.

NOTE: Check to be sure air is **not** recirculating. Check for missing baffles.



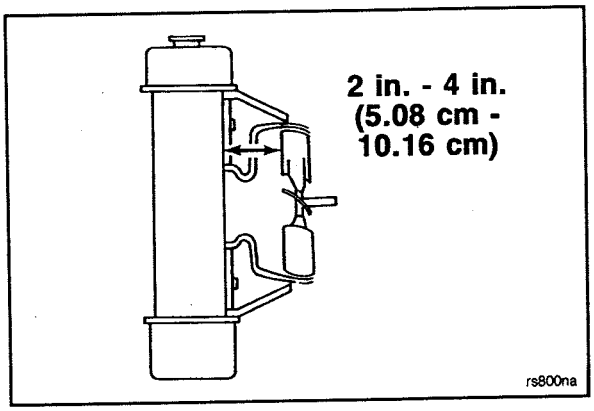
Initial Check

⚠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 allow proper airflow through the radiator to provide adequate engine cooling.

Inspect the fan shroud for proper fan clearance, cracks, air leaks, and damage. Replace if necessary. Refer to the equipment manufacturer's service manual for instructions.

Cummins Inc. recommends that fan clearance be between 5.08 to 10.16 cm [2 to 4 in] from the radiator core. Refer to the equipment manufacturer's service manual for alternative positions.



Fan Spacer and Pulley (008-039)

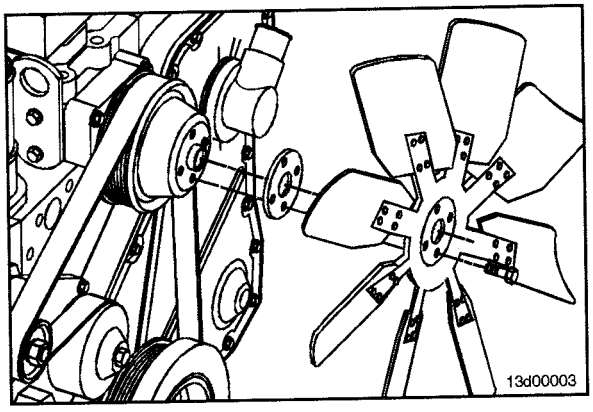
Preparatory Steps

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

Remove the cooling fan. Refer to Procedure 008-040.

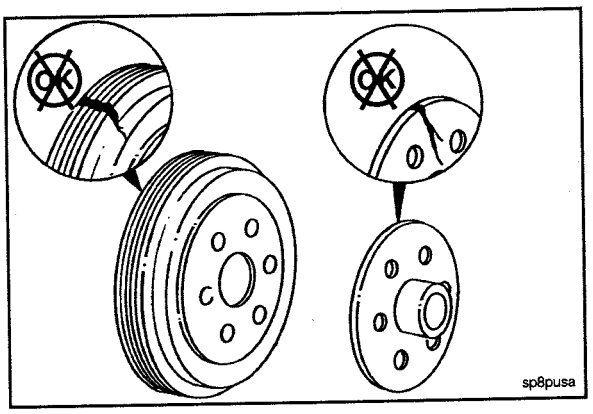
Remove

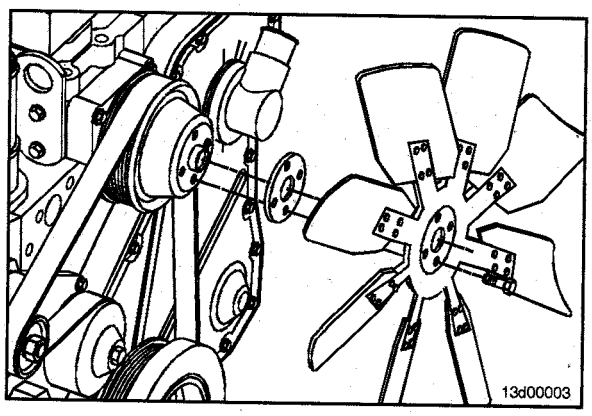
Remove the fan spacer and the fan pulley.



Inspect for Reuse

Check the spacer and pulley for cracks or damage.





Install

Install the fan pulley and the fan spacer.

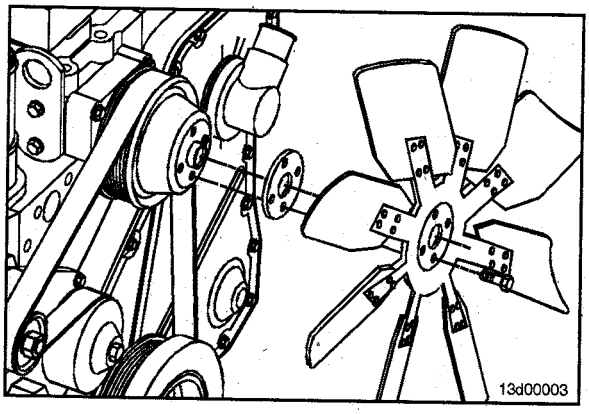
Finishing Steps

Install the cooling fan. Refer to Procedure 008-040.
Install the fan drive belt. Refer to Procedure 008-002.

Fan, Cooling (008-040)

Preparatory Steps

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



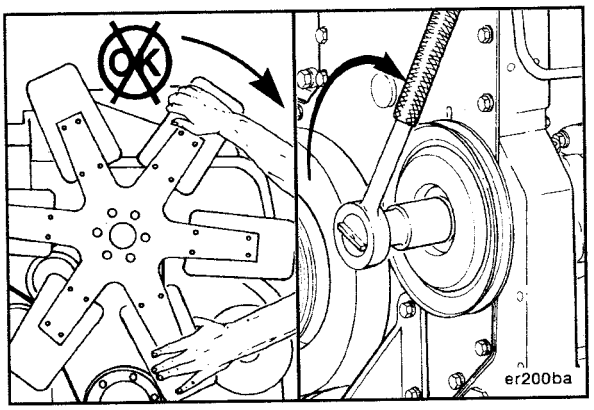
Remove

Remove the fan capscrews, the fan and the spacer.

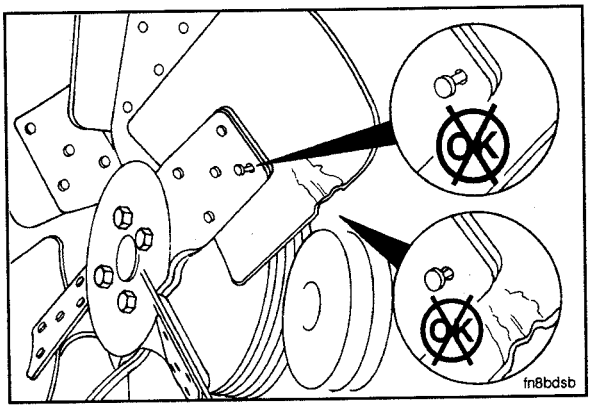
Inspect for Reuse

⚠WARNING⚠

Do not rotate the engine by pulling or prying on the fan. The fan blade(s) can be damaged and cause the fan to fail and cause personal injury or property damage. Use the accessory drive shaft or the crankshaft barring tool to rotate the crankshaft.

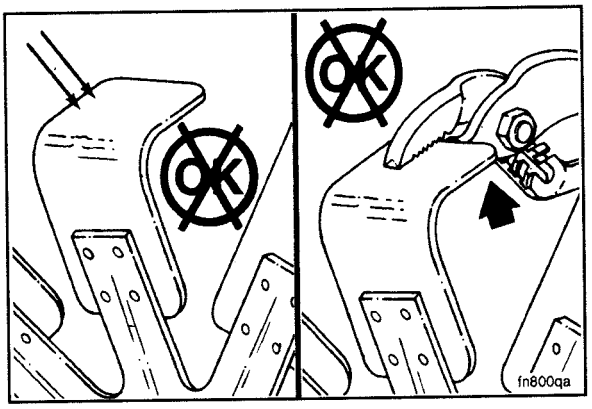


A visual inspection of the cooling fan is required daily. Check for cracks, loose rivets, and bent or loose blades. Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.



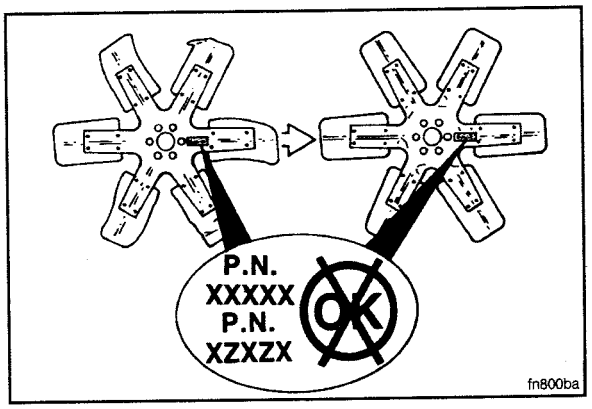
⚠WARNING⚠

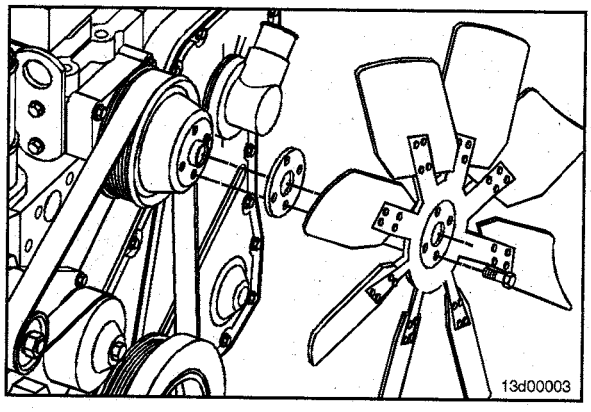
Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause personal injury or property damage.



Replace original equipment fan that is damaged with a fan of the identical part number. Cummins Inc. **must** approve any other fan changes to be covered under warranty.

Refer to the vehicle or equipment manufacturer's specifications for capscrew torque.





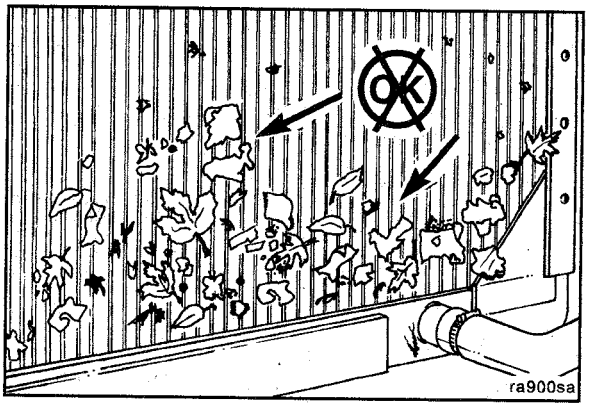
Install

Install the fan capscrews, the fan and the spacer.

Torque Value: 43 N•m [32 ft-lb]

Finishing Steps

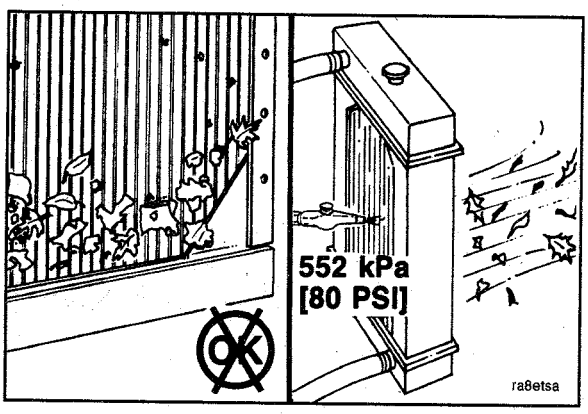
Install the fan drive belt. Refer to Procedure 008-002.



Radiator (008-042)

General Information

Air forced through the fins of the radiator by a fan cools the coolant pumped through the radiator. Environmental debris (such as paper, straw, lint, and dust) can obstruct the fins and stop the flow of air that will reduce the cooling effect of the radiator.



Initial Check

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Inspect for plugged radiator fins.

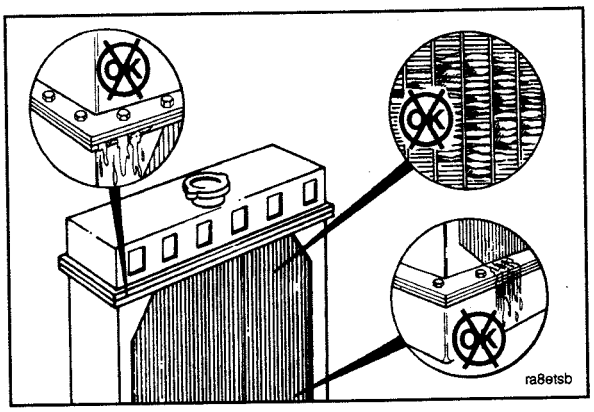
Use compressed air to blow out the dirt and debris.

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 equipment manufacturer's replacement procedures.

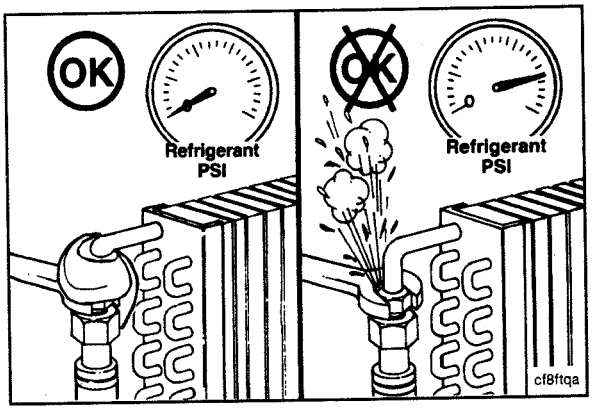


⚠WARNING⚠

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.

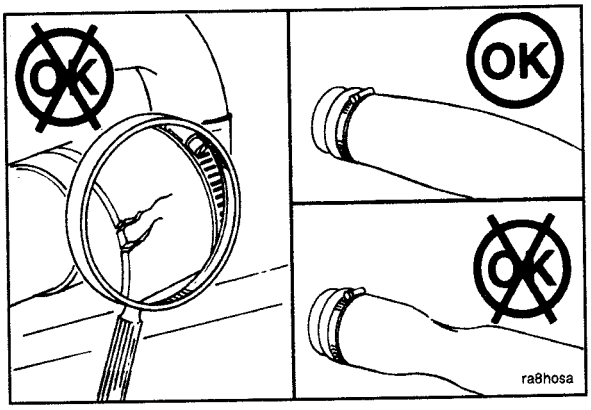


Radiator Hoses (008-045)

Inspect for Reuse

Inspect all hoses for cracks, cuts, or collapsing.

NOTE: The silicone engine coolant hose will exhibit swelling due to the elasticity of the hose.



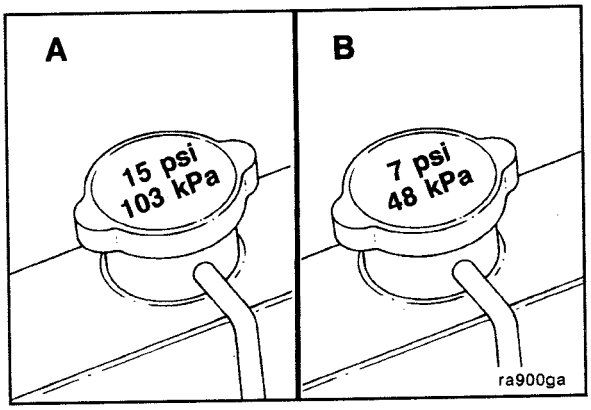
Radiator Pressure Cap (008-047)

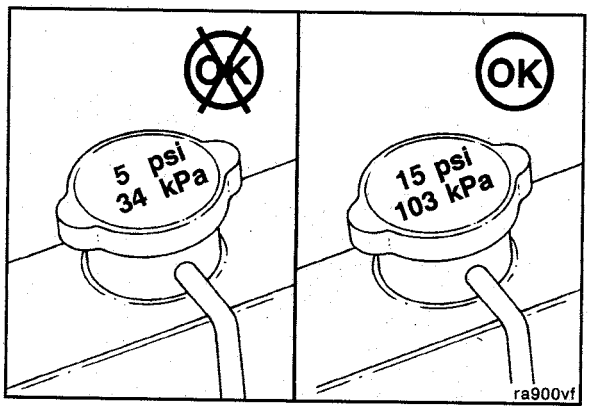
General Information

The system is designed to use a pressure cap to prevent boiling of the coolant.

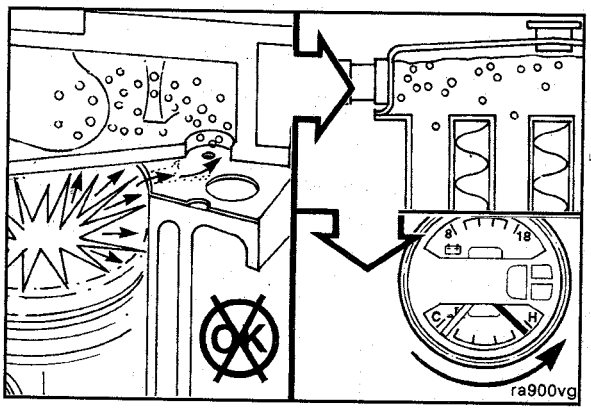
Different caps are specified for the two recommended systems:

Radiator Cap Pressure Test		
	System	Cap
A (Normal-Duty)	104°C [220°F]	103 kPa [15 psi]
B (Light-Duty)	99°C [210°F]	48 kPa [7 psi]



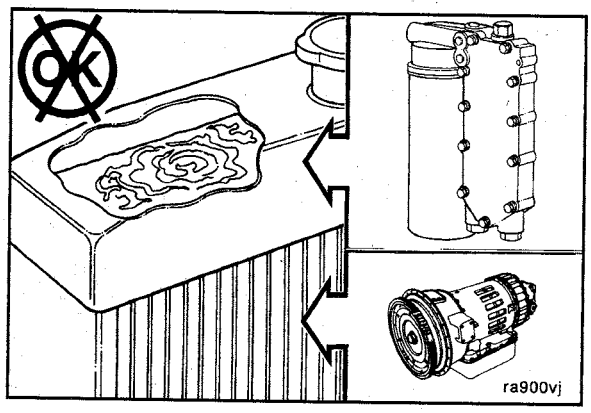


An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.



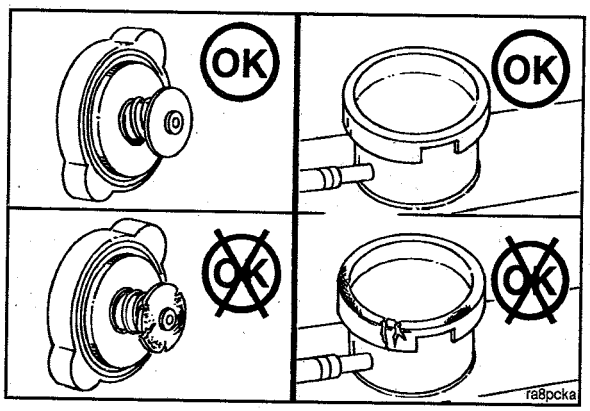
Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gases to the coolant system.



The operating pressure of the cooling system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems such as the head gasket or oil cooler. Refer to Section 7, Lubricating Oil System.

NOTE: Transmission fluid can also leak into the coolant through radiator bottom tank transmission oil coolers.



Inspect for Reuse

Be sure the correct radiator cap is being used. Refer to the Cooling System Specifications in Section V.

Inspect the rubber seal of the pressure cap for damage.

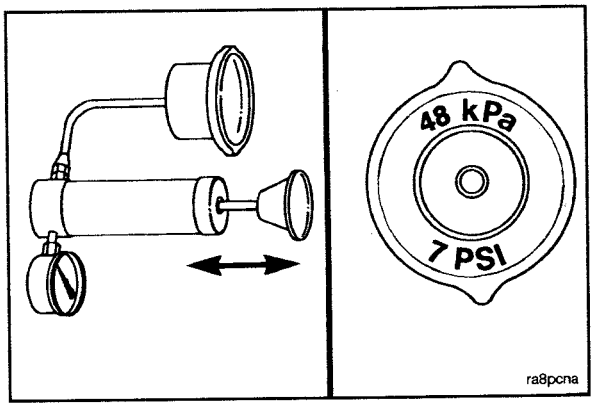
Inspect the radiator fill neck for cracks or other damage.

Refer to the equipment manufacturer's service manual 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.

Refer to the equipment manufacturer's service manual for radiator cap test procedure.

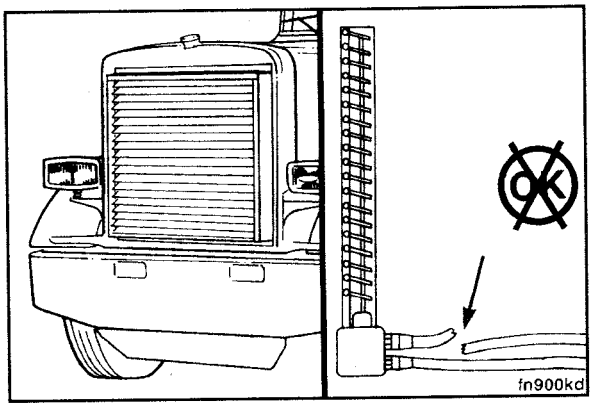


Radiator Shutter Assembly (008-049)

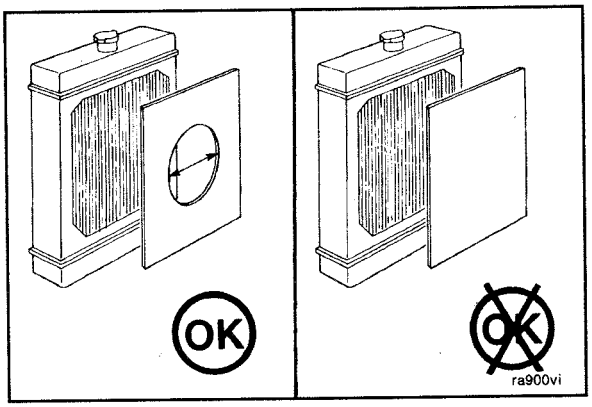
General Information

Shutters are designed to control air-flow across the radiator. If the shutters fail to open when needed, the engine can run hot. Failure of the shutters to close can result in too much air-flow and the engine running cold.

NOTE: Make sure that the air temperature sensor is functioning correctly. Check the air-operated shutter controls. Check for air leaks. Refer to the equipment manufacturer's service manual.



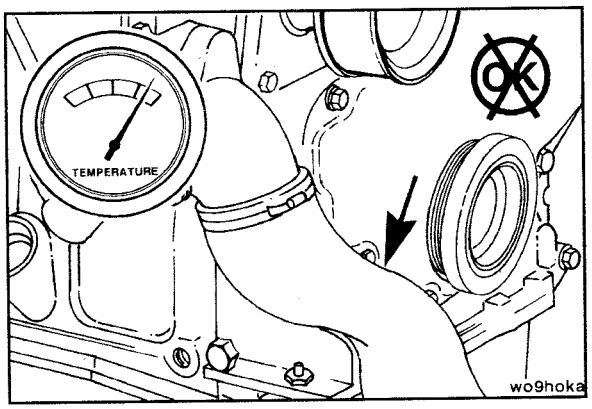
Winterfronts can be used on a charge air cooled engine, but **must** be designed to cover part of the frontal area of the cooling system. A minimum of 77419 sq mm [120 sq in] of charge air cooled frontal area **must** be left open to air-flow.

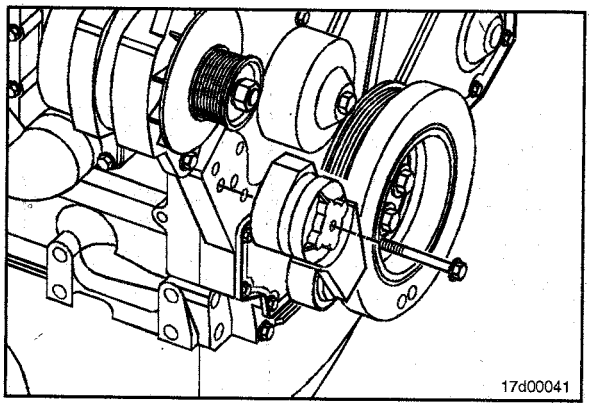


Water Pump (008-062)

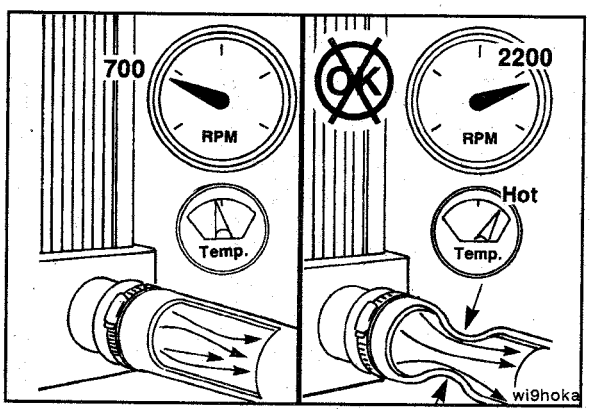
General Information

The water pump pulls coolant from the bottom of the radiator and pumps it through the engine and back to the top of the radiator for cooling. Reduced or interrupted flow will result in the engine running hot.



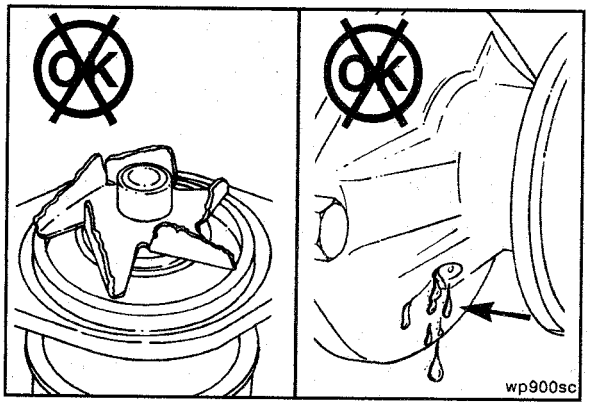


The pump is belt-driven from the crankshaft pulley. An automatic belt tensioner is used to prevent the belt from slipping on the pump pulley. A malfunction of the tensioner will cause the water pump impeller to rotate at a slower speed, reducing the amount of coolant flow.



The coolant flow can also be reduced if the inlet hose to the water pump collapses. A hose will usually **not** collapse while the engine is running at low speed. Check the hose while the engine is running at rated speed.

NOTE: Be sure the engine is warm, a minimum of 91°C [195°F], so the thermostat is open.



A worn or malfunctioning water pump will **not** produce the flow required to prevent the engine from running hot. However, be sure to check the other possibilities indicated in the Coolant Temperature above Normal symptom chart in Section TS before checking the flow or replacing the pump.

Preparatory Steps

⚠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.

⚠WARNING⚠

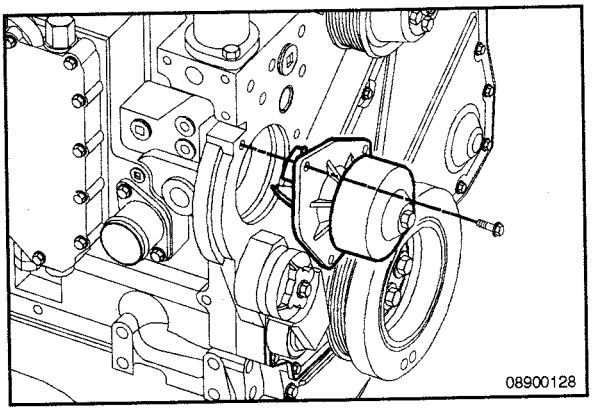
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain the coolant. Refer to Procedure 008-018.

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

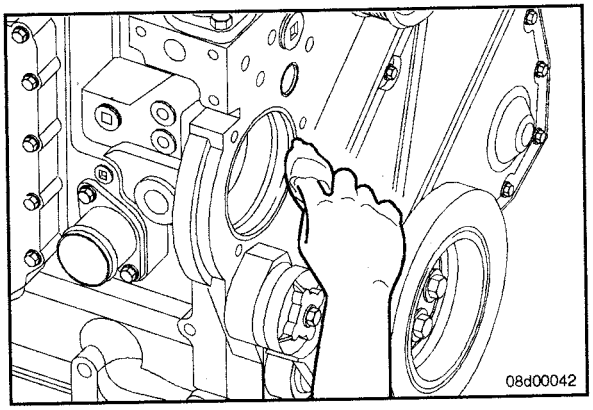
Remove

Remove the water pump capscrews and water pump.



Clean and Inspect for Reuse

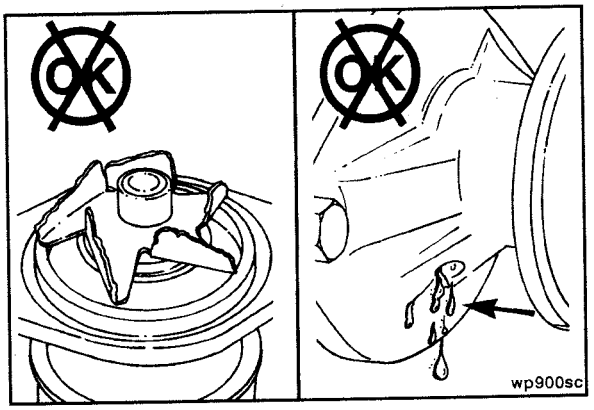
Clean the o-ring sealing surface on the water pump housing.



Inspect the water pump housing and impeller for cracks or damage.

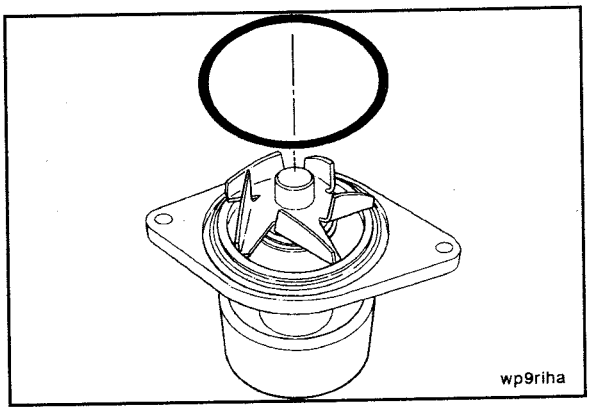
Inspect the water pump weep hole for an indication of a steady leak.

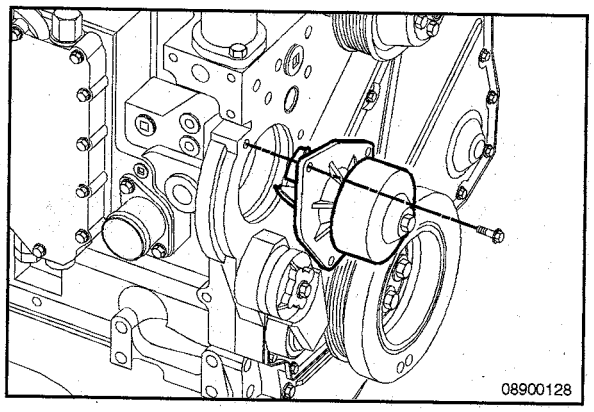
NOTE: A streak or chemical buildup at the weep hole is **not** justification for water pump replacement. If a steady flow of coolant or oil is observed, replace the water pump with a new or rebuilt unit.



Install

Install a new sealing ring into the pump groove.





Install the water pump.

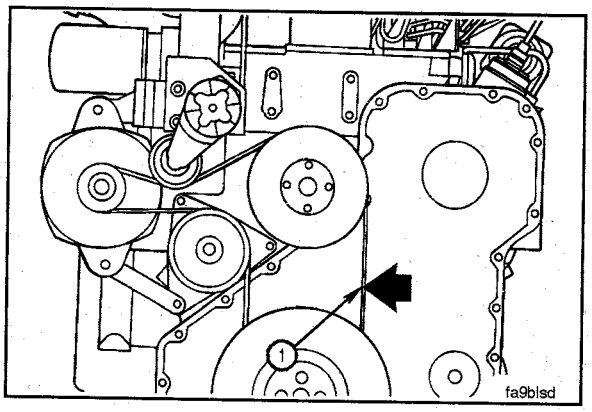
Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

Lift the tensioner and install the belt. Refer to Procedure 008-002.

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.

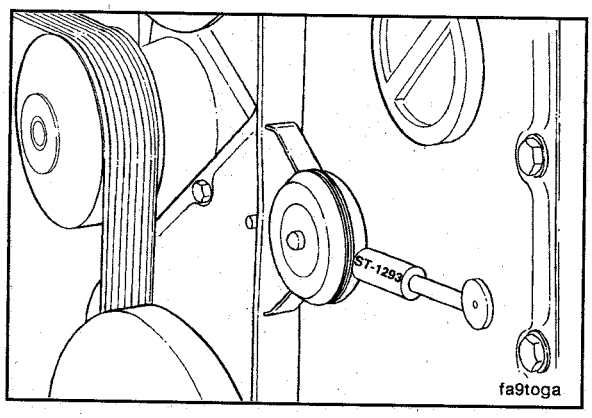


Belt Tensioner, Automatic (Water Pump) (008-080)

Initial Check

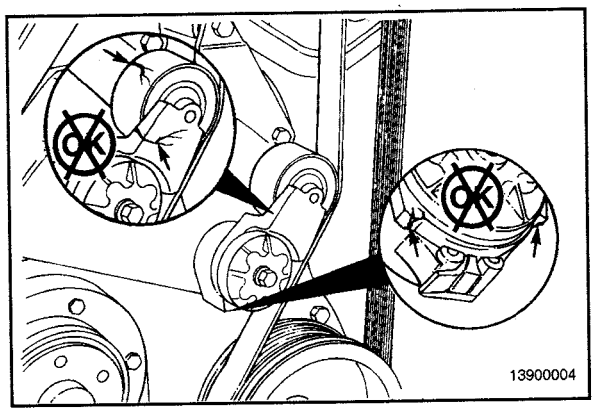
Check the belt deflection at the longest span of the belt. The deflection **must** be checked at the center (1) of the span.

The maximum deflection allowed in the belt is 9.5 to 12.7 mm [3/8 to 1/2-in].



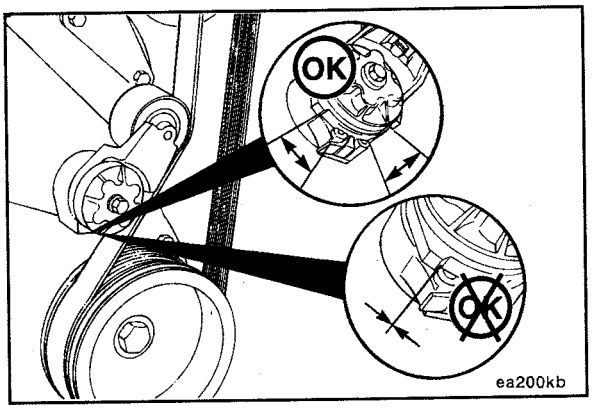
Use the Cummins belt tensioner gauge, Part Number ST-1293, to measure the tension in the drive belt. This needs to be in the range of 360 to 480 N [80 to 100 ft-lb].

Check the tensioner arm, pulley, and stops for cracks. If any cracks are noticed, the tensioner **must** be replaced.



With the belt on, verify that neither tensioner arm stops are in contact with the spring casing stop. If either stop is touching, the drive belt **must** be replaced.

After replacing the belt, if the tensioner arm stops are still in contact with the spring casing stop, replace the tensioner.



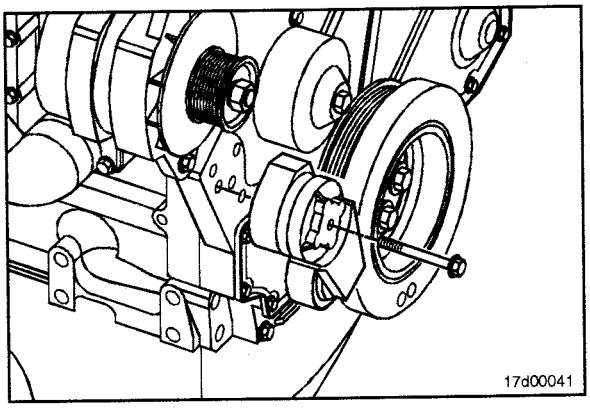
Preparatory Steps

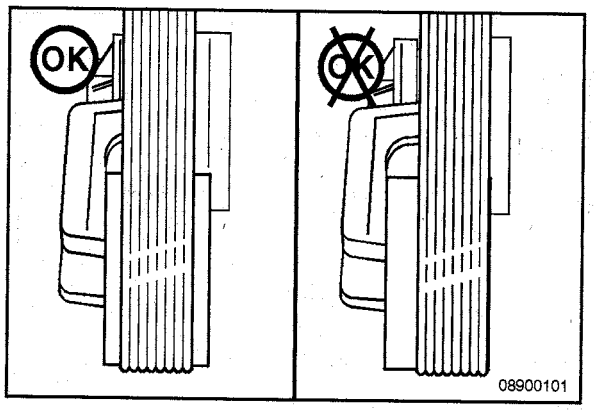
Lift the belt tensioner to relieve tension in the belt.

Remove the belt. Refer to Procedure 008-002.

Remove

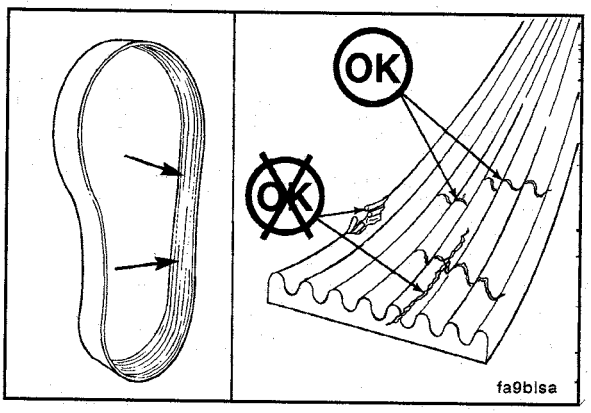
Remove the capscrew and belt tensioner from the bracket.





Inspect for Reuse

Check the location of the drive belt on the belt tensioner pulley. The belt should be centered on, or close to the middle of, the pulley. Unaligned belts, either too far forward or backward, can cause belt wear, belt roll-off failures, or increase uneven tensioner bushing wear.

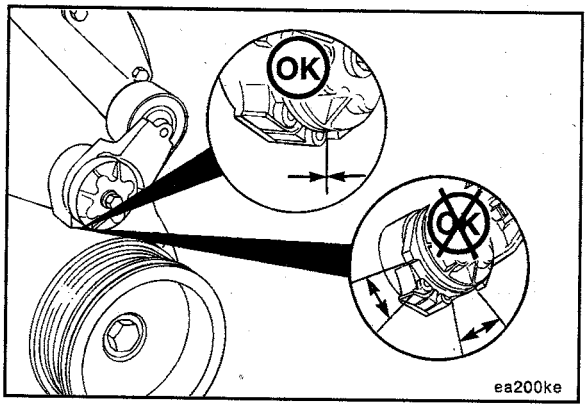


Check the belt for damage.

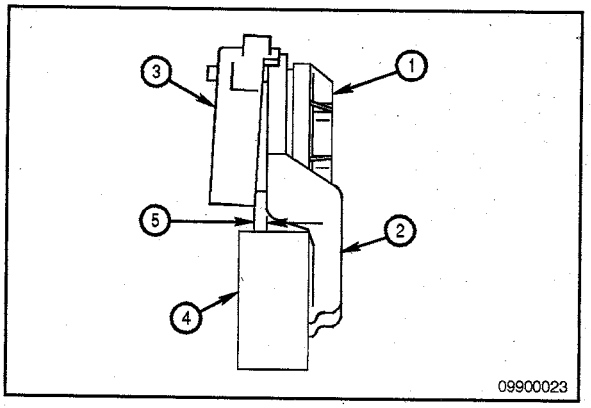
Transverse (across the belt width) cracks are acceptable.

Longitudinal (direction of the belt length) cracks that intersect with transverse cracks are **not** acceptable.

If the belt is frayed or has any piece of material missing, the belt is unacceptable and needs to be replaced.



With the belt removed, verify that the tensioner arm stop is in contact with the spring case stop. If these two are **not** touching, the tensioner **must** be replaced.

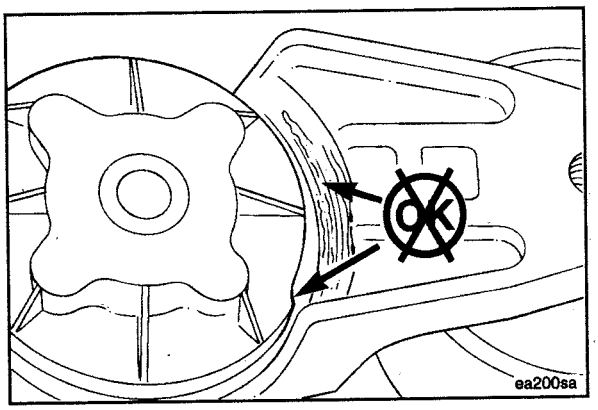


Measure the clearance between the tensioner spring case and the tensioner arm to verify tensioner wear-out and uneven bearing wear. If the clearance exceeds 3 mm [0.12 in] at any point, the tensioner failed and **must** be replaced as a complete assembly.

Experience has revealed that tensioners generally will show a larger clearance gap near the lower portion of the spring case, resulting in the upper portion rubbing against the tensioner arm. **Always** replace the belt when a tensioner is replaced.

1. . Tensioner cap
2. . Tensioner arm
3. . Spring case
4. . Tensioner pulley
5. . Clearance gap

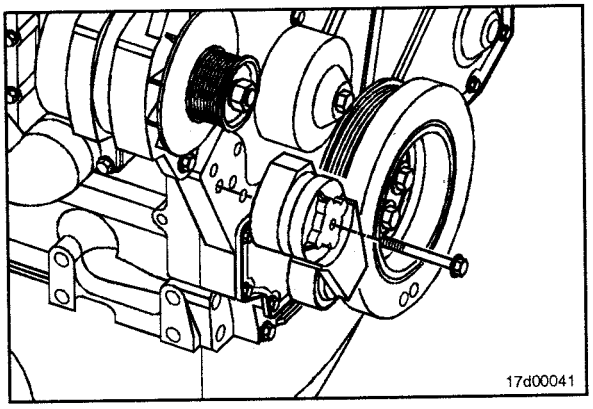
Inspect the tensioner for evidence of the tensioner arm contacting the tensioner cap. If there is evidence of the two areas making contact, the pivot tube bushing has failed and the tensioner **must** be replaced.



Install

Install the belt tensioner and capscrews.

Torque Value: 43 N•m [32 ft-lb]



Finishing Steps

Lift and hold the tensioner using a 3/8-inch square drive.

Install the drive belt and release the tensioner.

Service Tip: If difficulty is experienced installing the drive belt or if the belt seems too short, position the belt over the grooved pulleys first then, while holding the tensioner up, slide the belt over the water pump pulley.

Water Inlet Connection (008-082)

Preparatory Steps

⚠WARNING⚠

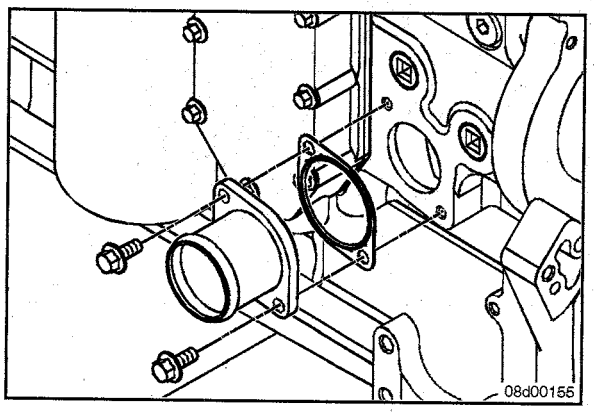
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

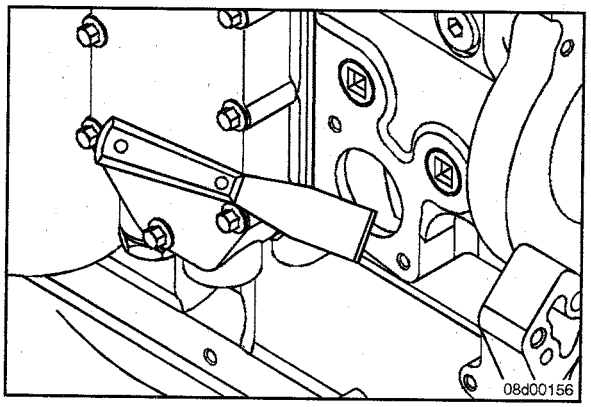
Drain the coolant. Refer to Procedure 008-018.

Remove the radiator hose.



Remove

Remove the water inlet connection capscrews.



Clean and Inspect for Reuse

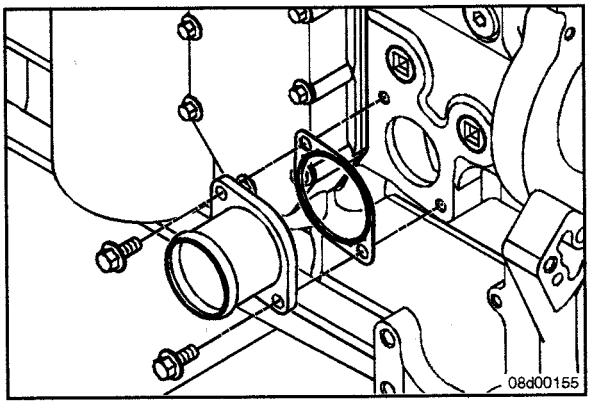
Clean all the mating surfaces.

Install

Install a new water inlet connection gasket.

Install the water inlet connection and mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]



Finishing Steps

Install the radiator hose.

Fill the engine with coolant. Refer to Procedure 008-018.

Operate the engine and check for leaks.

Notes

Section 9 - Drive Units - Group 09

Section Contents

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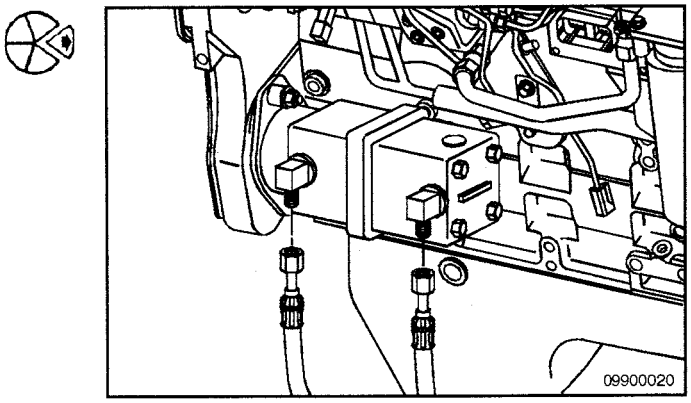
Hydraulic Pump Drive (009-016)

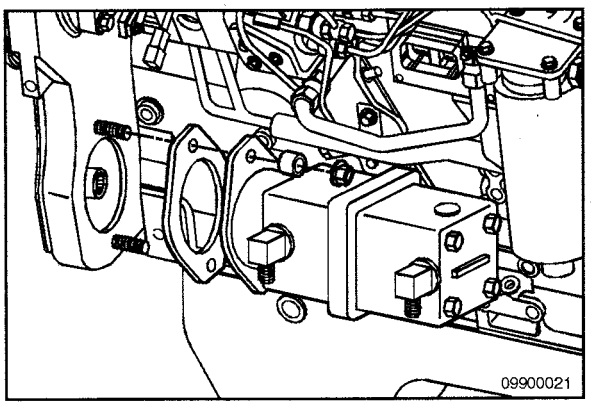
Remove

Disconnect all hydraulic lines from the pump.



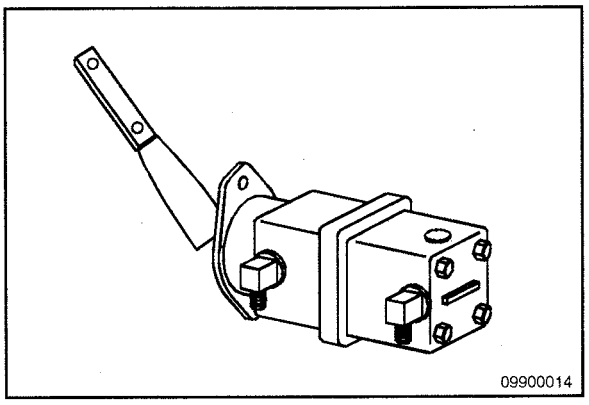
Remove the hydraulic pump and gear assembly.

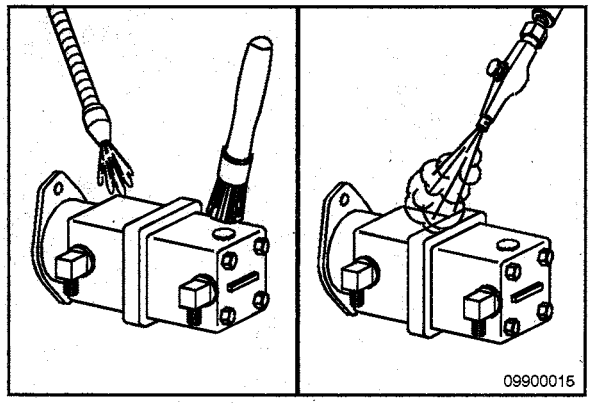
Refer to the equipment manufacturer's service manual for removal procedures.



Clean

Clean the gasket material from the hydraulic pump.





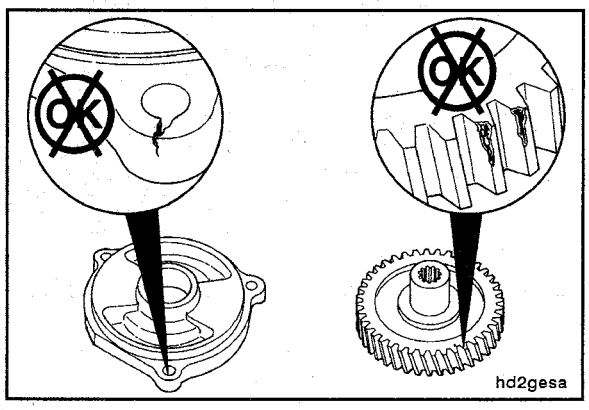
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

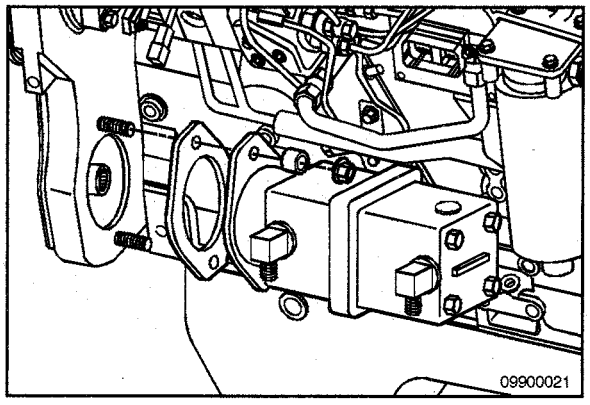
Clean the hydraulic pump gear with solvent.

Dry with compressed air.



Inspect for Reuse

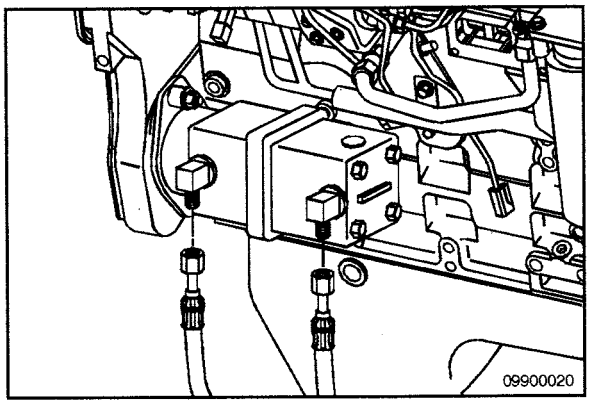
Inspect the hydraulic pump drive gear for damage.



Install

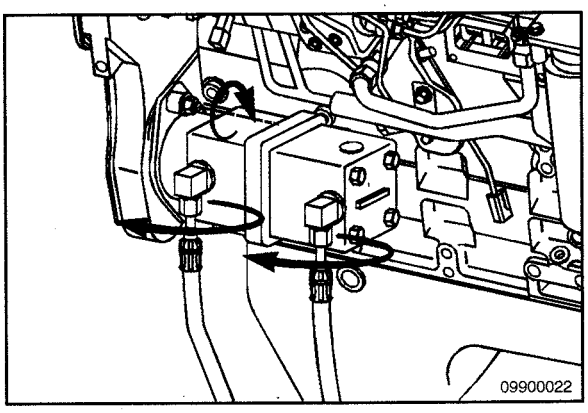
Use a new gasket and install the hydraulic pump.

Connect all hydraulic lines to the pump.



Tighten mounting bolts.

Torque Value: 43 N•m [32 ft-lb]



Notes

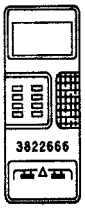
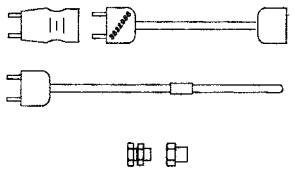
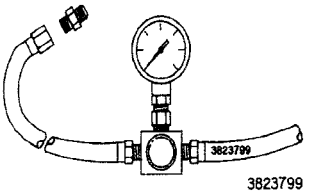
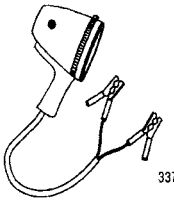
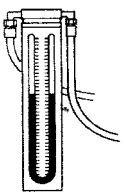
Section 10 - Air Intake System - Group 10

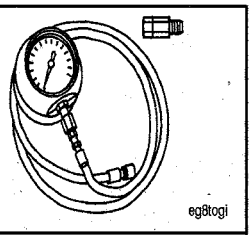
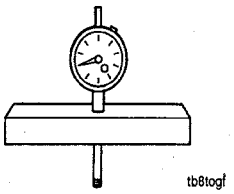
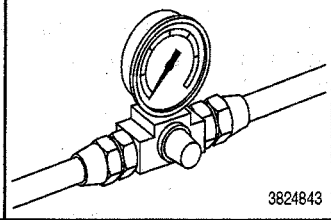
Section Contents

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
3376891	**Fluorescent Tracer** Add to oil. Used with black light to find oil leaks.	 3376891
3164489	**Fluke Digital Thermometer** Used to check voltage measurement.	 3822666
3822988	**Thermocouple Wire Kit** Used to check temperature.	 3822994
3823799	**Turbocharger Wastegate Pressure Setting Kit** Used to set wastegate pressure.	 3823799
3163338	**Black Light (DC)** Used to inspect for oil or fuel leak.	 3377394
ST-1111-3	**Manometer** Used to measure pressure, restriction (0 to 10 in H_2O) pressure differential with more accuracy.	 sg100ja

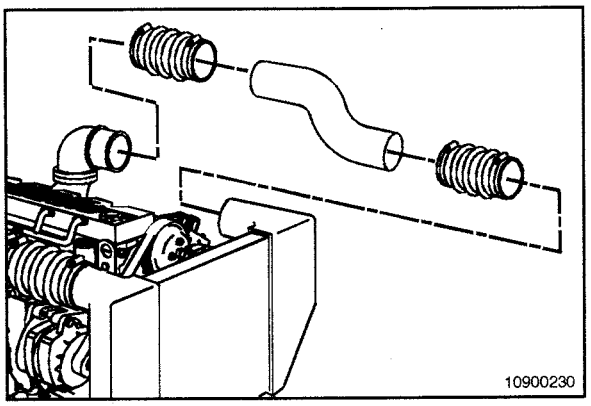
Tool No.	Tool Description	Tool Illustration
ST-1273	**Pressure Gauge (0 to 75 in Hg)** Used to measure the intake manifold pressure and exhaust back pressure.	
ST-537	**Dial Depth Gauge** Used to measure turbocharger axial motion.	
3824843	**Coupling** Used to apply regulated shop air pressure to variable geometry turbocharger actuator.	

Air Crossover (010-019)

Remove

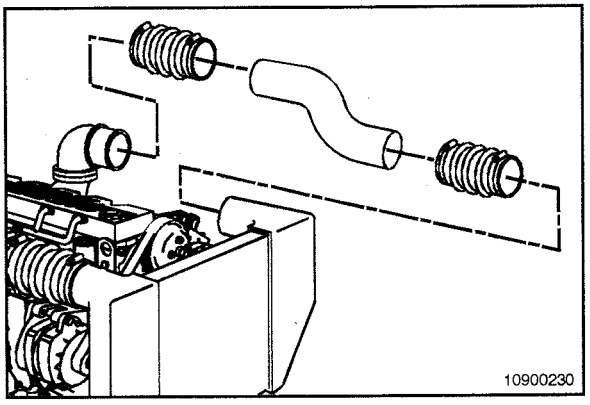
Loosen the hose clamps, and position the crossover tube so that it can be removed.

Remove the tube.



Inspect for Reuse

Check the crossover tube for cracks, holes, and worn sections. Replace with a new hose and clamps if necessary.

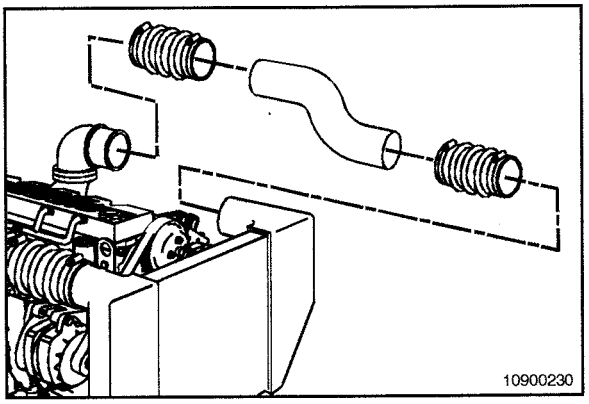


Install

Install the crossover tube and clamps in the reverse order of removal.

Tighten the clamps.

Torque Value: 5 N•m [44 in-lb]

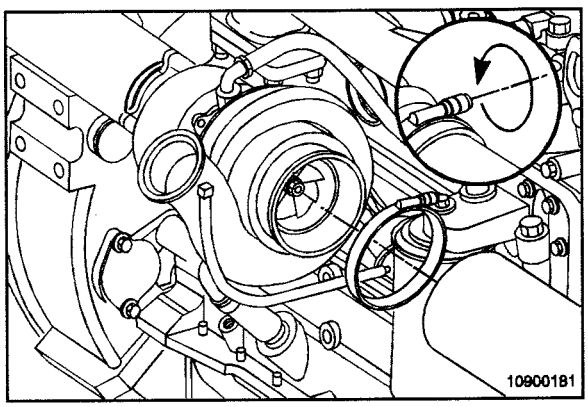


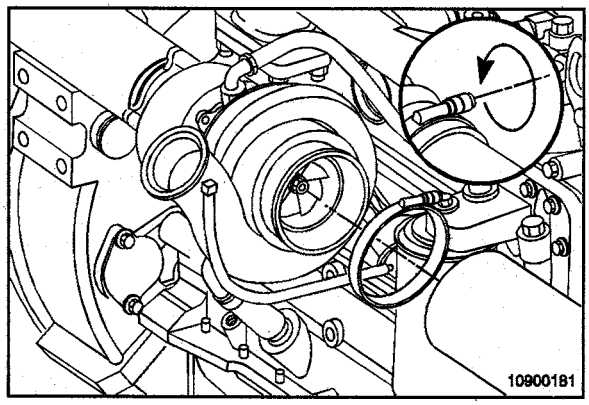
Air Inlet Connection (010-022)

Remove

Loosen air inlet clamps.

Remove the air inlet connection.



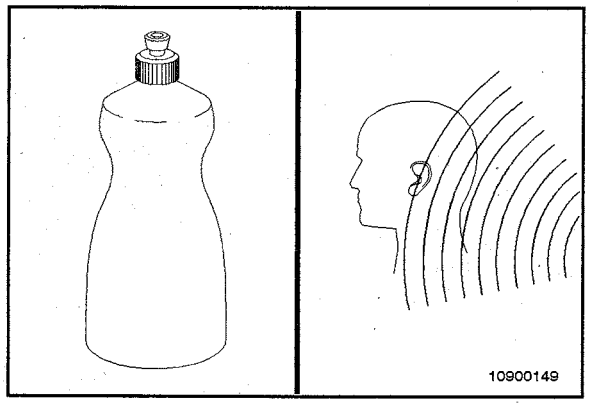


Install

Install the air inlet connection.

Tighten air inlet clamps.

Run engine and check for leaks.

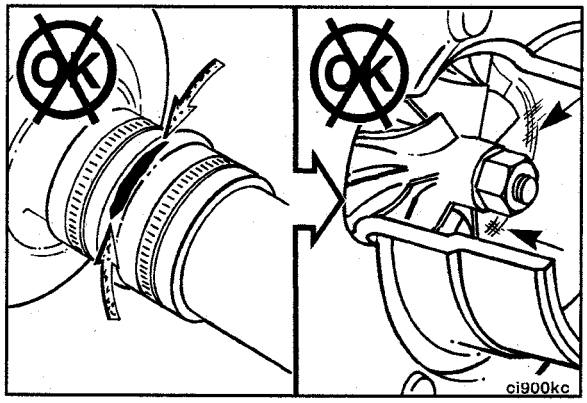


Air Leaks, Air Intake and Exhaust Systems (010-024)

Initial Check

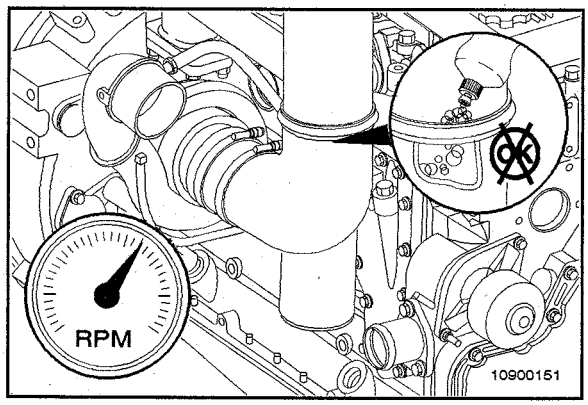
Leaks in the intake air system are most commonly identified by:

1. . Inspection of piping for cracked or loose clamps.
2. . Applying a solution of soapy water in the suspected area and inspecting for bubbles.
3. . Listening for a high-pitched whining or sucking sound in the suspected area.



⚠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 inlet air piping for cracked hoses and damaged or loose clamps.

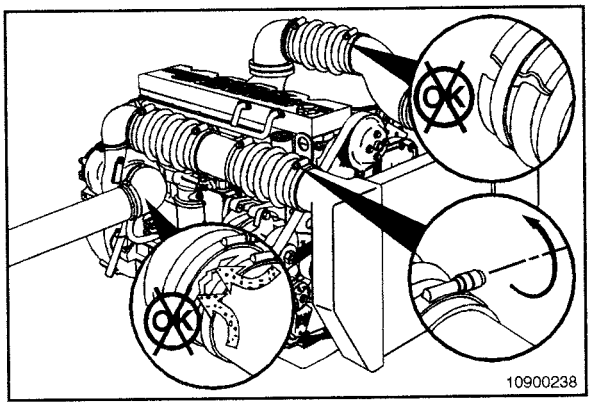
Operate the engine at high idle, and use a solution of soapy water to spot intake air leaks.

If an air leak exists, the soap bubbles will be drawn in with the air.

Replace damaged pipes and tighten loose clamps to make sure the air inlet system does **not** leak.

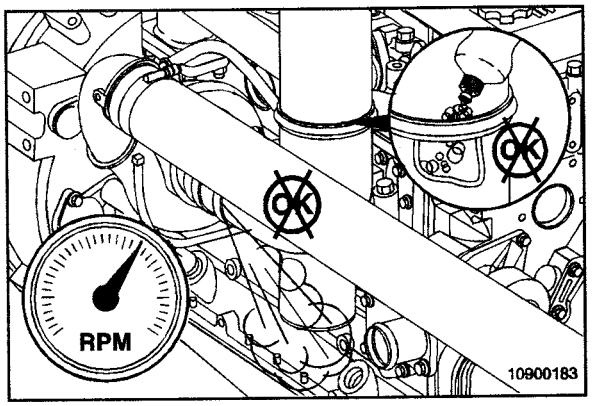
Check for corrosion of the inlet system piping under the clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system.

Disassemble and clean as required.



Pressure Side Intake System

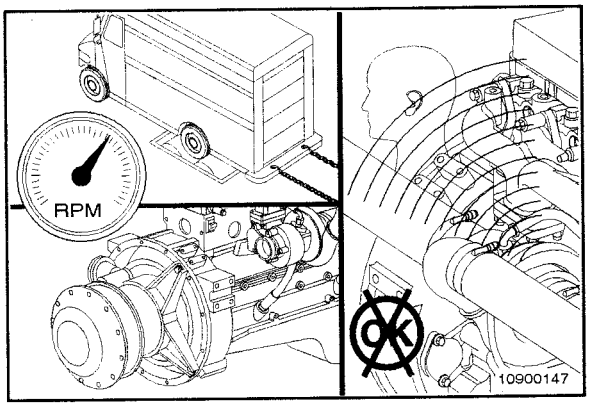
Leaks in the intake system will reduce the amount of air to the cylinders during engine operation and decrease engine performance.



Operate the engine at full throttle and rated rpm with maximum load.

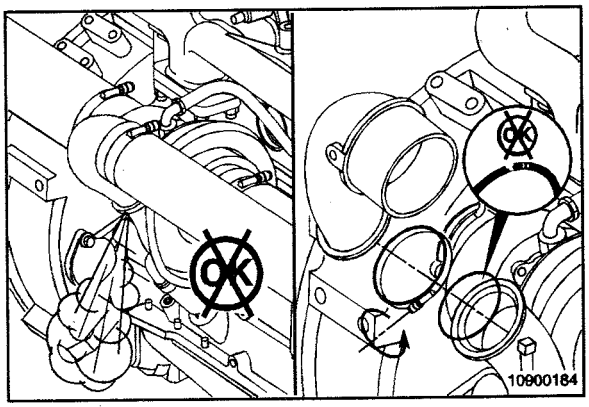
Listen for a high-pitched whistling sound from the turbocharger, nearby piping, and connections.

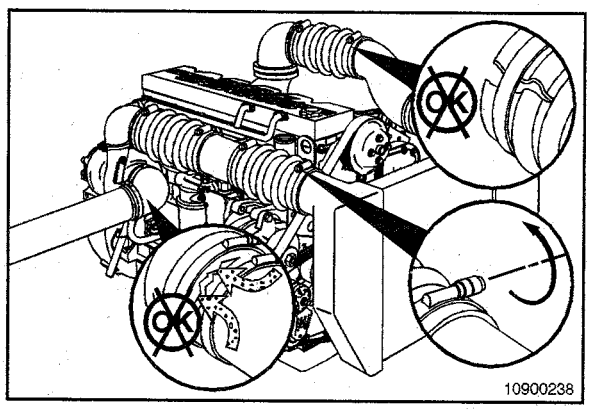
Apply a soapy water solution to sealing surfaces and inspect for bubbles. Bubbles can be easily detected.



Leaks can also be found at the turbocharger outlet connection.

Inspect for damage, replace sealing o-ring, and tighten loose clamps.



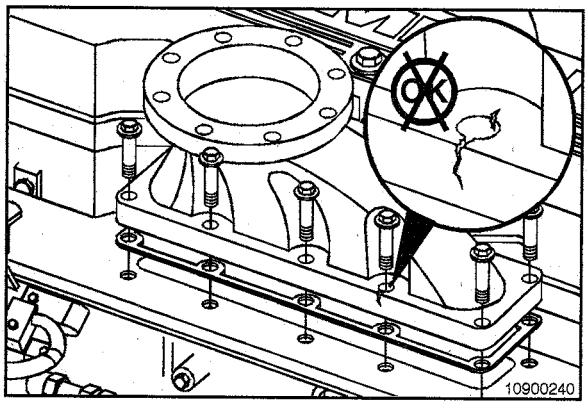


Any Charge Air Cooler Tubing or Connecting Hoses

Inspect the hose and tubing for damage.

Tighten loose clamps.

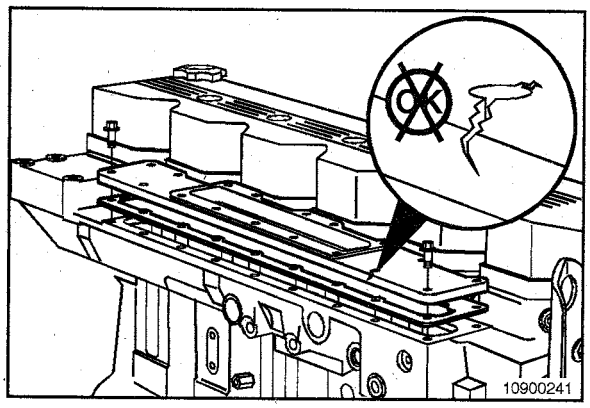
Refer to the equipment manufacturer's specifications for the correct torque value.



Air Intake Connection

Inspect for damage.

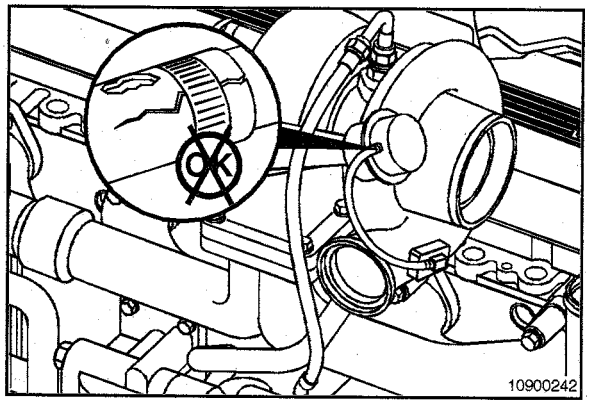
If necessary, replace the gasket or tighten loose clamps. Refer to Procedure 010-080.



Intake Manifold

Inspect for damage.

Replace the gasket, if necessary. Refer to Procedure 010-108.

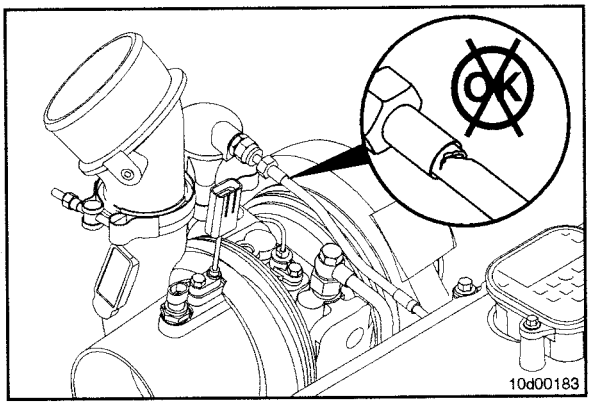


Wastegate Capsule/Plumbing

Inspect for damage.

Variable Geometry Turbocharger Actuator Plumbing

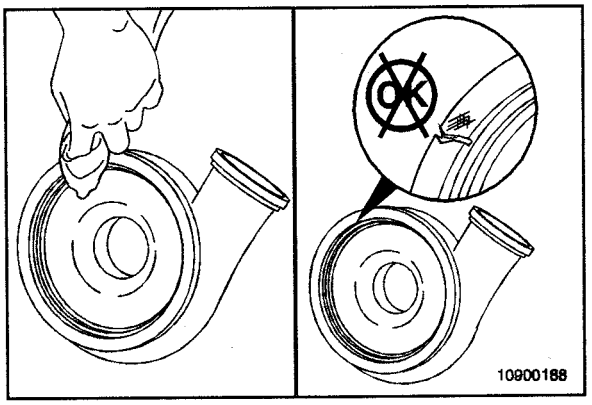
Inspect for cracks and/or air leaks.



Compressor Housing Sealing Surface

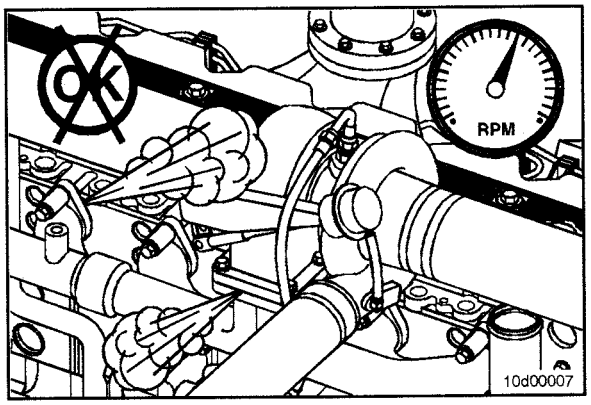
Inspect for damage.

Clean surface.



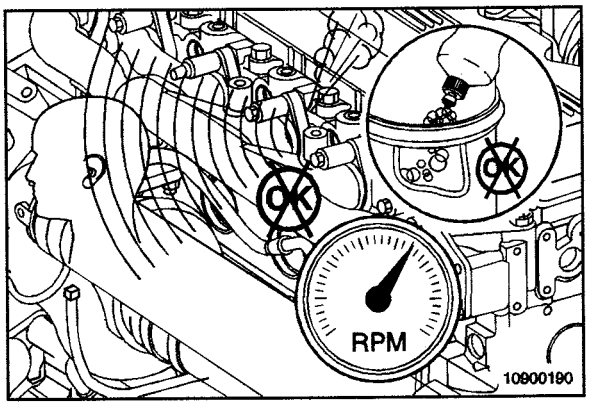
Exhaust System

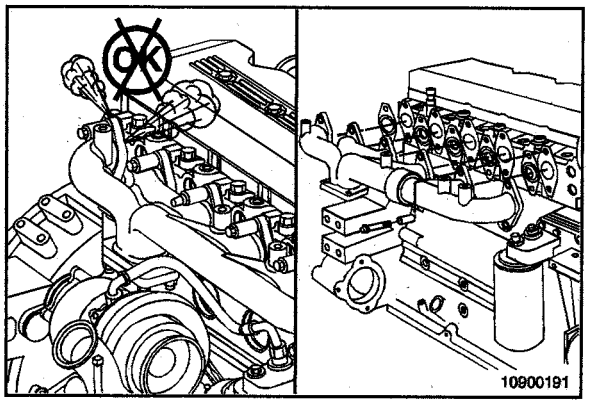
Leaks in the exhaust system will cause the turbocharger to operate at a lower speed, reducing the amount of air going to the cylinders during engine operation.



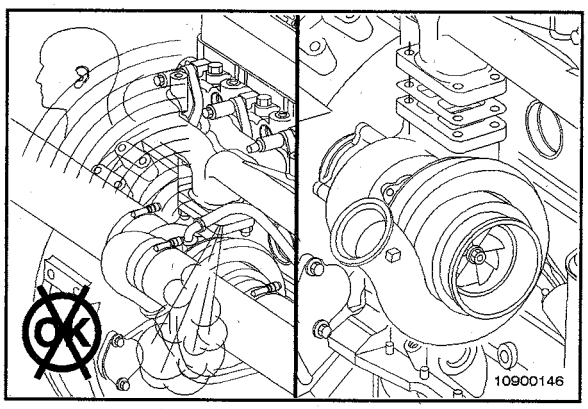
Operate the engine at full throttle and rated rpm with maximum load.

Leaks can be identified by noise, soapy water, or discoloration caused by the escaping hot gases.

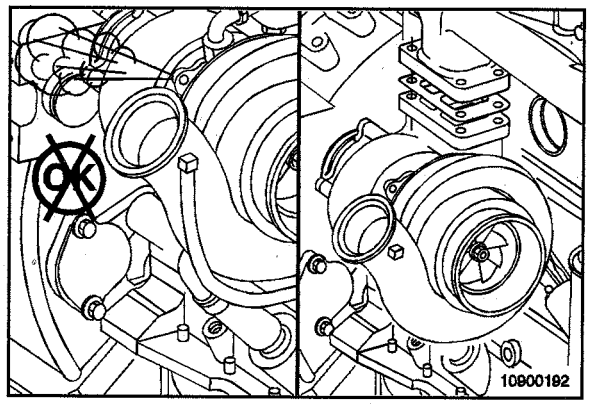




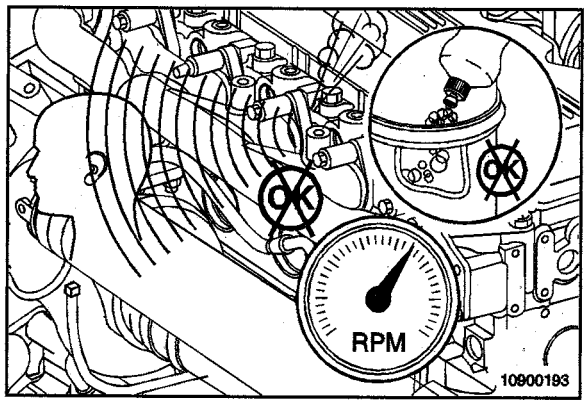
Inspect the exhaust manifold gaskets for leaks.



Inspect the turbocharger mounting gaskets for leaks.



Inspect the turbine housing sealing surface for leaks.



Operate the engine at full throttle and rated rpm with maximum load.

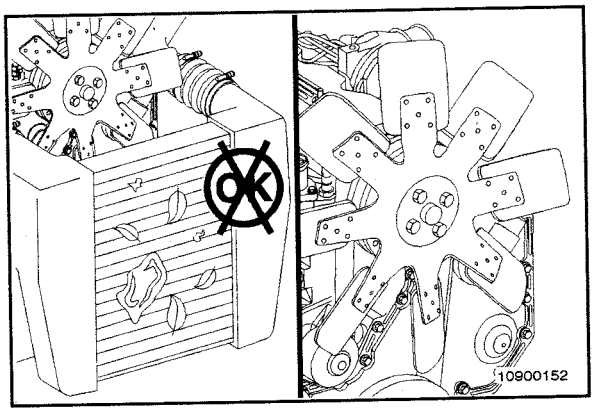
Listen and inspect again for leaks.

Charge-Air Cooler (010-027)

Clean

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 equipment manufacturer's instructions.



⚠WARNING⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

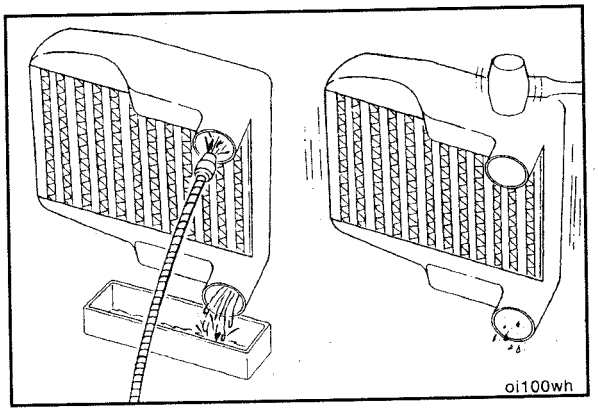
△CAUTION△

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 (i.e., the water runs clear).

NOTE: Make sure that the tubes are in the vertical direction when flushing.

If the debris can **not** be totally removed from the charge air cooler, the charge air cooler **must** be replaced.



⚠WARNING⚠

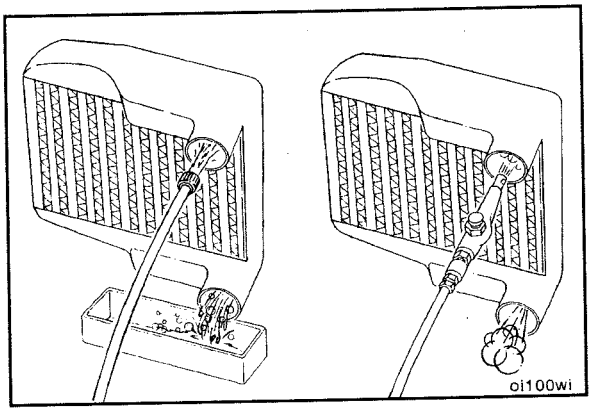
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

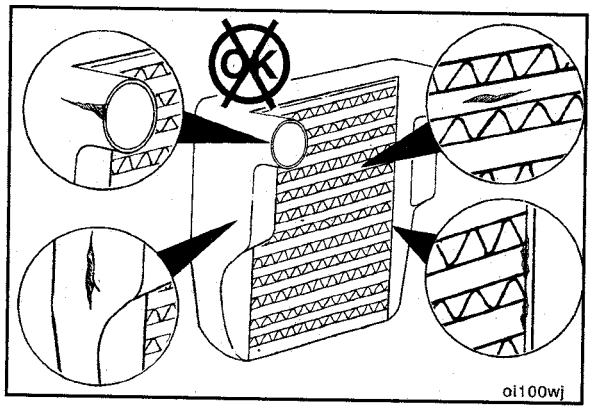
△CAUTION△

The charge air cooler must be rinsed, dried, and free of solvent, oil, and debris, or engine damage will result.

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.





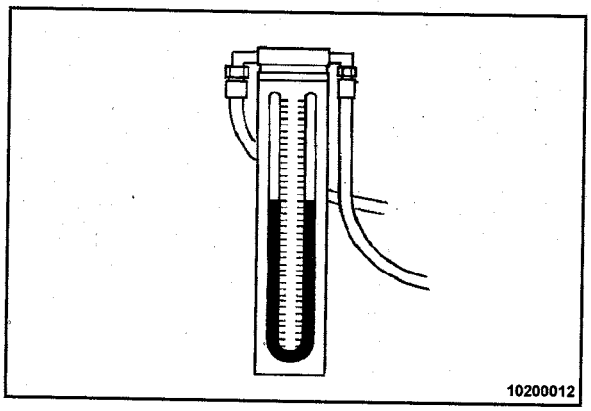
Inspect for Reuse

Inspect the charge air cooler for cracks, holes, or damage.

Inspect the tubes, fins, and welds for tears, breaks, or other damage. If any damage causes the charge air cooler to fail the air leak check, the charge air cooler **must** be replaced. Refer to Procedure 010-024.

Install the charge air cooler and charge air cooler piping on the vehicle. Refer to the vehicle manufacturer's instructions.

NOTE: Always clean and inspect the charge air cooler piping and hoses prior to installation.

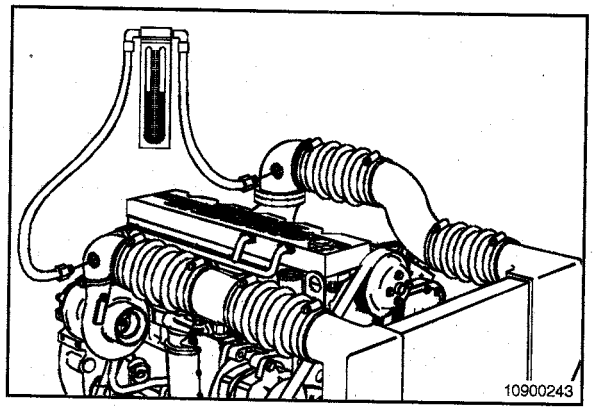


Pressure Test

Mercury Manometer, Part Number ST-1111-3

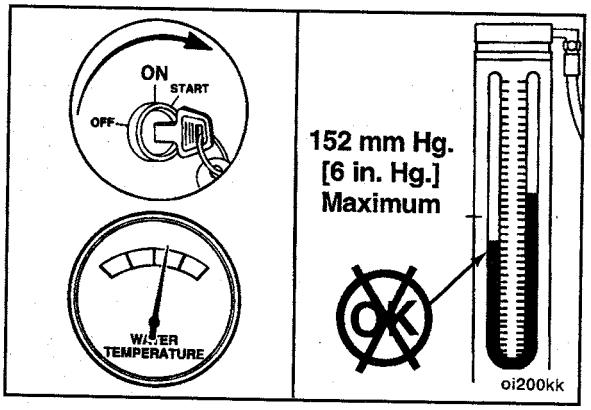
Preferred Method

Measure the charge air cooler system pressure drop with a mercury manometer.



Install one end of a mercury manometer, Part Number ST-1111-3, in the 1/8-inch fitting in the turbocharger compressor outlet elbow.

Install the other end of the mercury manometer in 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, restrictions, or damage.

Clean or replace, if necessary.

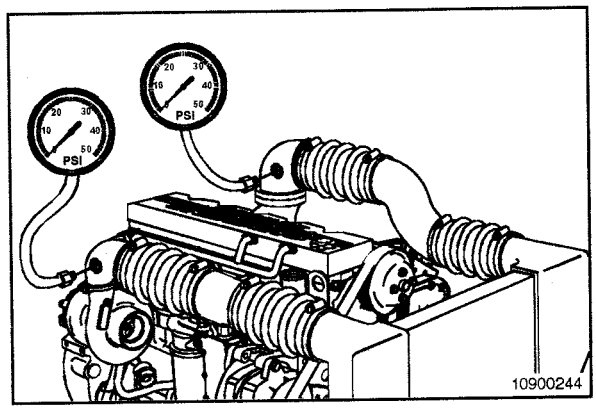
Pressure Gauge, Part Number ST-1273

Optional Method

Obtain two pressure gauges, Part Number ST-1273. Check both gauges on the same pressure source at 206 kPa [30 psi] to maintain consistency.

Install one pressure gauge in the 1/8-inch fitting in the turbocharger compressor outlet elbow.

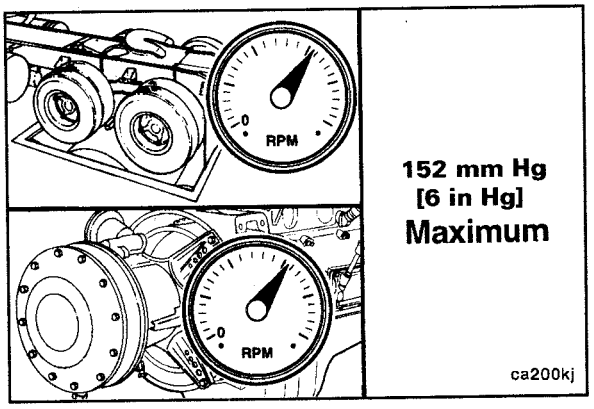
Install the other pressure gauge in the intake manifold.



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.



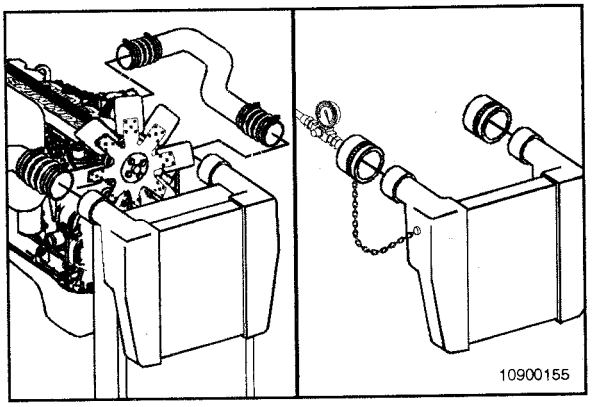
Leak Test

⚠ 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 be performed with securely fastened safety chains.

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.

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.

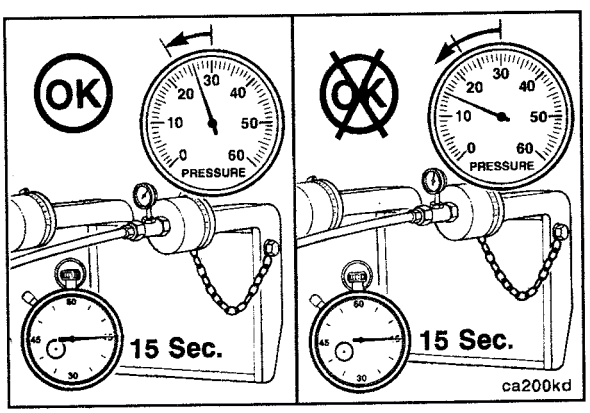


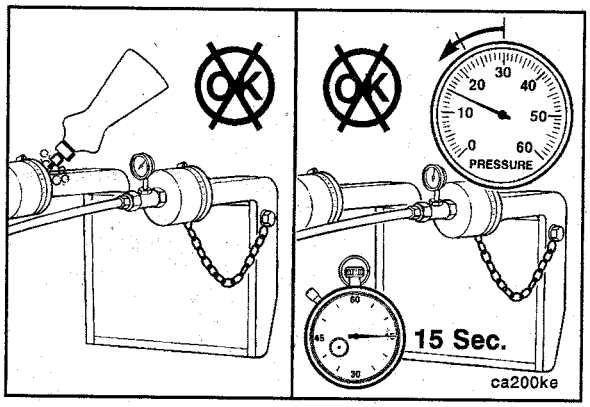
Apply air pressure to the cooler until the pressure gauge reads a steady 207 kPa [30 psi] of air pressure.

Shutoff the air flow to the cooler, and start a stopwatch at the same time. Record the leakage at 15 seconds.

If the pressure drop is 48 kPa [7 psi] or less in 15 seconds, the cooler is operational.

If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, check all connections again.

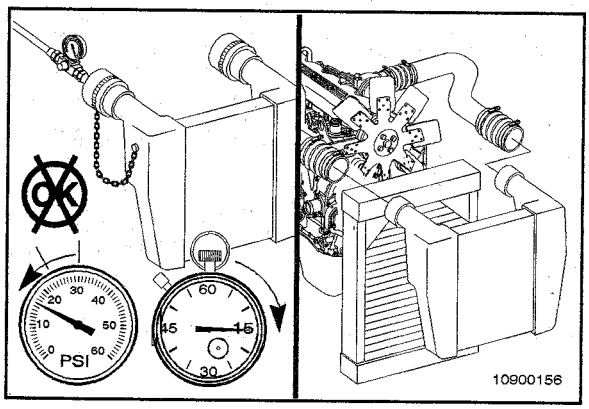




Determine if the pressure drop is caused by a leak in the charge air cooler or by a leaky connection. Use a spray bottle filled with soapy water applied to all hose connections, and watch for bubbles to appear at the location of the leak.

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.

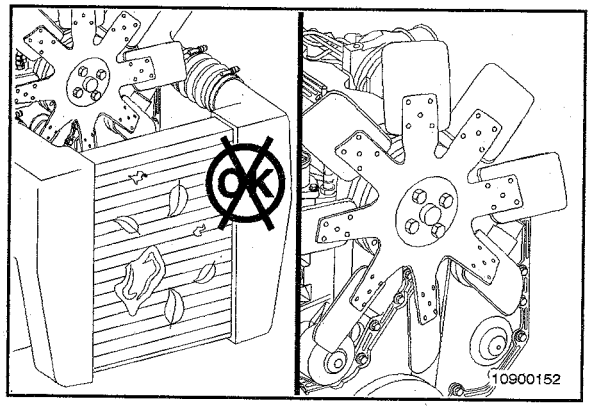
NOTE: If a charge air cooler leaks more than 48 kPa [7 psi] in 15 seconds, it will appear as a major leak in a leak tank.



If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, the charge air cooler **must** be replaced.

Refer to the equipment manufacturer's service manual for replacement instructions.

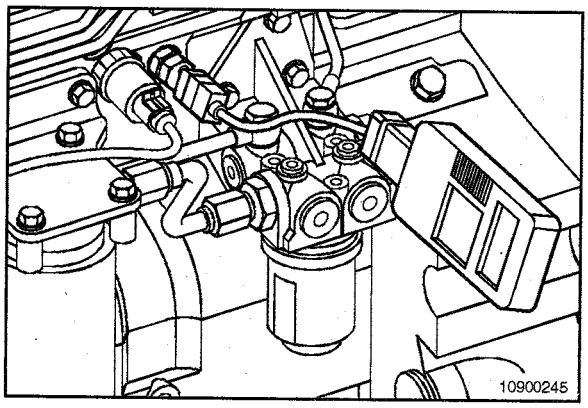
NOTE: Charge air coolers are **not** designed to be 100-percent leak-free. If the pressure drop is less than 48 kPa [7 psi] in 15 seconds, then the charge air cooler does **not** need to be replaced.



Temperature Differential Test

Inspect the charge air cooler fins for obstructions to air flow. 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 Number 3822666, into the intake manifold at the 1/8-inch NPT tap near the air horn connection with the intake manifold.

Another alternative is to use the monitor mode on the INSITE™ electronic service tool.

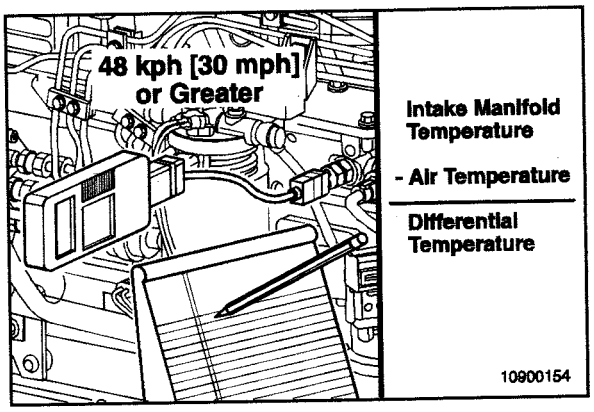
Install another thermocouple at the air cleaner inlet to measure ambient air temperature.

Perform a road test with the engine at peak power and a vehicle speed of 48 kph [30 mph] or greater.

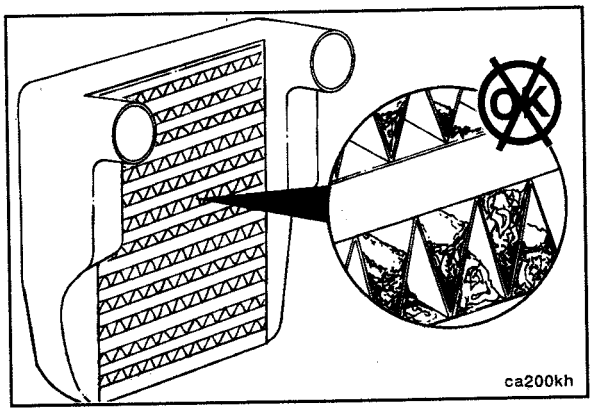
Record the intake manifold temperature and the ambient air temperature.

Calculate the differential temperature:

- Intake Manifold Temperature minus Ambient Air Temperature equals Differential Temperature
- Maximum Differential Temperature equals 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.



Cold Starting Aid (010-029)

Preparatory Steps

Disconnect the grid heater wiring.

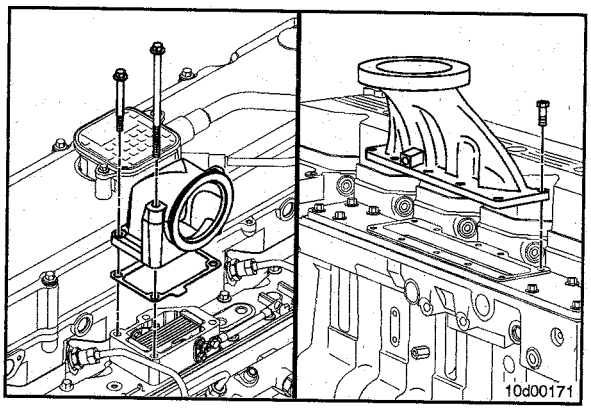
Remove the charge air cooler plumbing. Refer to Procedure 010-019.

Remove the air inlet connection, if equipped. Refer to Procedure 010-022.

Remove the air intake connection. Refer to Procedure 010-080.

Remove the turbocharger control valve, if equipped. Refer to Procedure 019-388.

Remove the high-pressure fuel lines, if required. Refer to Procedure 006-051.

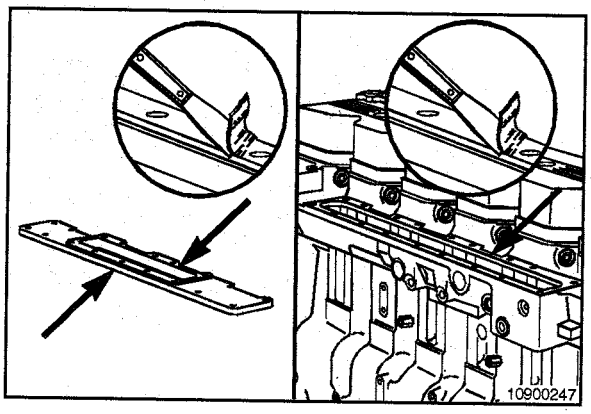


Remove

Remove the intake air heater.

NOTE: The intake heater is installed under the intake manifold cover on some engines. Refer to Procedure 010-108 if removing the intake manifold cover is required.

NOTE: If the grid heater is to be removed for any length of time, apply tape over the hole to keep debris out of the air intake.



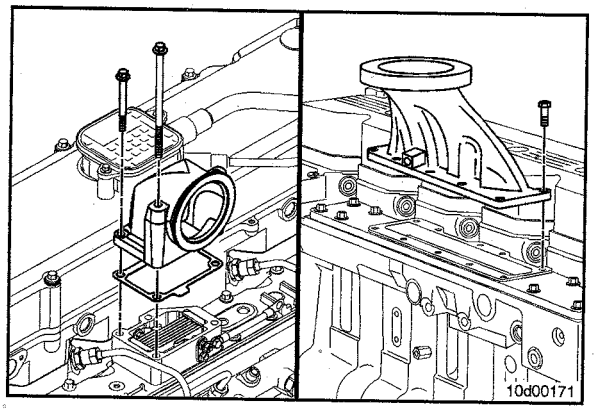
Clean and Inspect for Reuse

Clean the grid heater sealing surfaces.

Clean the intake cover sealing surface.

Clean the air intake connection sealing surface.

NOTE: Keep the gasket material and any other material out of the cylinder head intake manifold.



Install

Install the grid heater.

NOTE: For engines with the grid heater mounted under the intake manifold cover, refer to Procedure 010-108.

Finishing Steps

Install the high-pressure fuel lines, if removed. Refer to Procedure 006-051.

Install the air intake connection. Refer to Procedure 010-080.

Install the air inlet connection, if equipped. Refer to Procedure 010-022.

Install the charge air cooler plumbing. Refer to Procedure 010-019.

Install the turbocharger control valve, if equipped. Refer to Procedure 019-388.

Connect the grid heater wiring.

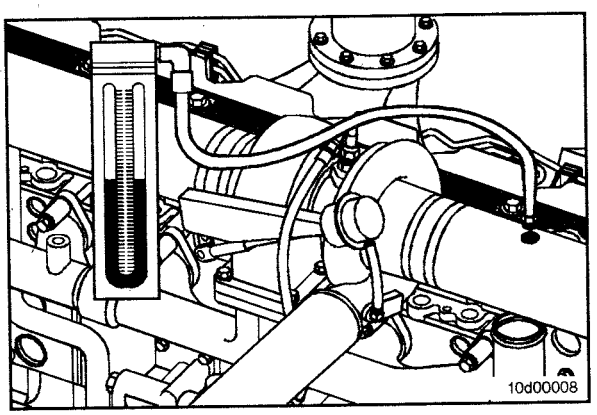
Operate the engine and check for leaks.

Air Intake Restriction (010-031)

Measure

Install a vacuum gauge or water manometer in the intake air piping.

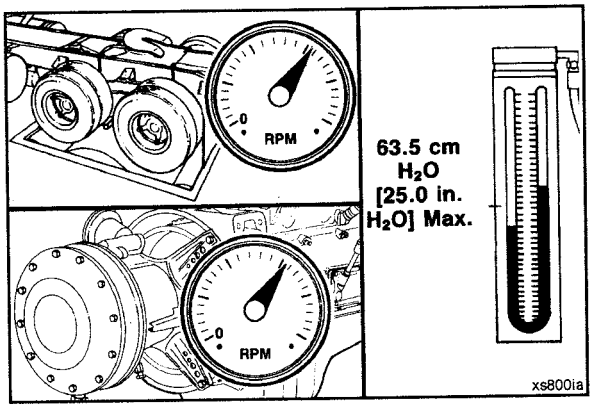
The gauge adapter **must** be installed at a 90-degree angle to the airflow in a straight section of pipe, one pipe diameter before the turbocharger.



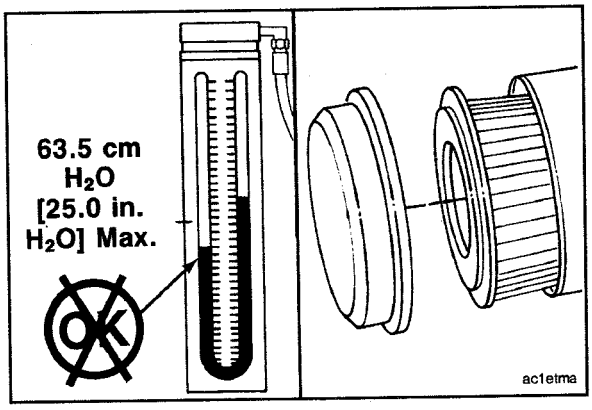
Operate the engine at full throttle and rated rpm with maximum load.

Record the data on the gauge or manometer.

Inlet Air Restriction		
cm H_2O		in H_2O
63.5	MAX	25.0

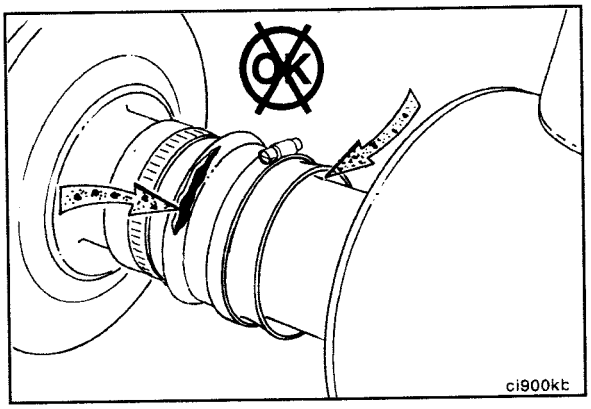


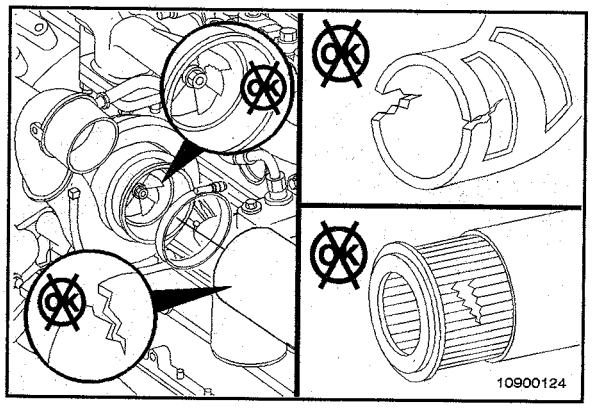
If restriction exceeds specifications, replace or clean the air filter element. Refer to the equipment manufacturer's instructions.



Inspect the intake piping for damage. Refer to the equipment manufacturer's repair instructions.

Remove the test equipment.





Turbocharger (010-033)

Initial Check

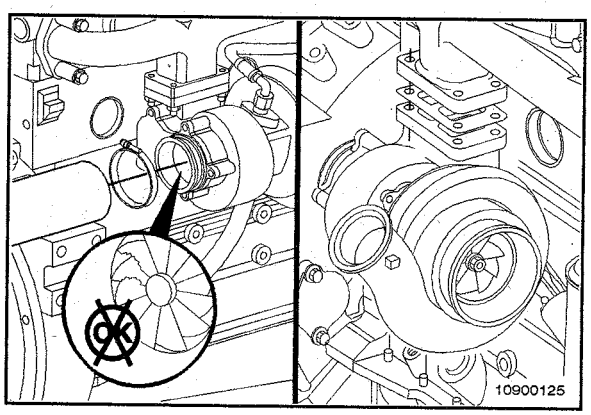
Remove the intake pipe from the turbocharger. See the Remove step in this procedure.

Inspect the turbocharger compressor impeller blades for damage.

Replace the turbocharger if damage is found. See the Remove and Install steps in this procedure.

If the compressor impeller is damaged, inspect the intake piping and filter element for damage.

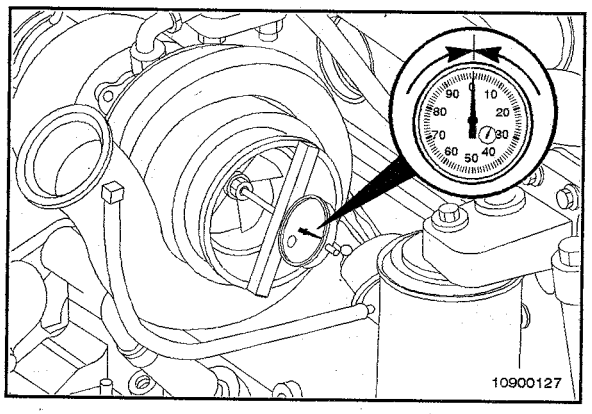
Repair any damage before operating the engine.



Remove the exhaust pipe from the turbocharger. See the Remove step in this procedure.

Inspect the turbine wheel for damage.

Replace the turbocharger if damage is found. See the Remove and Install steps in this procedure.



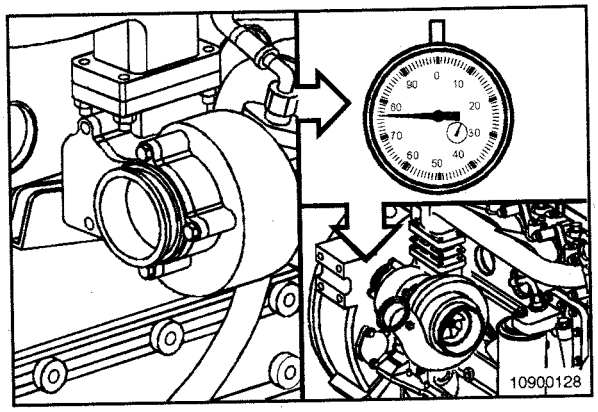
Axial Clearance Check

Use dial depth gauge, Part Number ST-537.

Push the rotor assembly away from the gauge.

Set the gauge on zero.

Push the rotor assembly toward the gauge and record the reading.



Axial Clearance (HX40WG - Wastegate)		
mm		in
0.025	MIN	0.001
0.127	MAX	0.005

Axial Clearance (HY40V Variable Geometry)		
mm		in
0.025	MIN	0.001
0.127	MAX	0.005

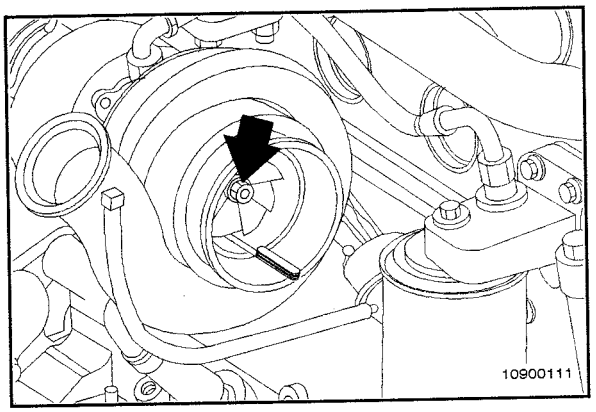
Replace the turbocharger if the clearance does **not** meet the specifications. See the Remove and Install steps in this procedure.

Radial Clearance Check

Use a wire-type feeler gauge to measure the clearance between the turbocharger compressor wheel and turbocharger compressor housing.

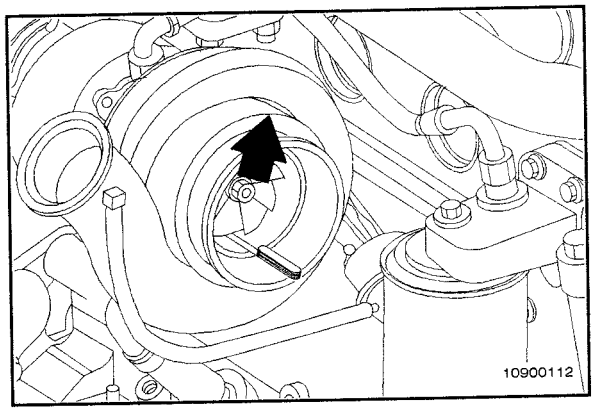
Gently push the compressor wheel toward the compressor housing and gauge.

Record the clearance.



With the feeler gauge in the same location, gently push the turbocharger compressor wheel away from the turbocharger compressor housing and measure the clearance between the compressor wheel and housing.

Subtract the smaller clearance from the larger clearance. This is the radial bearing clearance.

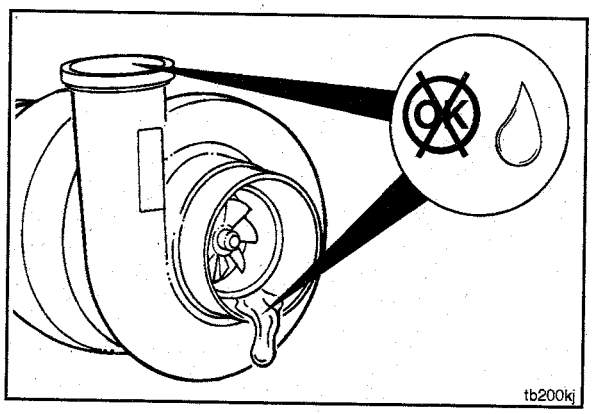


Wastegate Radial Bearing Clearance		
mm		in
0.330	MIN	0.013
0.508	MAX	0.020

For variable geometry turbocharger check the radial movement of the rotor system by pushing the turbocharger compressor wheel toward the wall of the compressor cover with light finger pressure. The turbocharger passes inspection if the wheel does **not** contact the compressor cover wall.

Repeat the procedure on the turbocharger turbine wheel.

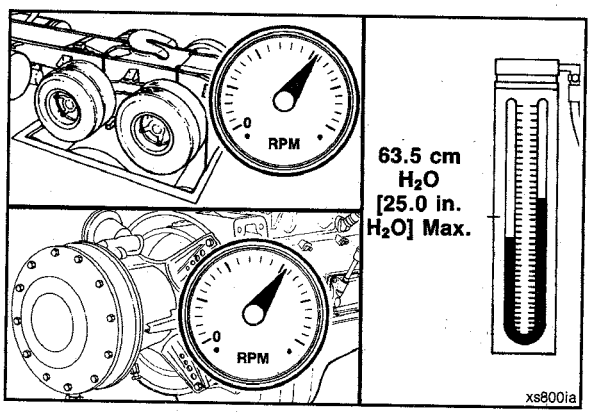
Replace the turbocharger if the radial bearing clearance does **not** meet specifications. See the Remove and Install steps in this procedure.



Leak Check

Inspect the turbocharger compressor intake and discharge for oil.

If oil is present in the compressor intake as well as in the discharge, check upstream in the turbocharger for the source of the oil.

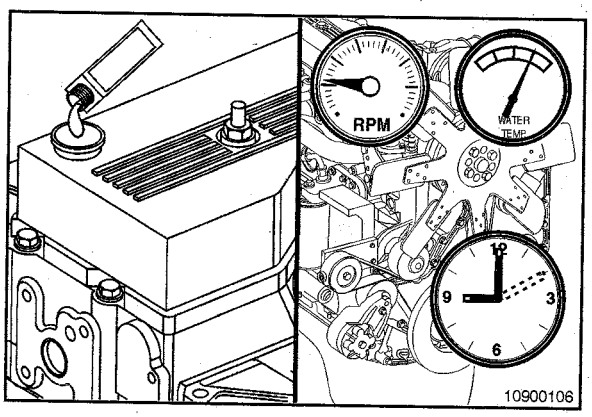


If oil is present **only** in the discharge side, install the air intake and charge air cooler piping. Refer to the OEM service manual.

Check for intake restriction. Refer to Procedure 010-031.

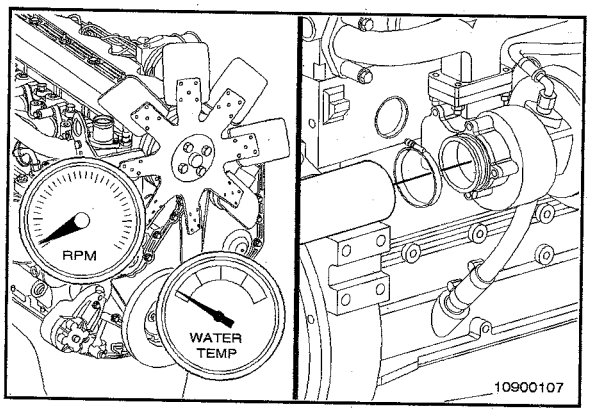
If no intake restriction is found, replace the turbocharger. See the Remove and Install steps in this procedure.

NOTE: If the engine experiences a turbocharger failure or any other occasion where oil is put into the charge air system, the charge air system **must** be inspected and cleaned. Refer to Procedure 010-027.



Add 1 unit of fluorescent tracer, Part Number 3376891, to each 38 liters [10.0 gal] of engine lubricating oil.

Operate the engine at low idle for 10 minutes.



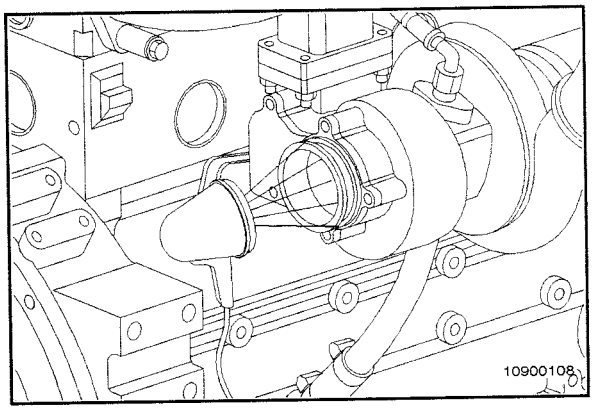
Shut off the engine.

Allow the turbocharger to cool.

Remove the exhaust pipe from the turbine housing. See the Remove step in this procedure.

Use a high-intensity black light, Part Number 3163339, to inspect the turbine outlet for leaks.

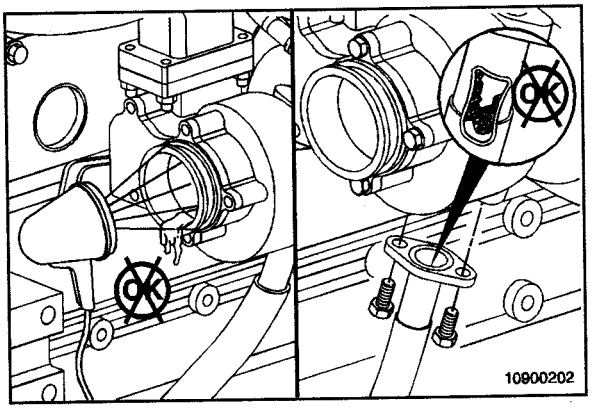
A yellow glow indicates an oil leak. A dark blue glow indicates fuel in the oil.



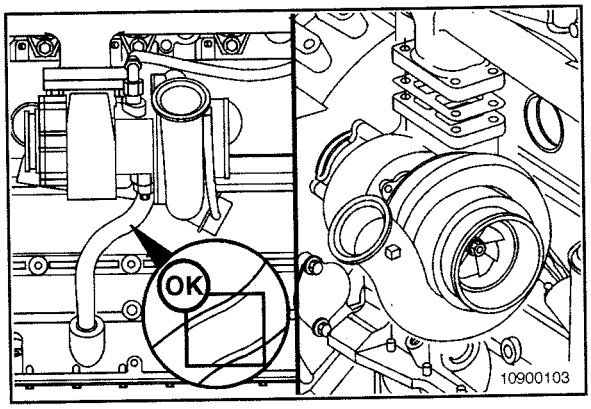
If oil is found on the turbine housing, remove the oil drain line and check for restrictions. Refer to Procedure 010-045.

Clear any restrictions found.

Install the turbocharger drain line. Refer to Procedure 010-045.



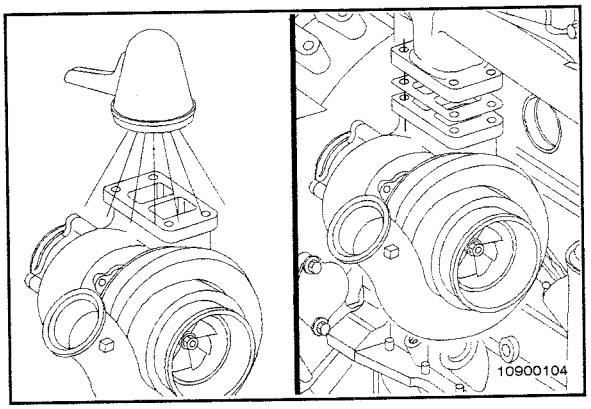
If the oil drain line was **not** restricted, remove the turbocharger. See the Remove and Install steps in this procedure.

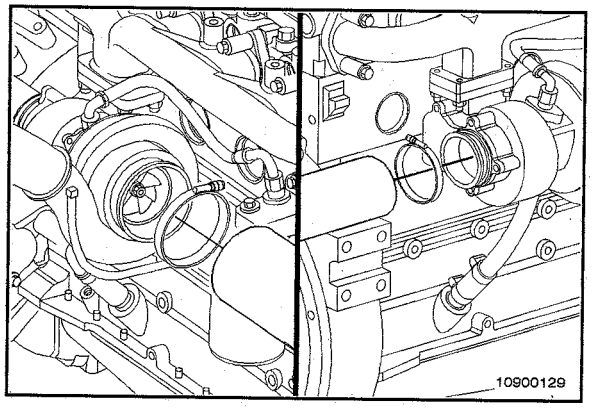


Use a high-intensity black light, Part Number 3163339, to inspect the turbine inlet for leaks.

A yellow glow indicates an oil leak from the engine.

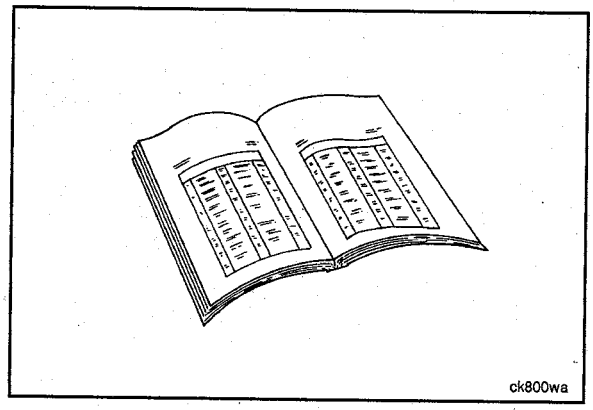
If a yellow glow is **not** seen in the turbine inlet, replace the turbocharger. See the Remove and Install steps in this procedure.





Install the exhaust pipe to the turbocharger turbine outlet and tighten the clamp. See the Install step in this procedure.

Install the intake pipe to the turbocharger compressor inlet and tighten the clamp. See the Install step in this procedure.



Preparatory Steps

⚠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.

⚠WARNING⚠

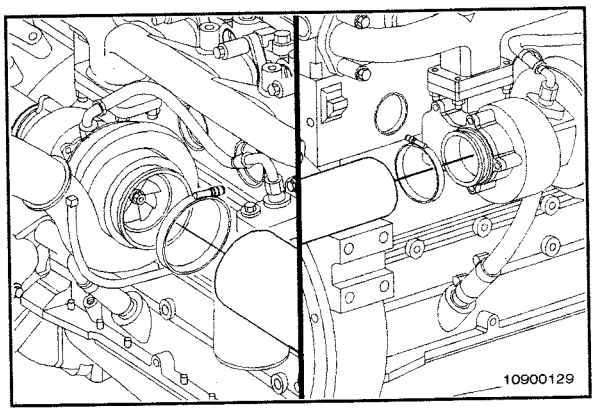
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Drain the coolant, variable geometry turbocharger **only**. Refer to Procedure 008-018.
- Remove the oil supply line from the turbocharger. Refer to Procedure 010-046.
- Remove the oil drain line from the turbocharger. Refer to Procedure 010-045.
- Remove the turbocharger coolant lines, variable geometry turbocharger **only**. Refer to Procedure 010-041.
- Disconnect the turbocharger actuator air supply line, variable geometry turbocharger **only**. Refer to Procedure 010-118.
- Disconnect the turbocharger speed sensor, variable geometry turbocharger **only**. Refer to Procedure 019-390 in the CM850 Electronic Control System ISC and ISL Engines Troubleshooting and Repair Manual, Bulletin 4021416.
- Disconnect the turbocharger compressor air inlet temperature sensor, if equipped. Refer to Procedure 019-035 in the CM850 Electronic Control System ISC and ISL Engines Troubleshooting and Repair Manual, Bulletin 4021416.

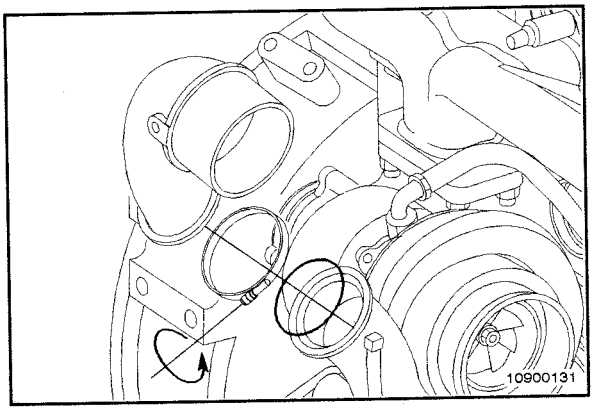
Remove

Remove the exhaust piping.

Remove the turbocharger compressor air inlet pipe.

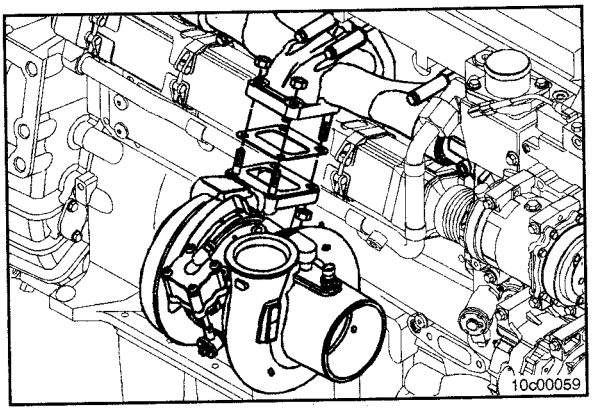


Remove the turbocharger compressor outlet elbow, v-band clamp, and o-ring from the turbocharger compressor outlet.



Remove the four turbocharger mounting nuts.

Remove the turbocharger and gasket.



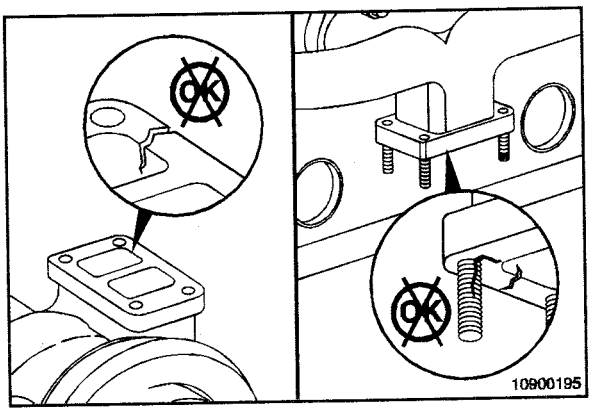
Clean and Inspect for Reuse

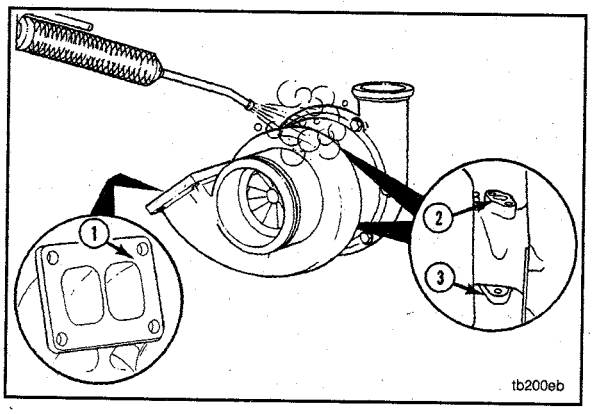
Clean the turbocharger and exhaust manifold gasket surfaces.

Inspect the turbocharger and exhaust manifold gasket surfaces, and mounting studs for cracks and damage.

Replace the turbocharger if any cracks are found in the mounting flange surfaces. See the Remove and Install steps in this procedure.

Replace the exhaust manifold if any cracks are found in the mounting flange surfaces. Refer to Procedure 011-007.





⚠WARNING⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠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.

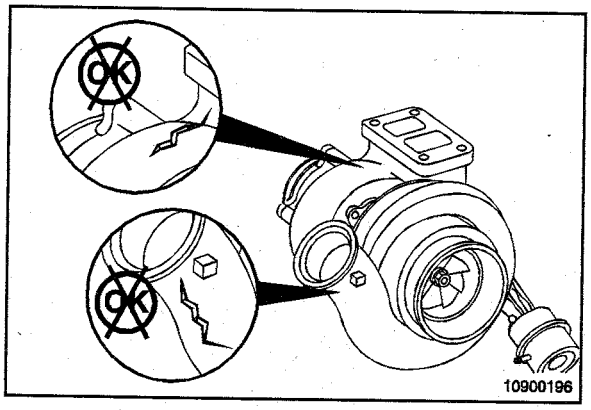
⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Remove all carbon deposits and gasket material from surfaces (1, 2, and 3).

Use solvent or steam to clean the exterior of the turbocharger.

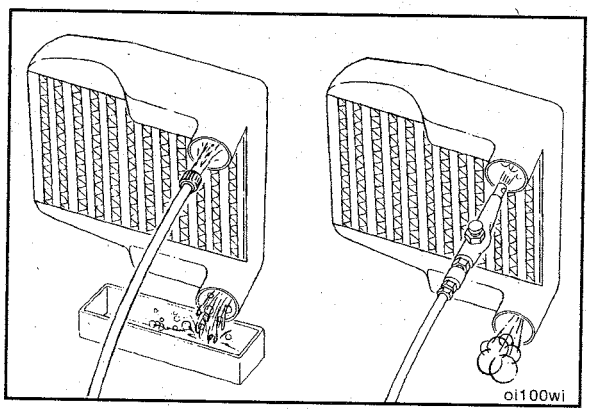
Dry with compressed air.



Inspect the turbine and compressor housings.

If cracks that go all the way through the outer walls are found, the turbocharger **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.



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 Procedure 010-027.

Install

Apply a film of high-temperature anti-seize compound to the turbocharger mounting studs.

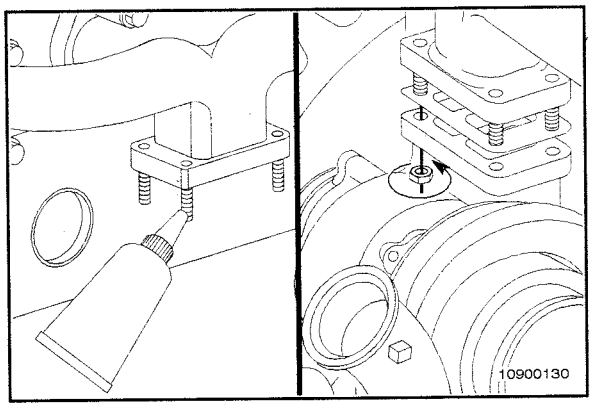
Use a new gasket and install the turbocharger.

Install and tighten the four mounting nuts.

NOTE: The torque values given have been established using anti-seize compound as a lubricant.

Torque Value:

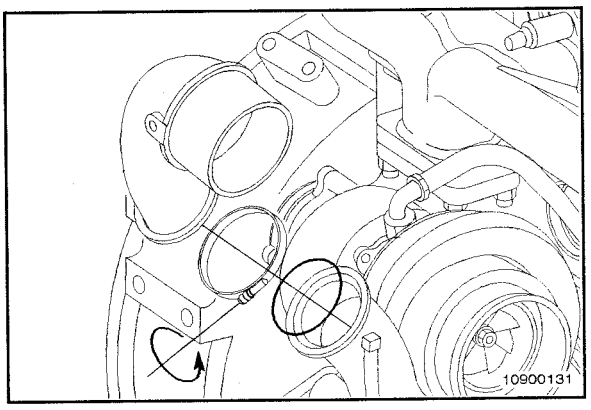
Variable Geometry Turbocharger	60 N•m	[44 ft-lb]
Wastegate Turbocharger	45 N•m	[33 ft-lb]



Install the turbocharger compressor outlet elbow, v-band clamp, and new o-ring seal on the turbocharger compressor discharge outlet.

Tighten the clamp.

Torque Value: 8 N•m [71 in-lb]

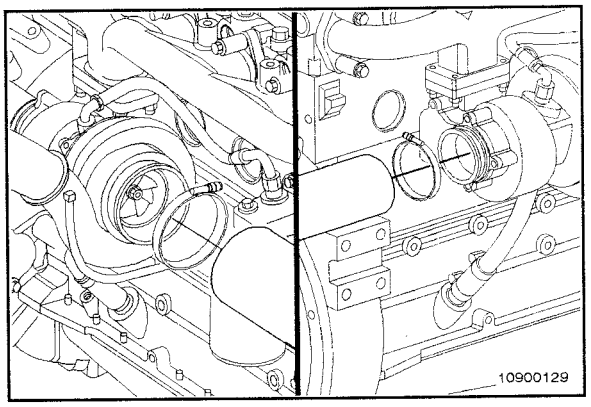


Install the intake pipe to the turbocharger compressor inlet and tighten the clamp.

Torque Value: 8 N•m [71 in-lb]

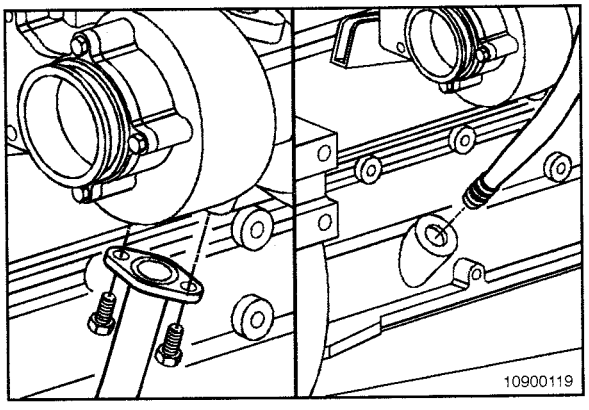
Install the exhaust pipe to the turbocharger turbine outlet and tighten the clamp.

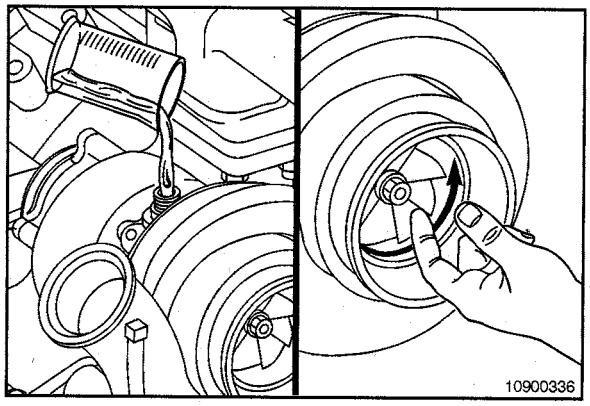
Torque Value: 8 N•m [71 in-lb]



Prime

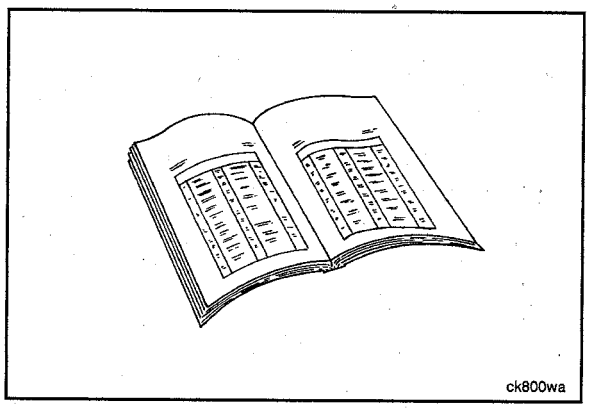
Install the turbocharger oil drain line. Refer to Procedure 010-045.





Lubricate the bearings by pouring 59 to 89 ml [2 to 3 oz] of clean 15W40 engine oil into the turbocharger oil supply line fitting. Rotate the turbine wheel to allow oil to enter the bearing. housing.

Install the turbocharger oil supply line. Refer to Procedure 010-046.



Finishing Steps

- Install the turbocharger coolant lines, variable geometry turbocharger **only**. Refer to Procedure 010-041.
- Connect the turbocharger actuator air supply line, variable geometry turbocharger **only**. Refer to Procedure 010-118.
- Connect the turbocharger speed sensor, variable geometry turbocharger **only**. Refer to Procedure 019-390 in the CM850 Electronic Control System ISC and ISL Engines Troubleshooting and Repair Manual, Bulletin 4021416.
- Connect the turbocharger compressor air inlet temperature sensor, if equipped. Refer to Procedure 019-035 in the CM850 Electronic Control System ISC and ISL Engines Troubleshooting and Repair Manual, Bulletin 4021416.
- Fill the cooling system, variable geometry turbocharger **only**. Refer to Procedure 008-018.
- Operate the engine and check for leaks.

Turbocharger Coolant Hoses (010-041)

Preparatory Steps

Variable Geometry

⚠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.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

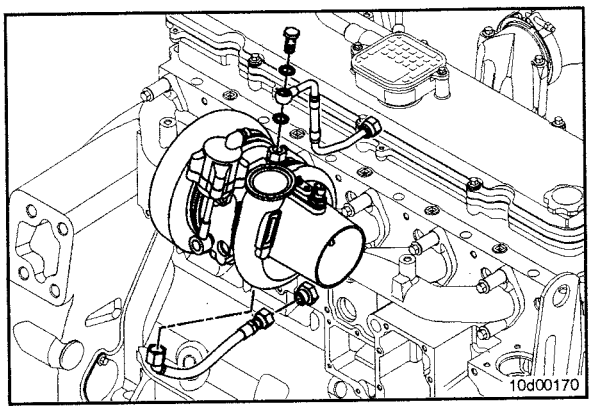
Drain the coolant. Refer to Procedure 008-018.

Remove

NOTE: Use a second wrench to hold the coolant line coupling while loosening the line.

Remove the turbocharger coolant supply line from the turbocharger and cylinder block.

Remove the turbocharger coolant return line from the turbocharger and the cylinder block.



Clean and Inspect for Reuse

⚠WARNING⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠

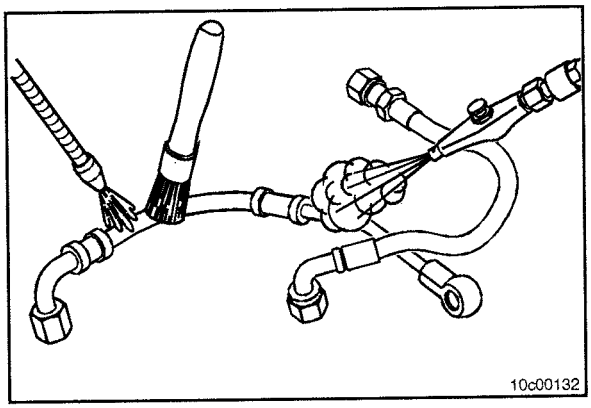
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

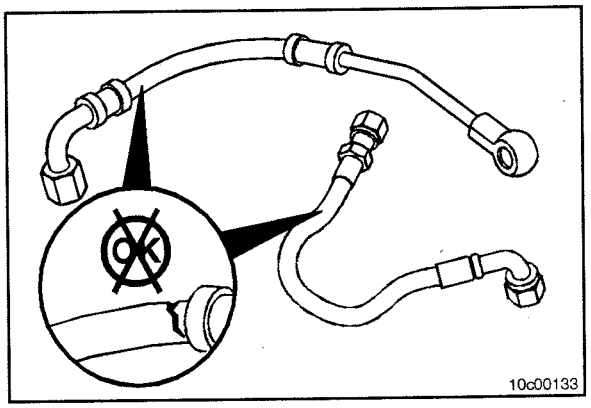
Clean the turbocharger coolant lines with solvent.

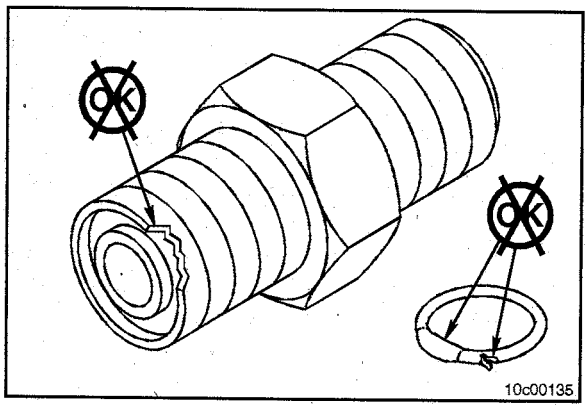
Dry with compressed air.



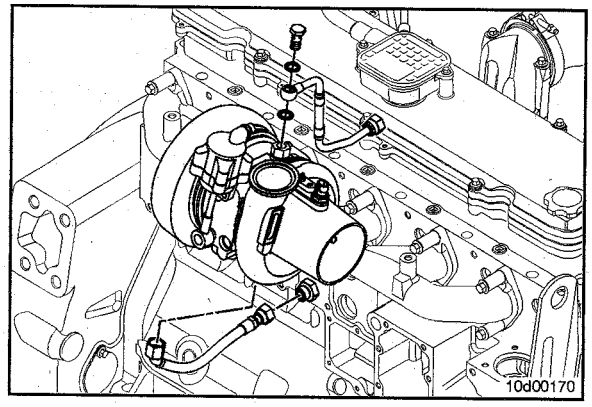
Check the o-rings for cuts or deformation. Replace as necessary.

Check the turbocharger coolant lines for cracks or other damage. Replace if damage if found.





Check the face of the coolant fittings on the engine and on the turbocharger to make sure the o-ring is in place and is **not** damaged. A damaged or missing o-ring will result in a coolant leak.



Install

Install the turbocharger coolant return line to the top of the turbocharger and the block.

Install the turbocharger coolant supply line to the bottom of the turbocharger and the block.

Check the face of the coolant fittings on the engine and on the turbocharger to make sure the o-ring is in place and is **not** damaged. A damaged or missing o-ring will result in a coolant leak.

NOTE: Use a second wrench to hold the coolant line coupling while tightening the line.

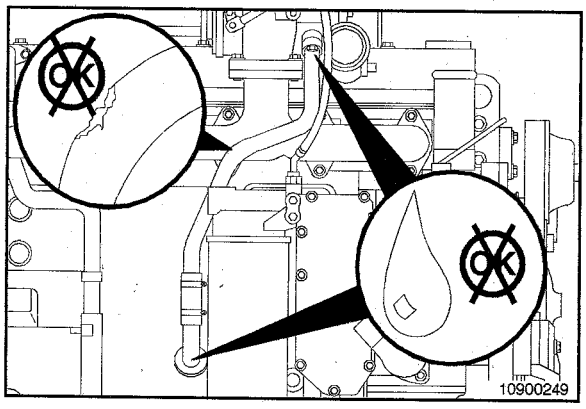
Tighten the fittings.

Torque Value: 46 N•m [34 ft-lb]

Finishing Steps

Fill the engine with coolant. Refer to Procedure 008-018.

Operate the engine and check for leaks.



Turbocharger Oil Drain Line (010-045)

Initial Check

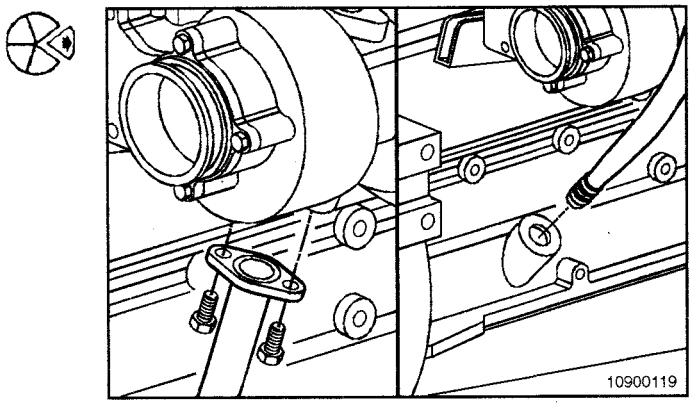
Inspect the turbocharger oil drain line for oil leaks or damage.

Repair as necessary.

Remove

Remove the capscrews from the oil drain tube.

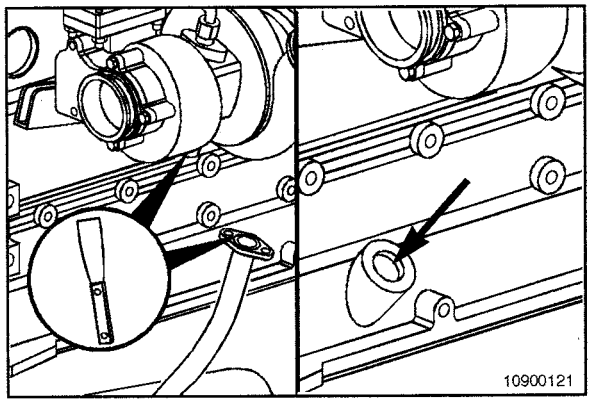
Pull the drain line out of the drain line boss.



Clean and Inspect for Reuse

Clean the gasket sealing surfaces.

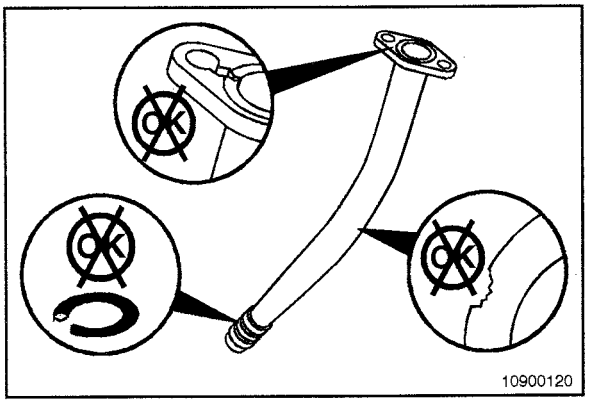
Clean the o-ring seating bore and make sure it is free of dirt and debris.



Inspect the line for cracks, wear, and damage.

Inspect the o-ring for fretting and cracking. Replace if necessary.

Check the rubber section of the drain line for deterioration.



Install

Apply a thin film of oil to the drain line o-rings.

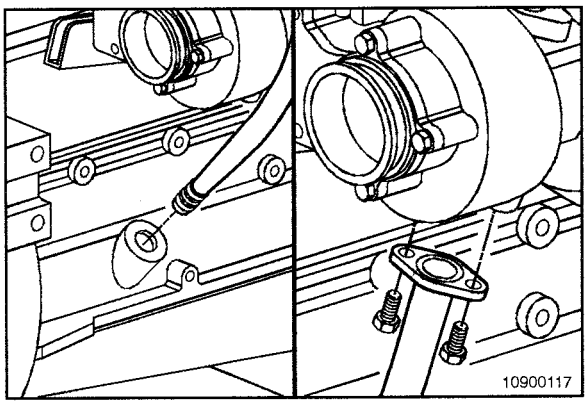
Push the drain line into the drain line boss. Be sure both o-rings are completely seated in the bore.

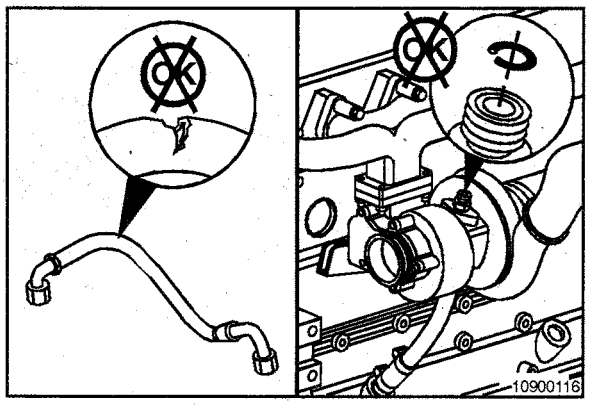
Install a new gasket.

Install and tighten the turbocharger oil drain line.

Torque Value: 27 N•m [20 ft-lb]

Operate the engine and check for leaks.

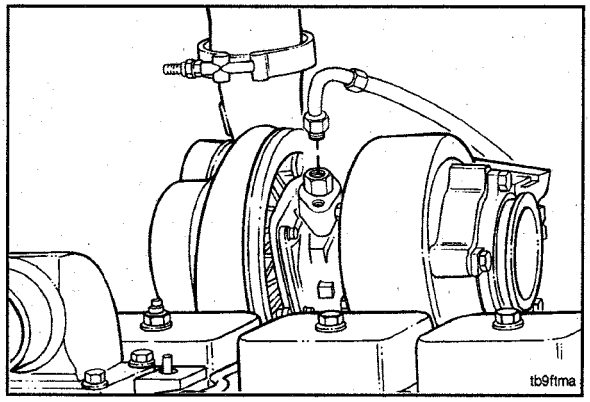




Turbocharger Oil Supply Line (010-046)

Initial Check

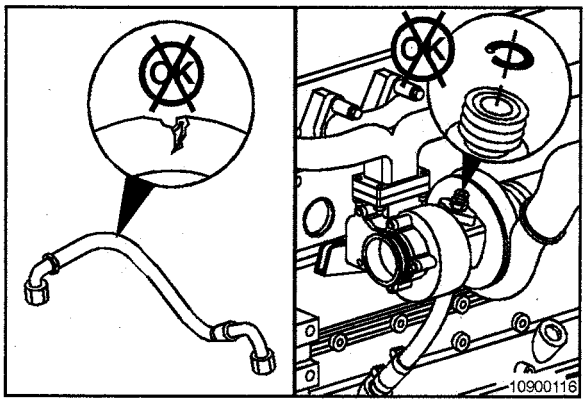
Inspect the line for oil leaks or damage. Replace as necessary.



Remove

Remove the oil supply line from the oil filter head (1).

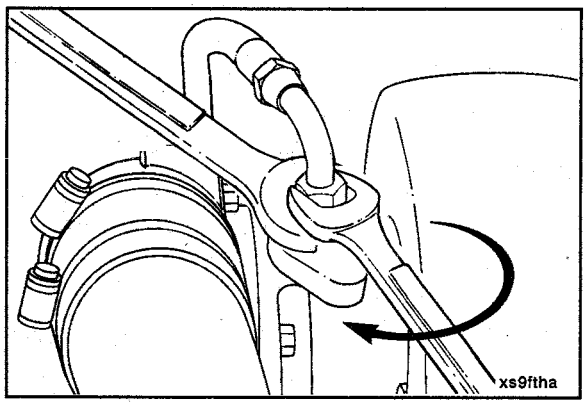
Remove the oil supply line from the turbocharger bearing housing (2).



Inspect for Reuse

Inspect the line for cracks, wear, and damage.

Inspect o-rings for cracking and fretting. Replace as necessary.



Install

Apply a thin film of oil to the o-ring seals.

Fill the turbocharger oil inlet with clean oil.

Install the oil supply line at both the filter head and the turbo bearing housing.

Tighten the oil supply line to final torque.

Torque Value: 24 N•m [18 ft-lb]

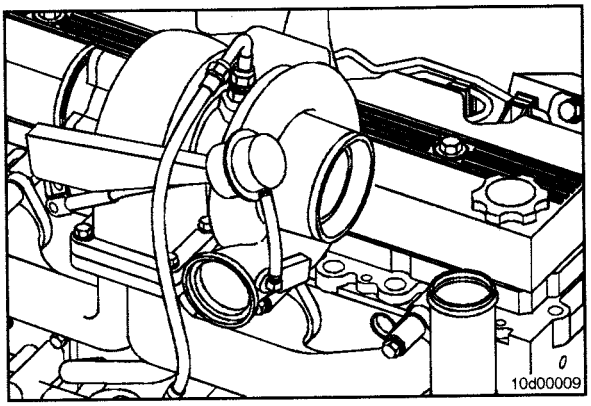
Turbocharger Wastegate Actuator (010-050)

Initial Check

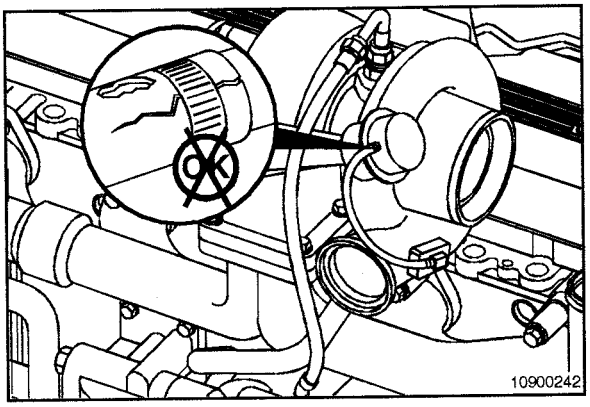
⚠CAUTION⚠

All wastegates come precalibrated and can not be adjusted in the field. Attempts to adjust the wastegate can result in engine damage.

The integral wastegate line takes boost from the turbocharger compressor outlet to the wastegate capsule.

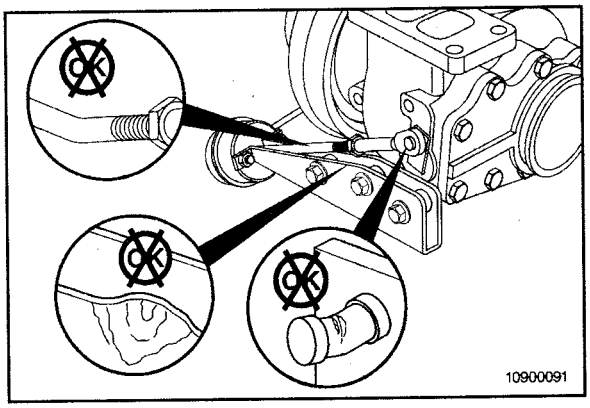


Inspect the integral wastegate actuator hose for cracks or holes. Replace the hose if damaged.



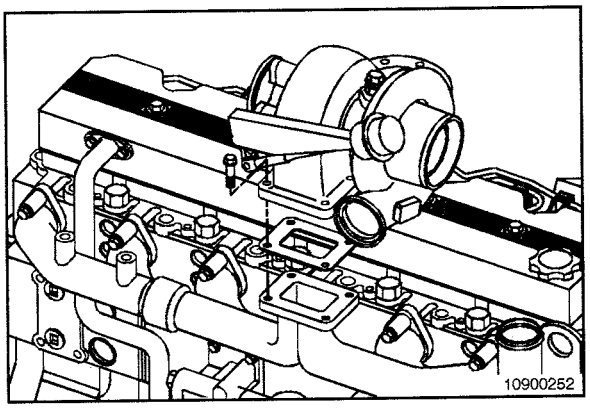
Inspect the wastegate mounting bracket, actuator rod, and lever for damage. A bent wastegate mounting bracket, actuator rod, or lever can cause improper operation.

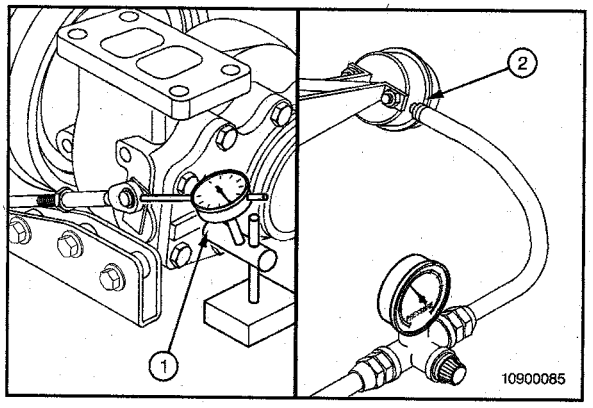
If the wastegate mounting bracket, actuator rod, or lever is bent, it **must** be replaced.



Test

In some applications the turbocharger **must** be removed to test the wastegate actuator. Refer to Procedure 010-033.





Disconnect the integral boost line from the wastegate capsule.

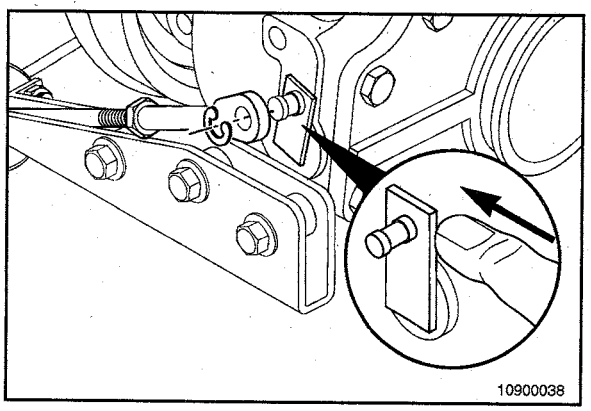
Attach a dial indicator (1) as shown, so that its shaft is in line with the wastegate actuator rod. Set the indicator to zero.

Connect clean, regulated air pressure and a pressure gauge to the capsule. Apply 200 kPa [29 psi] to make sure the wastegate is functioning properly.

The rod **must** move approximately 5 mm [0.200 in] without any sticking or air leakage.

Air **must not** be heard, such as air leaking through a functional wastegate capsule.

A small amount of travel when air pressure is first applied is normal. The tolerance is being removed from the system.

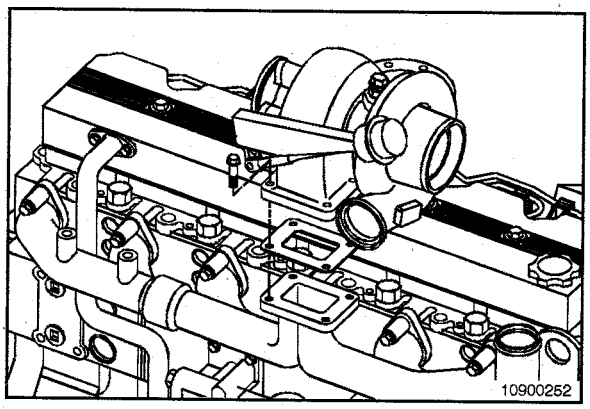


If no movement of the actuator rod is detected, detach the actuator control rod from the wastegate lever pin.

Actuate the lever by hand to be sure that the shaft rotates freely and is **not** seized.

If the wastegate lever can **not** be moved by hand, replace the turbocharger. Refer to Procedure 010-033.

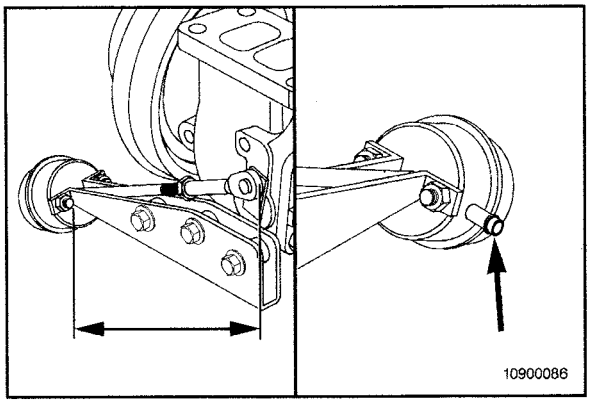
If the wastegate lever moves freely by hand, replace the turbocharger wastegate actuator.



Remove

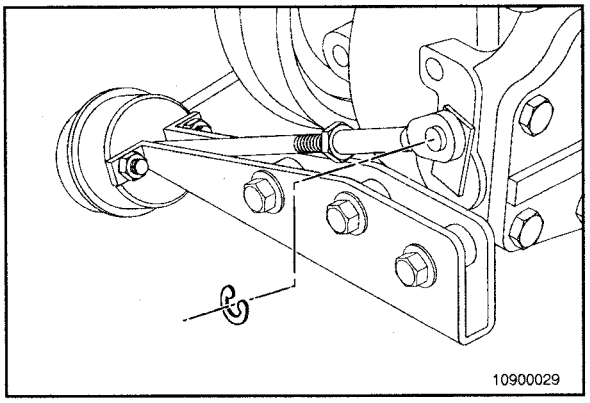
In some applications the turbocharger **must** be removed in order to remove the wastegate actuator. Refer to Procedure 010-033.

Prior to removal, note position length of the control rod from the boost capsule housing and orientation of the boost capsule hose connector in relation to the mounting bracket.



Remove the retaining clip from the control lever.

Remove the integral boost line from the wastegate capsule.



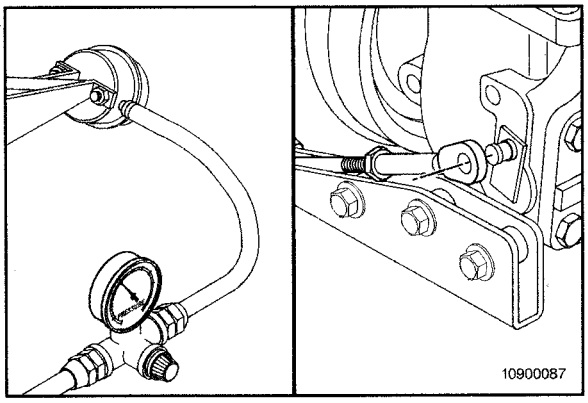
⚠CAUTION⚠

Be careful not to bend the control lever. Engine damage can result.

Air Regulator with Pressure Gauge

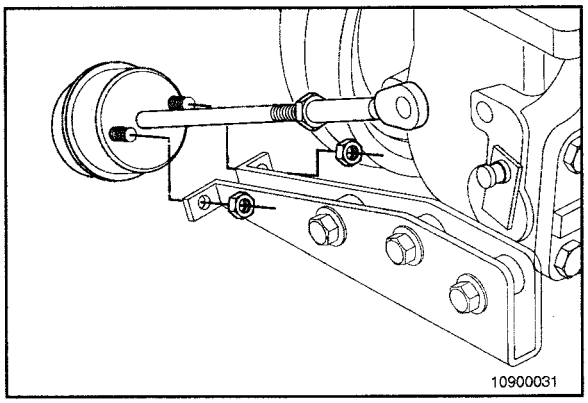
Remove the boost capsule actuator rod end from the turbocharger wastegate lever. This can be accomplished by slowly applying regulated air pressure to the boost capsule until the control rod is activated.

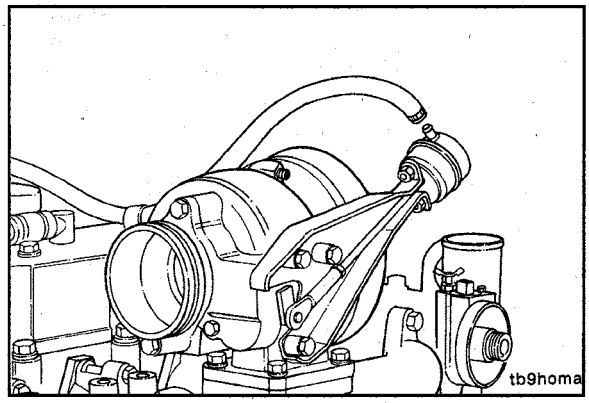
Remove the control rod from the turbocharger wastegate lever pin.



If the boost capsule diaphragm material is ruptured and will **not** hold air pressure, 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.

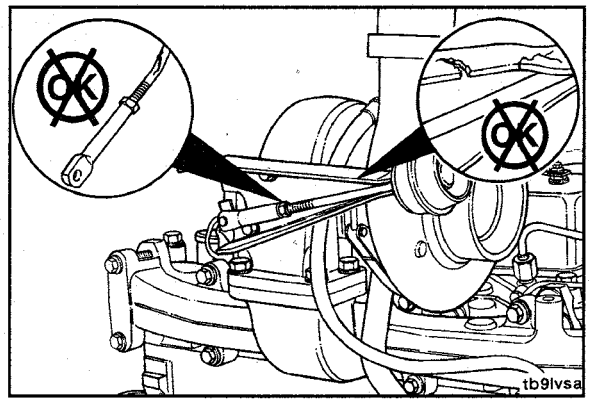
Loosen the boost capsule mounting capscrews, disconnect the air supply hose, and remove the assembly from the mounting bracket.





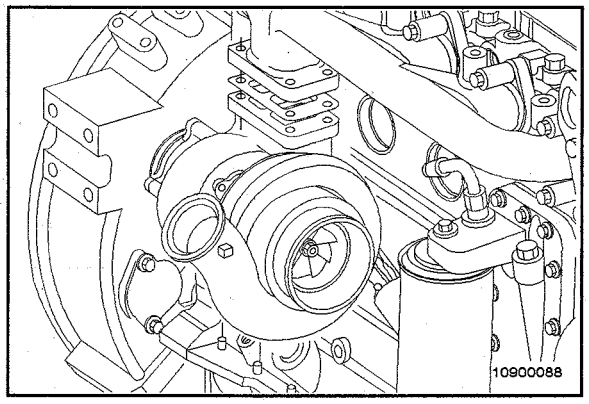
Clean and Inspect for Reuse

Inspect the wastegate actuator hose for cracks or holes. Replace the hose if damaged.



Inspect the wastegate mounting bracket, actuator rod, and lever for damage. A bent wastegate mounting bracket, actuator rod, or lever can cause improper operation.

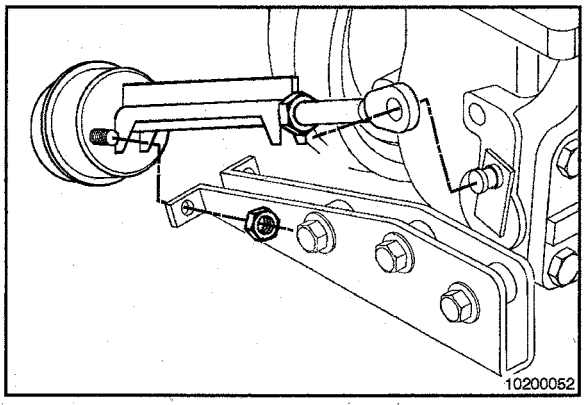
If the wastegate mounting bracket, actuator rod, or lever is bent, it must be replaced.



Install

Precalibrated Wastegate Actuator

In most applications, the turbocharger **must** be removed in order to remove the wastegate actuator. Refer to Procedure 010-033.



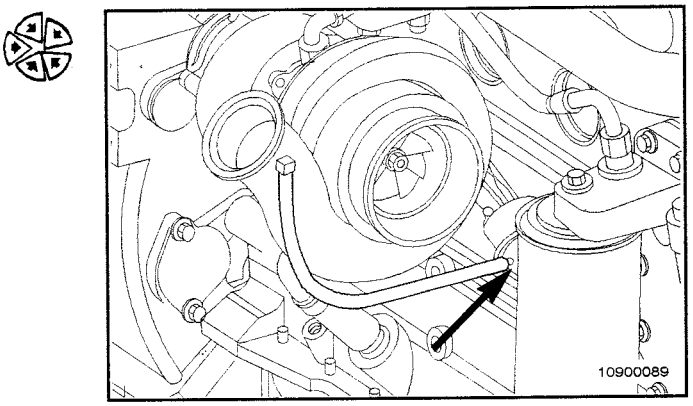
Fit the actuator mounting studs into the holes in the bracket, and fit both actuator mounting capscrews.

Refit the end-link onto the crank-pin. Install the control rod retaining clip.

Torque Value: 8 N•m [71 in-lb]

Cut the tie wrap and remove the tie wrap and spacer piece.

Refit the air supply hose to the actuator using the new hose clamp provided.

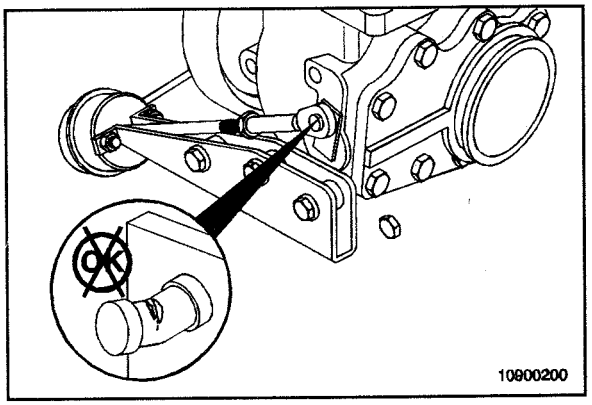


Turbocharger Wastegate Valve Body (010-055)

Maintenance Check

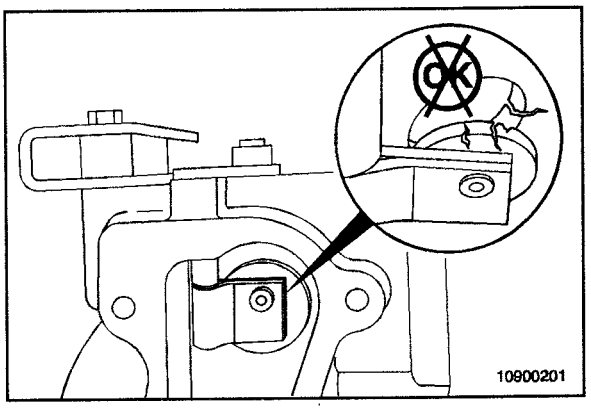
Inspect the lever pin.

Replace the turbocharger if worn excessively, Refer to Procedure 010-033.



Inspect the valve and valve seat for cracks or erosion.

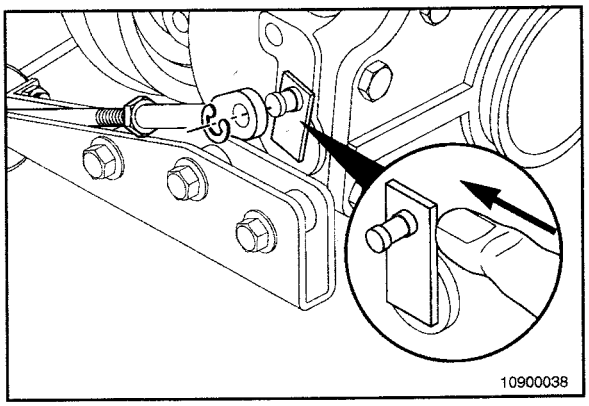
Replace the turbocharger if damage is found. Refer to Procedure 010-033.

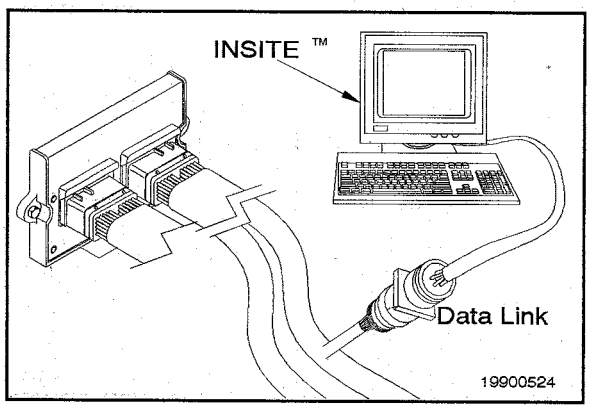


Actuate the lever by hand to verify that the shaft rotates freely and is **not** seized.

Check for excessive movement between the shaft and bushing.

Replace the turbine housing if the shaft and bushing are damaged or seized.

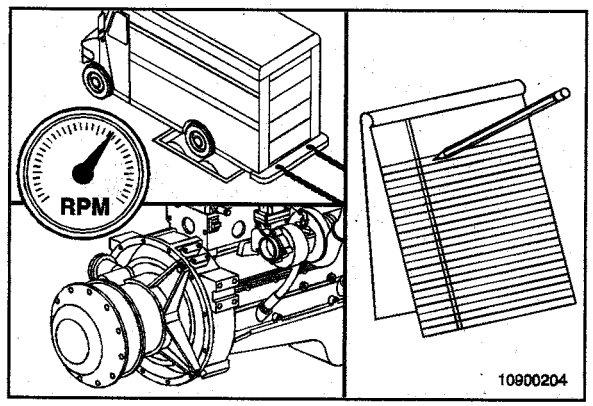




Intake Manifold Pressure (010-057)

Measure

Measure boost pressure at the intake manifold by using INSITE™ for hookup and monitoring procedures.



Operate the engine at rated rpm and full load. Record the boost reading.

Air Intake Connection (010-080)

Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the batteries and grid heater wiring.

Remove the air inlet crossover tube. Refer to Procedure 010-019.

Remove the air inlet connection, if equipped. Refer to Procedure 010-022.

Remove the injector supply lines, if required. Refer to Procedure 006-051.

Remove

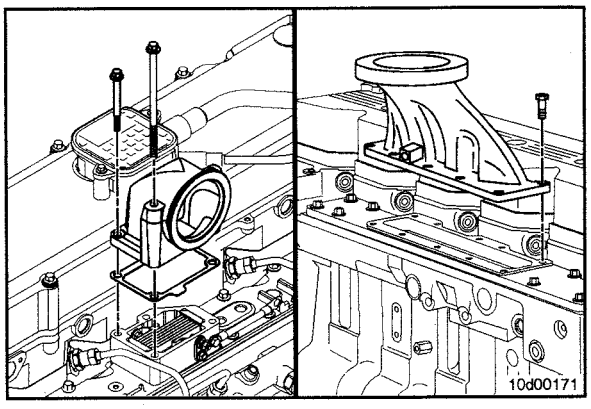
Remove the mounting capscrews.

Remove the air intake connection.

Tape off the intake manifold opening to prevent debris from entering the intake system.

NOTE: Be sure **not** to tape over the entire manifold edges so that the surface can be cleaned.

NOTE: On engines with the grid heater mounted on top of the intake manifold cover, the grid heater will now be loose.

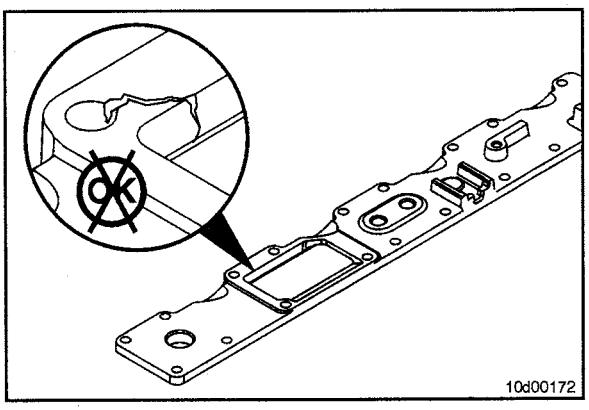


Clean and Inspect for Reuse

Clean the sealing surfaces.

NOTE: Keep gasket material and any other material out of the air intake.

Inspect the air intake connection for cracks or other damage.

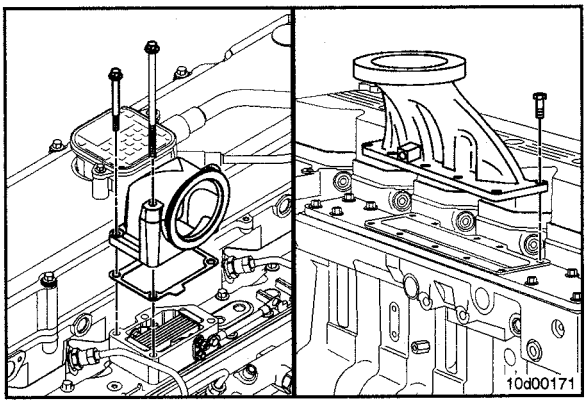


Install the air intake connection and a new gasket.

Torque Value: 24 N•m [18 ft-lb]

NOTE: Some capscrews are shared with fuel line braces on some engines.

NOTE: On some engines, the air intake connection mounts on top of the grid heater and shares capscrews.



Finishing Steps

Install the injector supply lines, if removed. Refer to Procedure 006-051.

Connect the air inlet connection, if equipped. Refer to Procedure 010-022.

Install the air crossover tube. Refer to Procedure 010-019.

Connect the cold starting aid and batteries.

Operate the engine and check for leaks.

Air Intake Manifold Cover (010-108)

Preparatory Steps

Disconnect the cold starting aid.

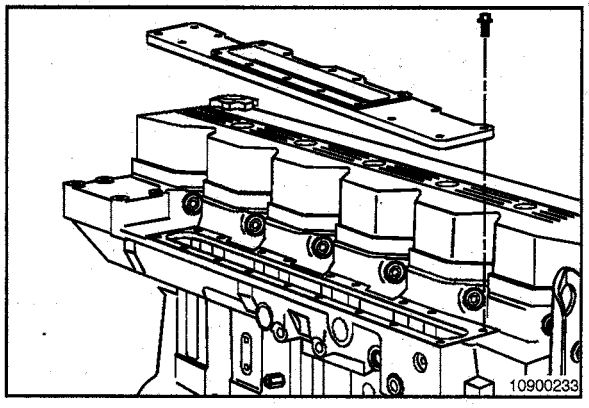
Remove the air crossover tube. Refer to Procedure 010-019.

Disconnect the air inlet connection, if equipped. Refer to Procedure 010-022.

Remove the air intake connection. Refer to Procedure 010-080.

Remove the injector supply lines, if required. Refer to Procedure 006-051.

Remove the turbocharger control valve, if equipped. Refer to Procedure 019-388 in Troubleshooting and Repair Manual, CM870 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.



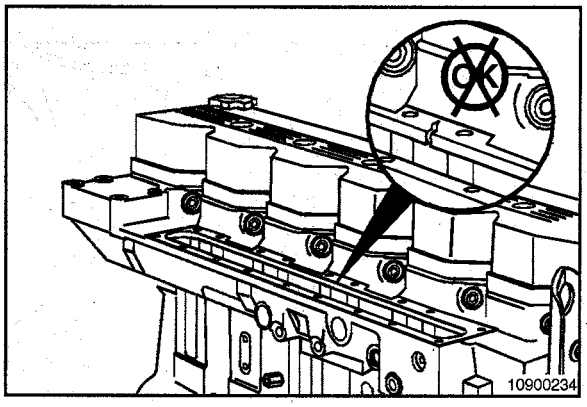
Remove

Some engines have a grid heater mounted on top of the intake manifold cover. Remove the grid heater, if equipped. Refer to Procedure 010-029.

Remove the mounting capscrews and the intake cover.

Tape off the intake manifold opening to prevent debris from entering the intake system.

NOTE: Be sure **not** to tape over the entire manifold edges so that the surface can be cleaned.



Clean and Inspect for Reuse

Clean the sealing surfaces.

NOTE: Keep the gasket material and any other material out of the air intake.

Remove the tape.

Inspect the intake manifold for cracks or other damage.

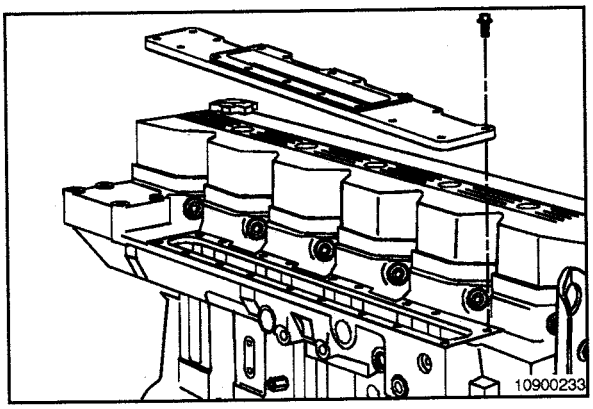
NOTE: When inspecting the intake manifold for oil or debris from an air system failure, also inspect the cylinder head for oil and debris.

Install

Install the cover with intake air heater (if equipped) and a new gasket.

Torque Value: 24 N•m [18 ft-lb]

NOTE: Some capscrews are shared with fuel line braces on some engines.



Finishing Steps

Install the grid heater, if equipped. Refer to Procedure 010-029.

Install the injector supply lines, if removed. Refer to Procedure 006-051.

Install the air intake connection. Refer to Procedure 010-080.

Install the air inlet connection, if used. Refer to Procedure 010-022.

Install the turbocharger control valve, if equipped. Refer to Procedure 019-388 in Troubleshooting and Repair Manual, CM870 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.

Install the air crossover tube. Refer to Procedure 010-019.

Connect the cold starting aid.

Operate the engine and check for leaks.

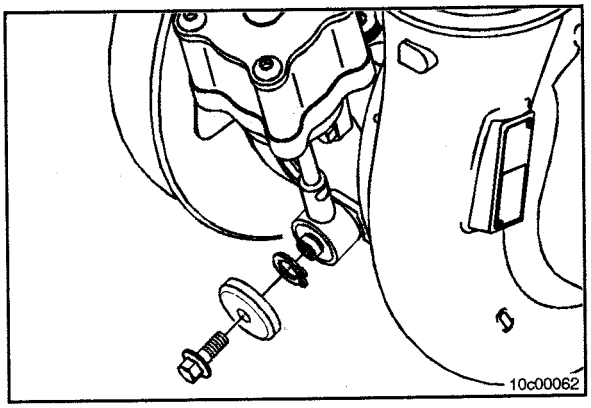
Turbocharger, Variable Geometry Actuator (010-113)

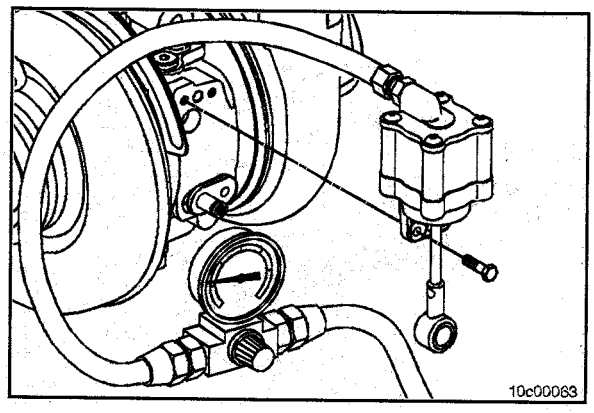
Remove

Remove the air line from the actuator.

Remove the capscrew holding the actuator rod to the turbocharger cross-shaft.

Remove the snap ring from the cross-shaft.

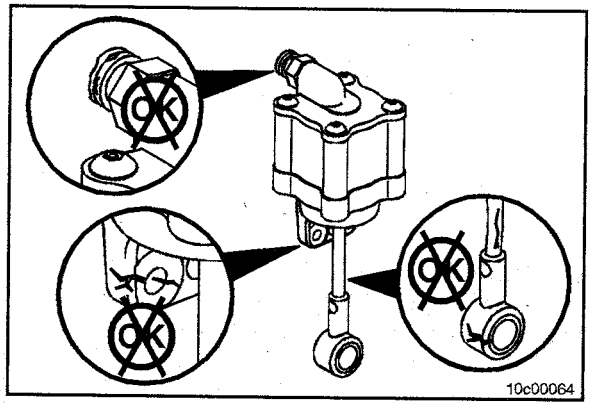




Loosen the two capscrews holding the actuator to the turbocharger bearing housing.

Use coupling, Part Number 3824843, to apply 414 kPa [60 psi] regulated air pressure to the actuator air inlet to reduce spring load at the linkage.

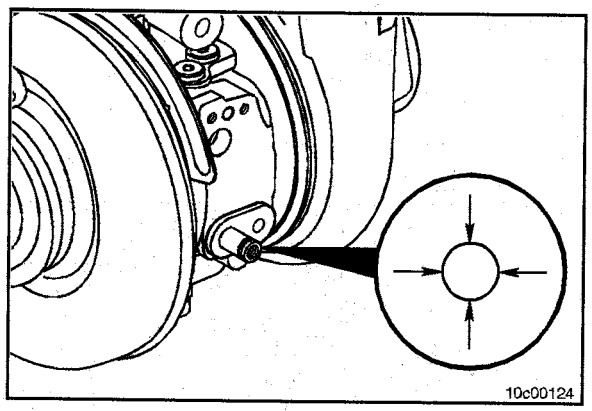
Remove the two loosened capscrews and actuator.



Clean and Inspect for Reuse

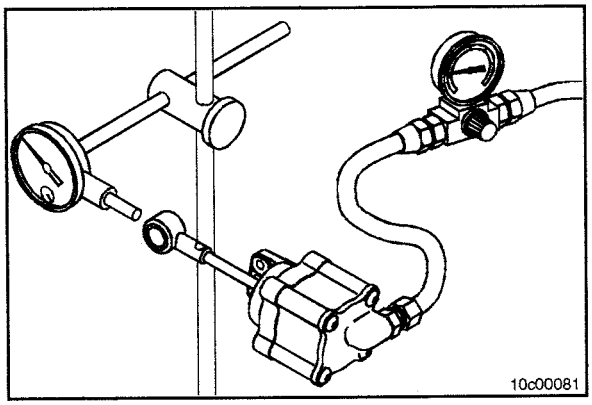
Inspect the actuator mounting bracket, rod and body. If the actuator is bent or cracked, it **must** be replaced.

Inspect the bushing in the actuator rod end that attaches to the turbocharger cross-shaft for wear, scoring, or damage. Replace the actuator, if damage is found.



Inspect the outside diameter of the turbocharger cross-shaft pin. Replace the turbocharger if wear is found.

Test



Attach a dial indicator as shown, so the shaft is in line with the actuator rod. Set the dial indicator to zero with no air pressure applied to the actuator.

Connect a clean, regulated air pressure supply and a pressure gauge to the actuator. Apply a minimum of 414 kPa [60 psi] air pressure to make sure the actuator is functioning properly.

The rod **must** move without any sticking.

Actuator Movement Range 10.8 mm [0.425 in]

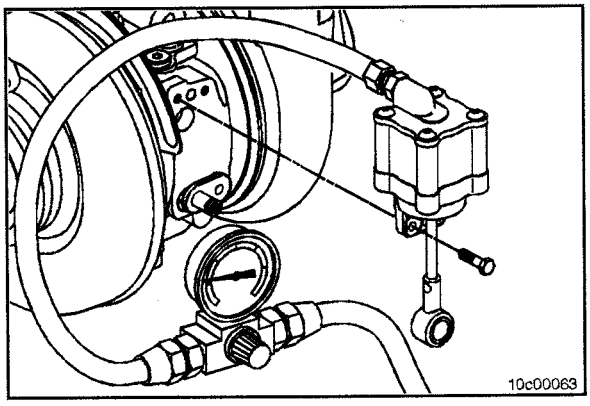
NOTE: No air **must** be heard leaking through a functional actuator.

Spray soapy water on the actuator housing to check for air leaks. Replace the actuator housing if leaks are found.

Replace the actuator if no movement of the actuator rod is detected, the actuator is sticking, or an air leak is found.

NOTE: This test can be performed with the actuator removed or installed on the turbocharger.

Install

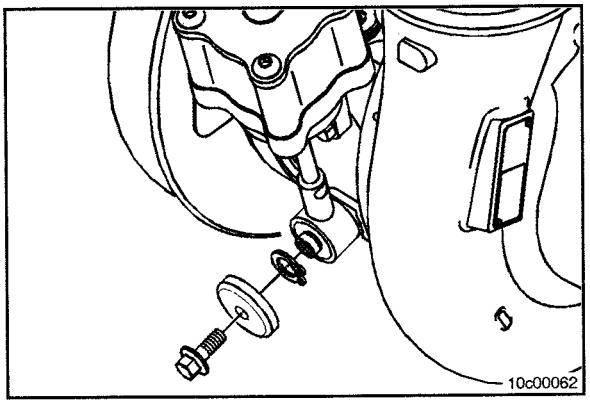


Use coupling, Part Number 3824843, to apply 414 kPa [60 psi] regulated air pressure to the actuator.

Install the actuator on the turbocharger bearing housing.

Install and tighten the two capscrews.

Torque Value: 17 N•m [150 in-lb]



Install the actuator rod to the turbocharger cross-shaft.

Install the snap ring.

Install and tighten the capscrew.

Torque Value: 23 N•m [17 ft-lb]

Finishing Steps

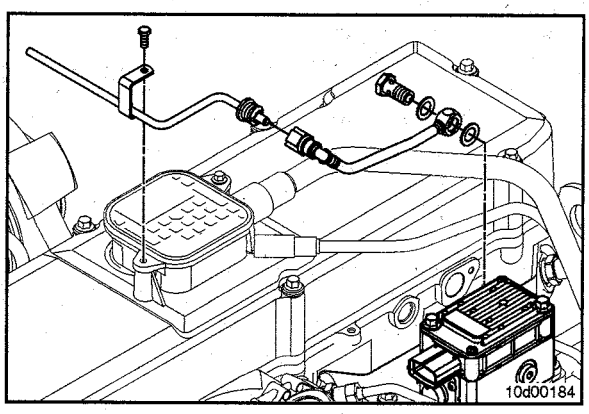
Install the turbocharger actuator air supply line to the actuator. Refer to Procedure 010-118.

Operate the engine and verify proper operation. Check for air leaks.

Turbocharger Actuator Air Line (010-118)

Preparatory Steps

Remove the turbocharger control valve, if necessary. Refer to Procedure 019-388 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.



Remove

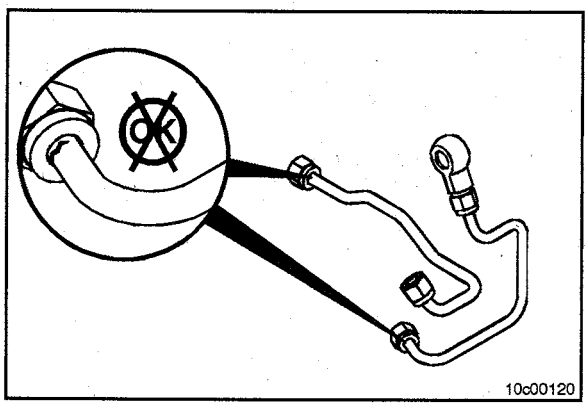
Disconnect the air line from the turbocharger actuator.

Disconnect the air line from the quick-connect fitting on the intake side of the engine.

Remove the mounting capscrew from the crankcase breather.

Disconnect the banjo fitting from the turbocharger control valve.

Use masking tape to tape the end of the air line and turbocharger control valve to prevent contamination.



Clean and Inspect for Reuse

Inspect the air line for wear or damage.

Inspect the o-rings for signs of damage or distortion.

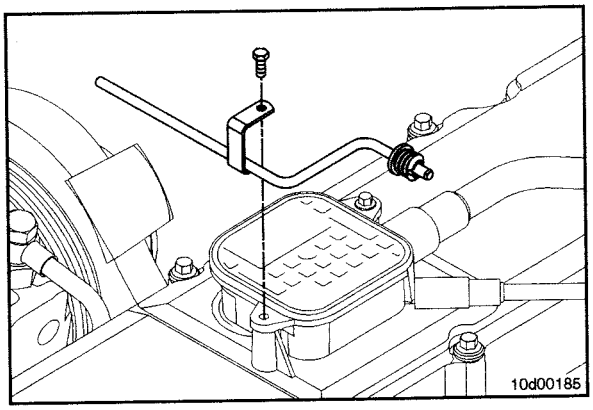
Replace as necessary.

Install

Remove the masking tape from the ends of the turbocharger actuator supply line before installing the line.

Install the air line and the mounting capscrew to the crankcase breather.

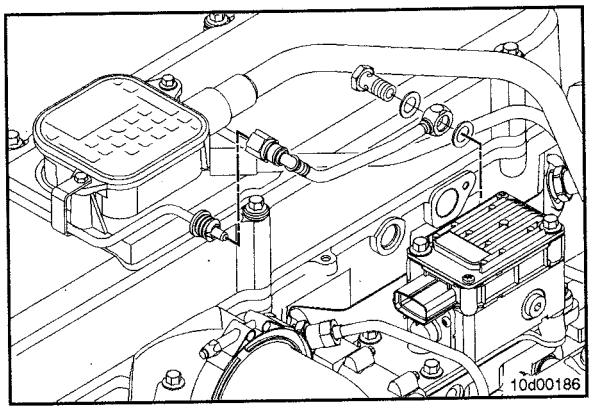
Torque Value: 5 N•m [44 in-lb]



Connect the flexible elbow to the turbocharger control valve using new sealing washers.

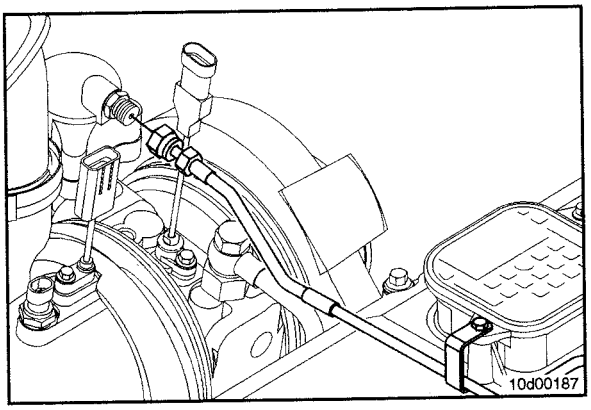
Torque Value: 18 N•m [160 in-lb]

Install the quick connect fitting to the air line.



Connect the air supply line to the turbocharger actuator.

Torque Value: 24 N•m [18 ft-lb]



Finishing Steps

Operate the engine and check for proper operation. Check for air leaks.

Notes

Section 11 - Exhaust System - Group 11

Section Contents

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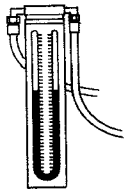
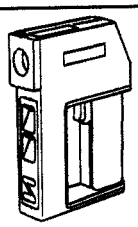
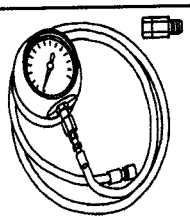
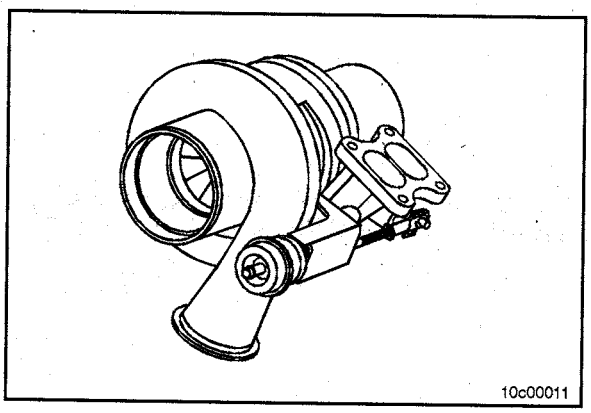
Service Tools

Exhaust 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.

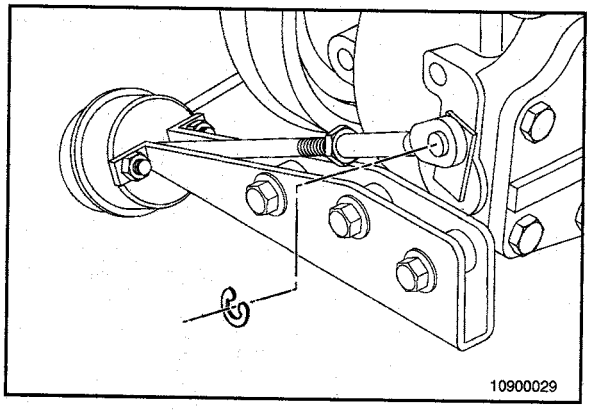
Tool No.	Tool Description	Tool Illustration
ST-1111-3	**Manometer** Used to measure exhaust restriction.	
3824941	**Infrared Thermometer** Used to measure the surface temperature of exhaust components.	
ST-1273	**Pressure Gauge** Used to measure in Hg pressure.	



Exhaust System - Overview (011-999)

General Information

The wastegated turbocharger is a Holset® Model HX40. 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 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.

Exhaust Manifold, Dry (011-007)

Preparatory Steps

⚠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.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain the cooling system, variable geometry turbochargers **only**. Refer to Procedure 008-018.

Remove the air crossover tube and charge air cooler hose. Refer to Procedure 010-019.

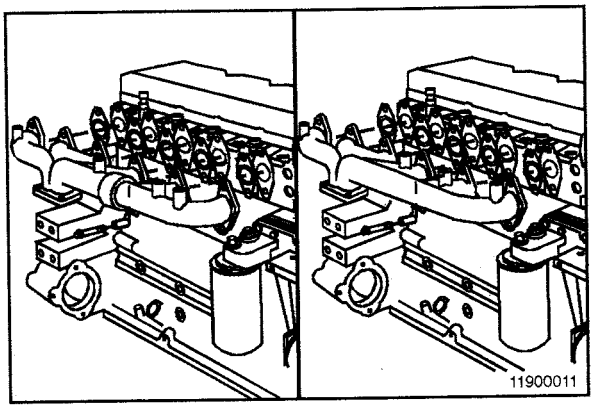
Disconnect the air intake and exhaust piping. Refer to Procedure 010-022.

Remove the turbocharger, if used. Refer to Procedure 010-033.

Remove

Remove the exhaust manifold and gaskets.

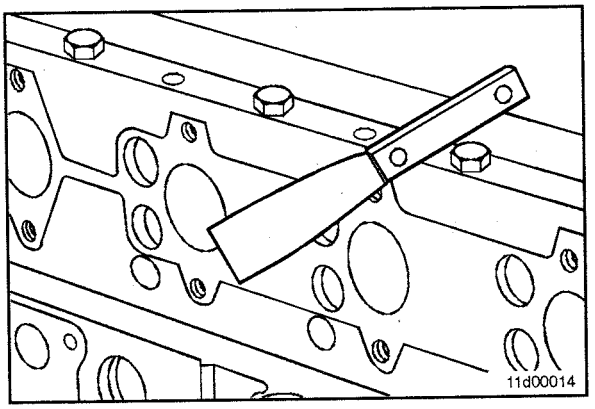
NOTE: Apply a thin coating of nickel-based high-temperature compound grease to the coarse threads of the manifold capscrews.



Clean

Clean the sealing surfaces of the head and exhaust manifold.

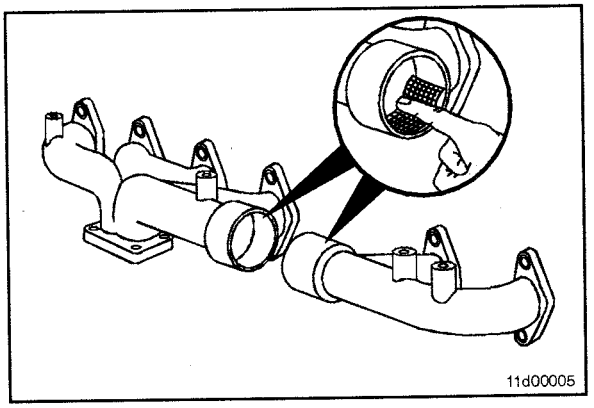
Use 240-grit inert cloth to remove carbon deposits from the sealing surfaces.



Multipiece Only

Clean the multipiece sealing joint.

Use 240-grit cloth to remove carbon deposits from the sealing surfaces.



⚠WARNING⚠

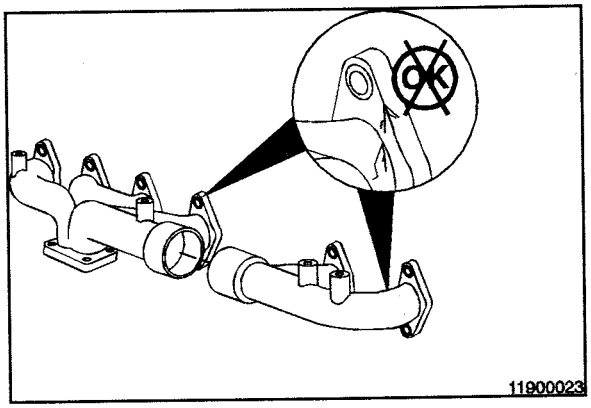
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

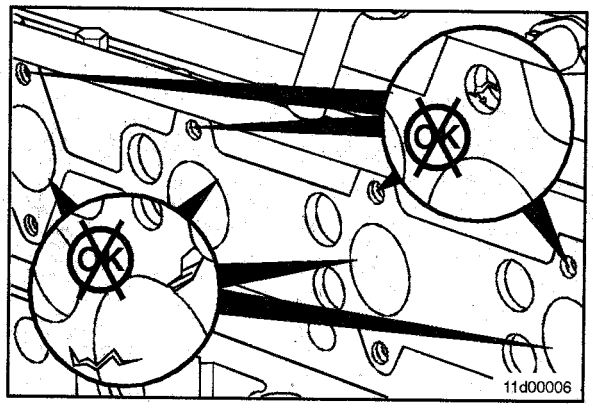
⚠WARNING⚠

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 to clean the exhaust manifold.

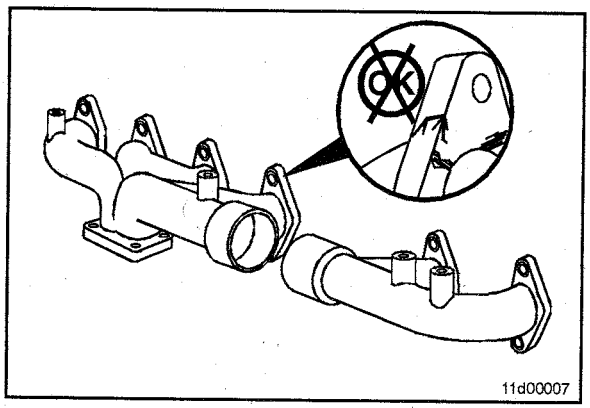
Dry with compressed air.



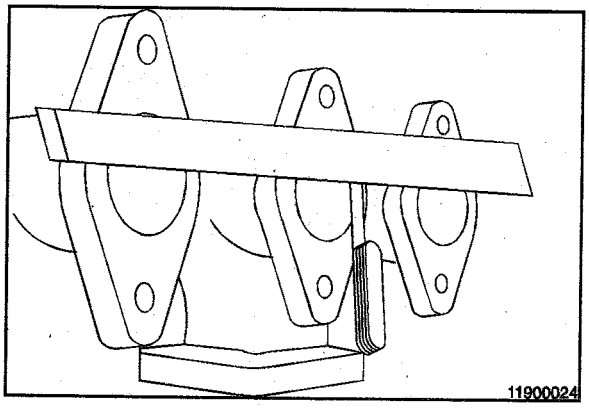


Inspect the exhaust manifold for cracks, burnout, or damaged threads.

NOTE: If the exhaust manifold is damaged, check the charge air cooler. A charge air cooler failure can cause progressive damage to the exhaust manifold. Refer to Procedure 010-027.



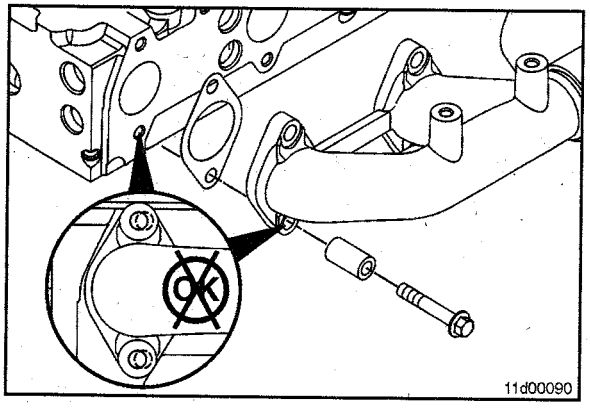
Inspect the gasket surfaces for gouges, scratches, or burnout.



Measure the manifold surface for flatness. Place a ruler over all exhaust ports in the manifold. Measure, with a feeler gauge, the gap between the port surface and the ruler.

Exhaust Manifold Flatness		
mm		in
0.20	MAX	0.008

If any port measures out of specification, replace the manifold.



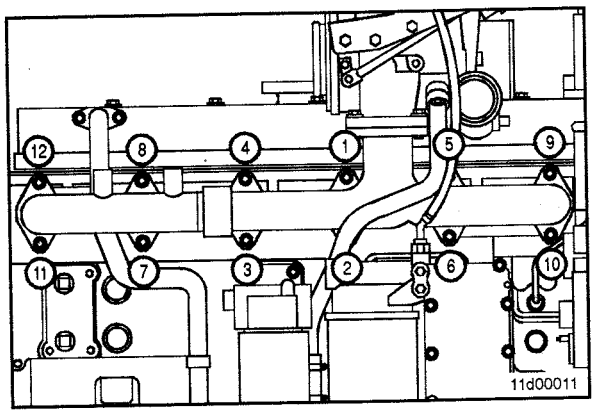
Check the manifold to cylinder head fit. If the manifold mounting capscrew holes do **not** line up with the tapped holes in the cylinder head, replace the exhaust manifold.

Install

Install the exhaust manifold and new gaskets.

Torque Value: 43 N•m [32 ft-lb]

Follow the tightening sequence shown in the illustration.



Finishing Steps

Install the turbocharger. Refer to Procedure 010-033.

Connect the air intake and exhaust pipe. Refer to Procedure 010-026.

Connect the charge air cooler hose and crossover tube. Refer to Procedure 010-019.

Fill the cooling system, variable geometry turbochargers **only**. Refer to Procedure 008-018.

Operate the engine and check for leaks.

Exhaust Restriction (011-009)

Measure

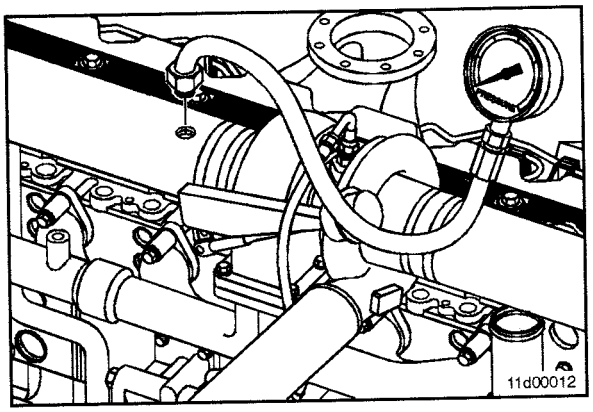
Install pressure gauge, Part Number ST-1273 to the pressure tap in the exhaust head pipe or at the inlet of the muffler, diesel oxidation catalyst, or exhaust gas filter.

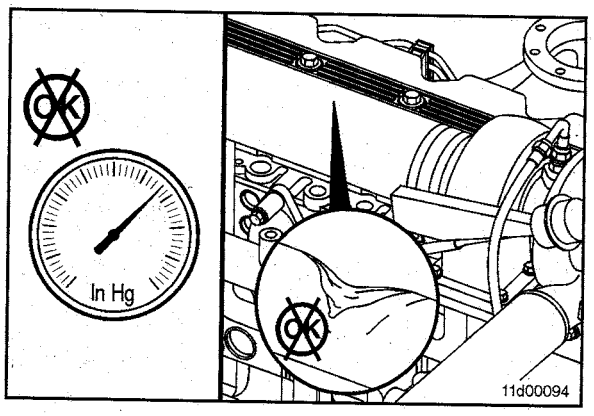
Operate the engine at rated speed and load. Record the exhaust restriction.

Exhaust Restriction - Muffler		
mm Hg		in Hg
76	MAX	3

Exhaust Restriction - Diesel Oxidation Catalyst		
mm Hg		in Hg
114	MAX	4.5

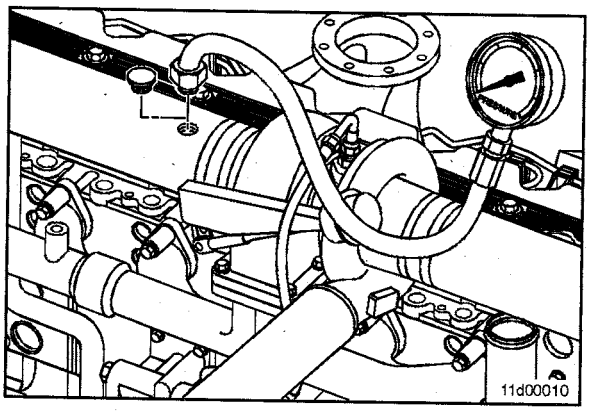
Exhaust Restriction - Exhaust Gas Filter		
mm Hg		in Hg
140	MAX	5.5





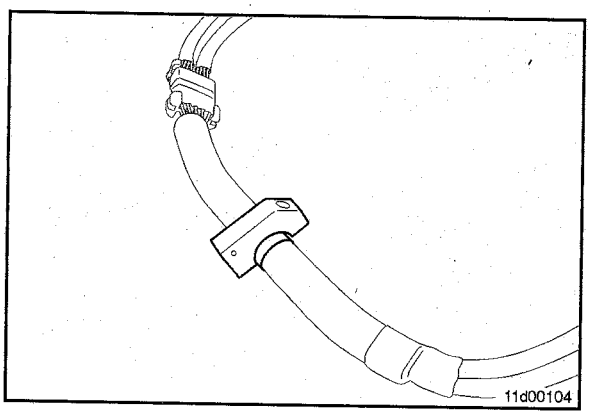
If the exhaust restriction exceeds the specifications inspect:

1. . The exhaust piping for damage. Refer to the OEM repair instructions.
2. . The diesel oxidation catalyst and/or muffler. Refer to the OEM repair instructions.
3. . The exhaust gas filter (if equipped). Refer to the OEM repair instructions.



Remove the test equipment.

Install the pipe plug.



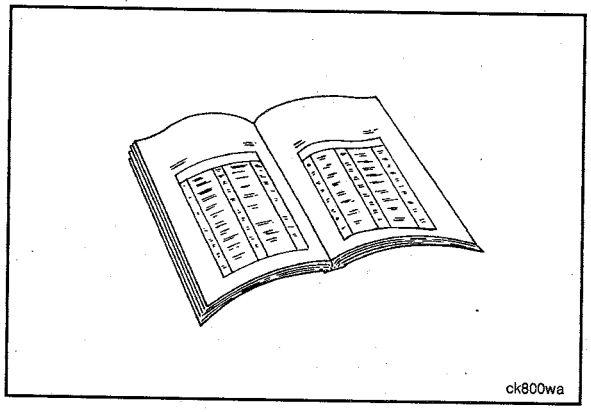
Exhaust Gas Treatment Monitor Unit (011-035)

General Information

The exhaust gas treatment monitor unit needs to be reset after removal and installation of the following components:

- exhaust gas pressure sensor
- exhaust gas temperature sensor
- exhaust gas treatment monitor harness.

To reset, pass a magnet over the white strip in the center of the exhaust gas treatment monitor unit. The exhaust gas treatment fault code and maintenance lamps on the vehicle dashboard will flash twice to signify that the exhaust gas treatment monitor unit has been reset.



Remove

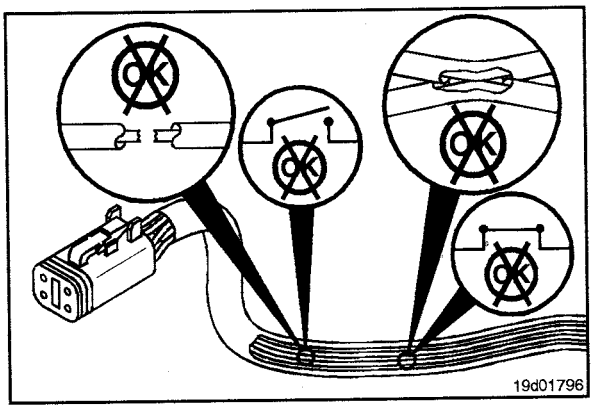
Disconnect the power leads. Refer to the vehicle manufacturer's service manual.

Disconnect the exhaust gas treatment monitor harness. Refer to Procedure 011-038.

Inspect for Reuse

Inspect the connectors for any damage, or bent or broken pins. Repair or replace, if necessary.

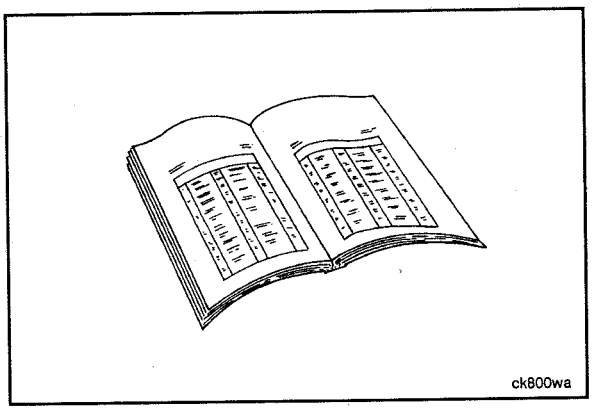
Inspect for damaged or exposed wires. Repair or replace, if necessary.



Install

Connect the exhaust gas treatment monitor harness. Refer to Procedure 011-038.

Connect the power leads. Refer to the vehicle manufacturer's service manual.



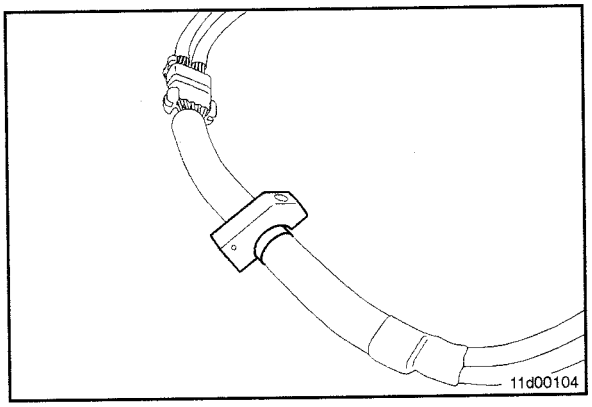
Exhaust Gas Treatment Monitor Unit (011-035)

General Information

The exhaust gas treatment monitor unit needs to be reset after removal and installation of the following components:

- exhaust gas pressure sensor
- exhaust gas temperature sensor
- exhaust gas treatment monitor harness.

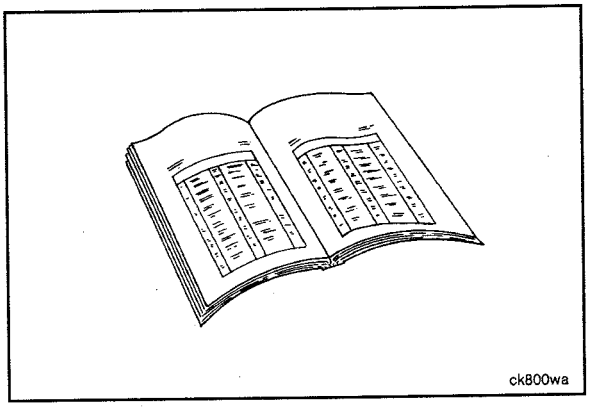
To reset, pass a magnet over the white strip in the center of the exhaust gas treatment monitor unit. The exhaust gas treatment fault code and maintenance lamps on the vehicle dashboard will flash twice to signify that the exhaust gas treatment monitor unit has been reset.

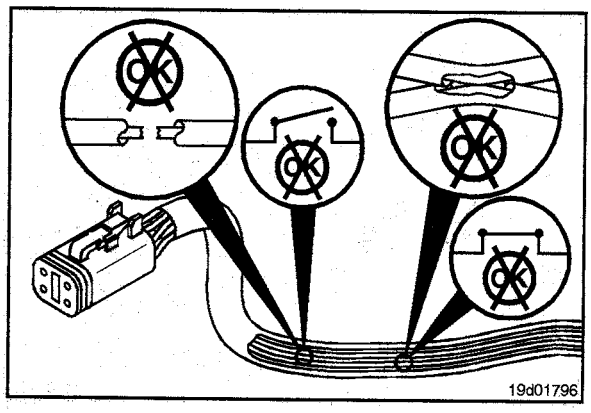


Remove

Disconnect the power leads. Refer to the vehicle manufacturer's service manual.

Disconnect the exhaust gas treatment monitor harness. Refer to Procedure 011-038.

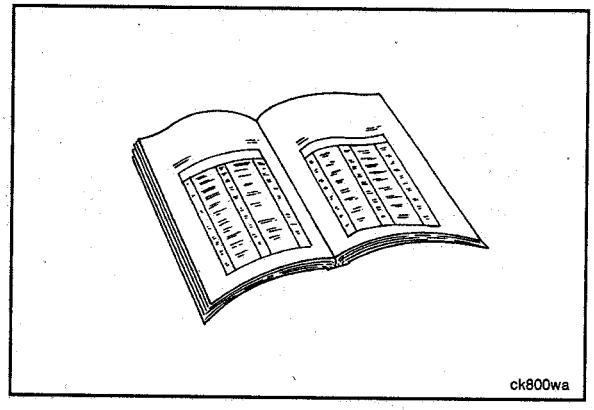




Inspect for Reuse

Inspect the connectors for any damage, or bent or broken pins. Repair or replace, if necessary.

Inspect for damaged or exposed wires. Repair or replace, if necessary.



Install

Connect the exhaust gas treatment monitor harness. Refer to Procedure 011-038.

Connect the power leads. Refer to the vehicle manufacturer's service manual.

Exhaust Catalyst (011-036)

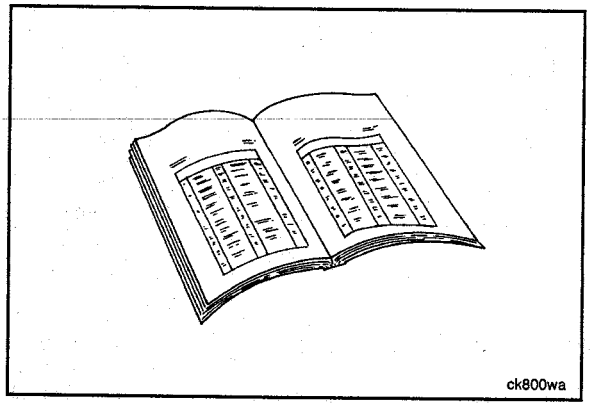
Preparatory Steps

⚠CAUTION⚠

Do not touch the surface of the exhaust catalyst during or up to 30 minutes after operation. All surfaces are hot and may cause burns.

Disconnect the exhaust gas temperature sensor, if necessary. Refer to Procedure 011-037.

Disconnect the exhaust gas pressure sensor, if necessary. Refer to Procedure 011-039.



Remove

⚠CAUTION⚠

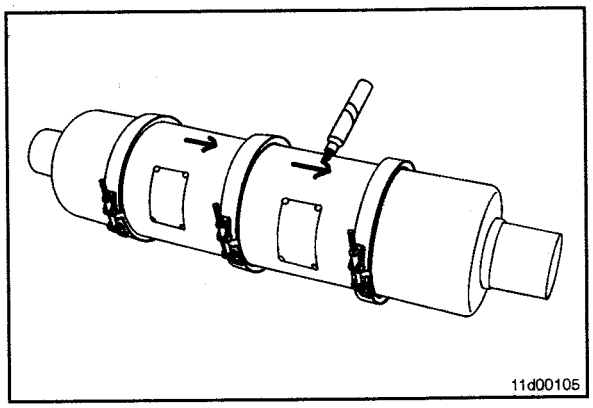
The component weighs 50 lbs or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

Remove the exhaust gas filter assembly from the vehicle. Refer to the vehicle manufacturer's service manual.

NOTE: It may be possible to remove the V-band clamps and separate the exhaust gas filter as listed in the Disassemble step with the exhaust gas filter assembly still installed in the vehicle.

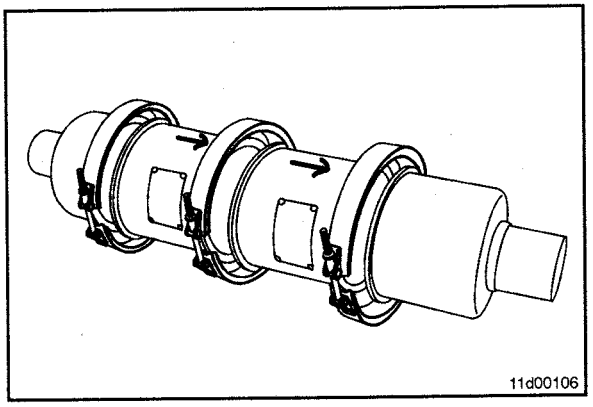
Disassemble

Mark the direction of exhaust flow on both the exhaust gas filter catalyst section and the exhaust gas filter section to aid in assembly.



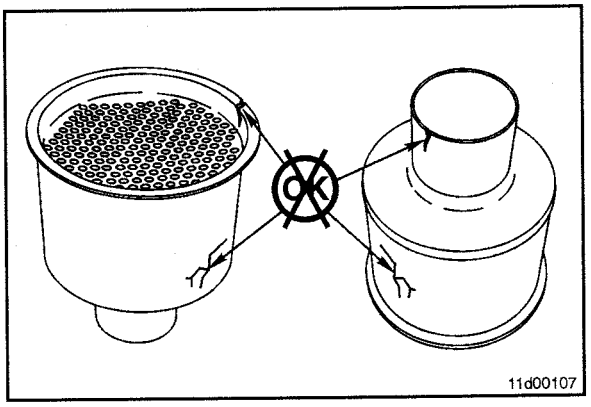
Remove the V-band clamps holding the sections together. Separate the mating sections by approximately one half inch to allow removal over the gasket retainer rings.

Discard the gaskets.



Clean and Inspect for Reuse

Check the inlet section for any cracks or damage. Replace if necessary.

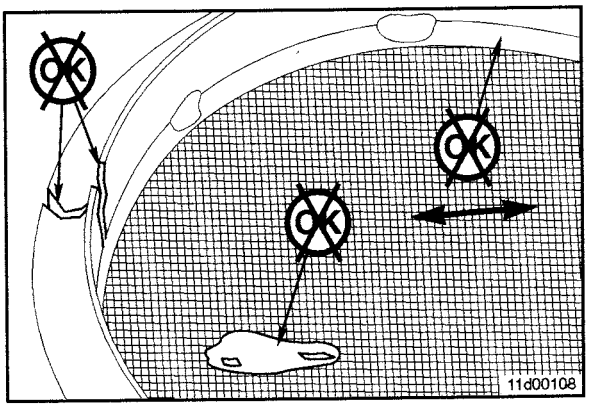


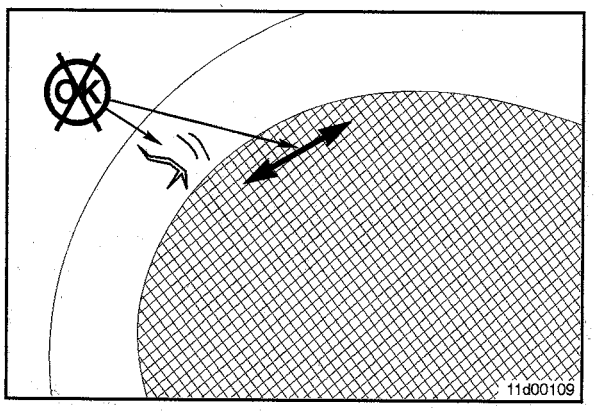
Check the inlet and outlet face of the catalyst section for:

Fuel, oil, or coolant buildup. A fluid soaked exhaust gas catalyst will have a glossy sheen and a strong fuel or oil odor. Replace the exhaust gas filter catalyst section if any damage is found.

Cracks or gouges deeper than 5/32 inch. Replace the exhaust gas filter catalyst section if any damage is found.

If the exhaust gas filter catalyst section has shifted, moved or is loose inside the canister, replace the exhaust gas filter catalyst.



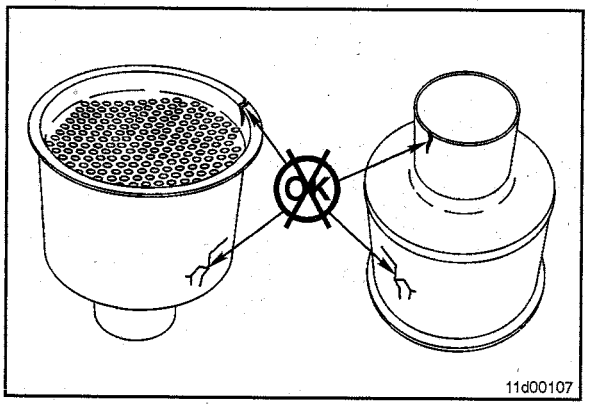


Inspect the exhaust gas filter for any cracks or gouges. Replace the exhaust gas filter section if any damage is found.

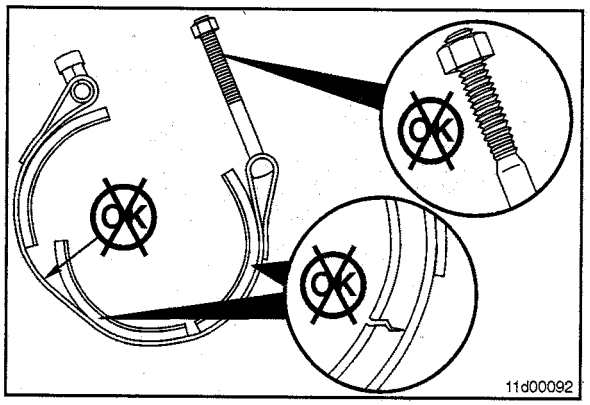
Inspect the outlet face of the exhaust gas filter for any black areas. Replace the exhaust gas filter section if there are more than 20 damaged cells.

If the exhaust gas filter has shifted, moved, or is loose inside of the canister, replace the exhaust gas filter section.

Return the exhaust gas filter section to the nearest Cummins Authorized Repair Location for cleaning.



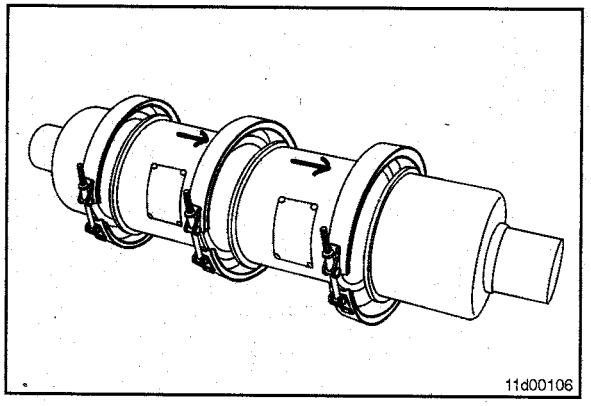
Check the outlet section for any cracks or damage. Replace if necessary.



Inspect the V-band clamps for signs of over-extension. The band **must not** be bent or damaged.

Inspect the V-band clamp threads for damage.

Replace the V-band clamp if damage is found.



Assemble

Assemble the sections of the exhaust gas filter using the V-band clamps and new gaskets. Make sure marks on the exhaust side of the catalyst and filter sections are aligned with the outlet.

Tighten the V-band clamp.

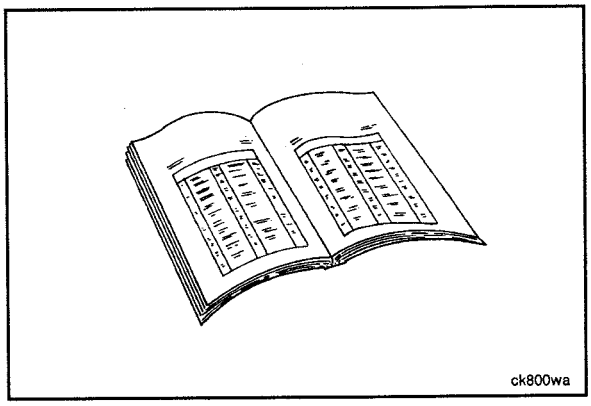
Torque Value: 20 N•m [180 in-lb]

Install

⚠CAUTION⚠

The component weighs 50 lbs or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

Install the exhaust gas filter assembly into the vehicle. Refer to the vehicle manufacturer's service manual.



Finishing Steps

Connect the exhaust gas temperature sensor, if necessary. Refer to Procedure 011-037.

Connect the exhaust gas pressure sensor, if necessary. Refer Procedure 011-039.

Operate the vehicle and check for leaks.

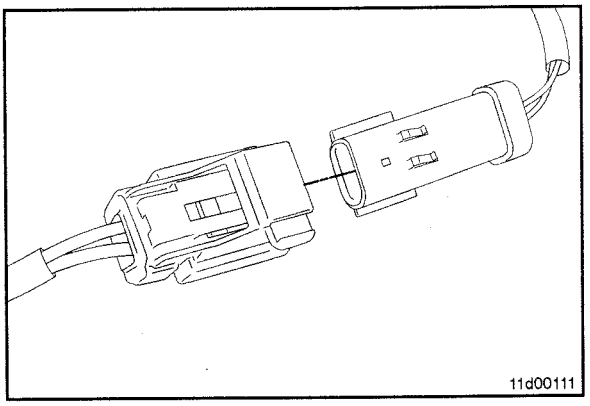
Exhaust Gas Temperature Sensor (011-037)

Remove

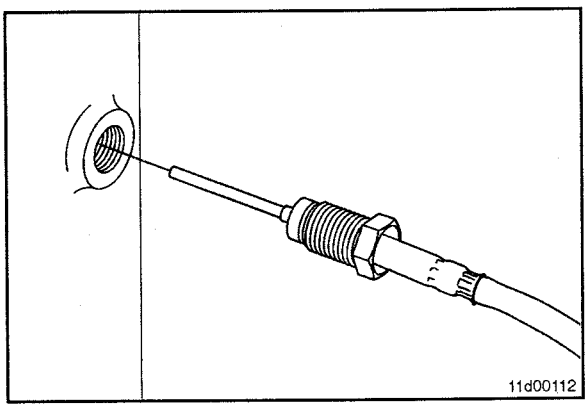
Slide the locking tab on the top side of the connector to the unlock position.

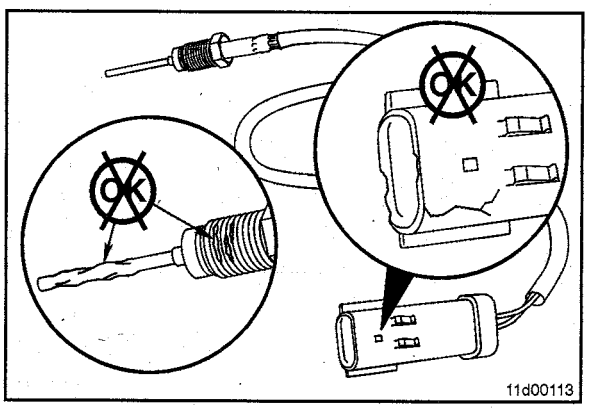
Press down on the tab near the end of the harness connector where the harness wires lead into the connector.

Pull outward on the connector away from the sensor to disconnect.



Remove the sensor from the mounting boss in the exhaust piping.

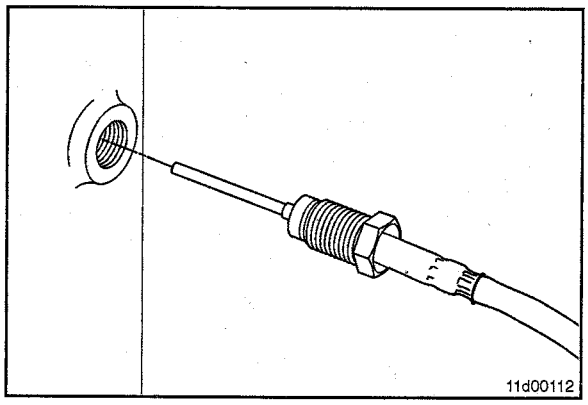




Clean and Inspect for Reuse

Inspect for damaged or exposed wires, bent or broken pins, damaged connectors, or damaged threads.

Replace if any damage is found.



Install

Put a light coating of anti-seize on the exhaust gas temperature sensor mounting threads.

Install the sensor into the mounting boss in the exhaust piping.

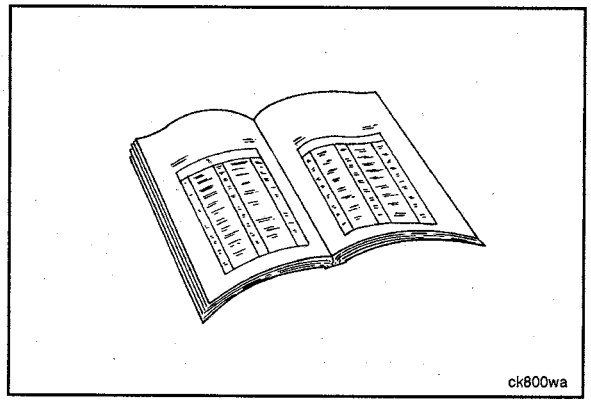
Tighten the sensor.

Torque Value: 13.5 N•m [120 in-lb]

Push the connectors together until they lock.

Slide the locking tab to the lock position.

Reset the exhaust gas treatment monitor unit. Refer to Procedure 011-035.



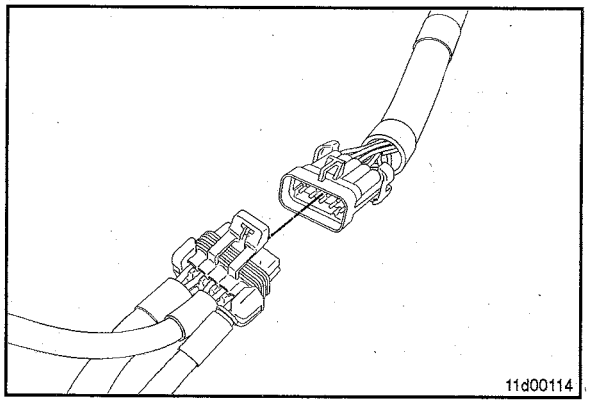
Exhaust Gas Treatment Monitor Harness (011-038)

Preparatory Steps

Disconnect the exhaust gas treatment monitor diagnostic lamps and the OEM harness connector to the exhaust gas treatment monitor harness. Refer to the vehicle manufacturer's service manual.

Disconnect the exhaust gas temperature sensor. Refer to Procedure 011-037.

Disconnect the exhaust gas pressure sensor. Refer to Procedure 011-039.



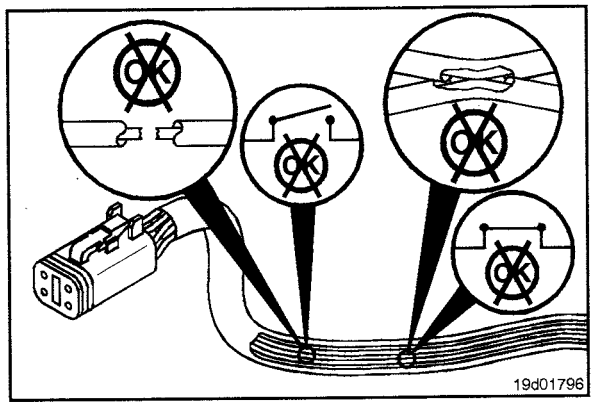
Remove

Disconnect the exhaust gas treatment monitor harness from the exhaust gas treatment monitor unit by pulling up on the tab and releasing the connector.

Inspect for Reuse

Inspect the connectors for any damage or bent or broken pins. Repair or replace if necessary.

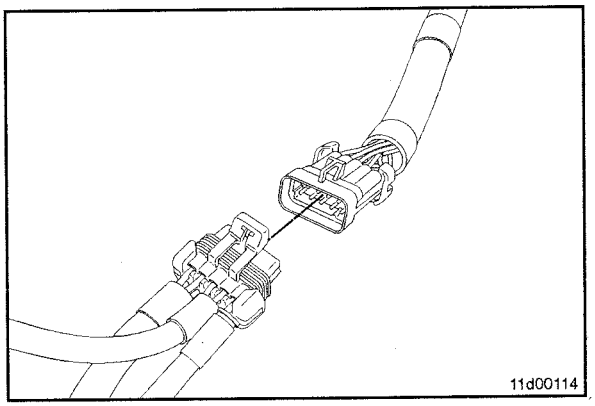
Inspect for damaged or exposed wires. Repair or replace if necessary.



Install

Connect the exhaust gas treatment monitor harness to the exhaust gas treatment monitor unit.

Push the connectors together until they lock.



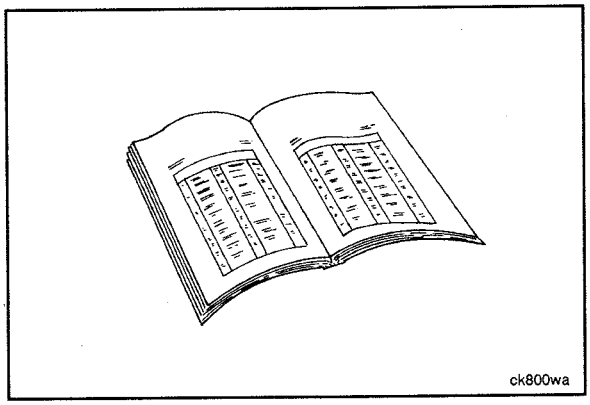
Finishing Steps

Connect the exhaust gas pressure sensor. Refer to Procedure 011-039.

Connect the exhaust gas temperature sensor. Refer to Procedure 011-037.

Connect the exhaust gas treatment monitor diagnostic lamps and the OEM harness. Refer to the vehicle manufacturer's service manual.

Reset the exhaust gas treatment monitor unit. Refer to Procedure 011-035.



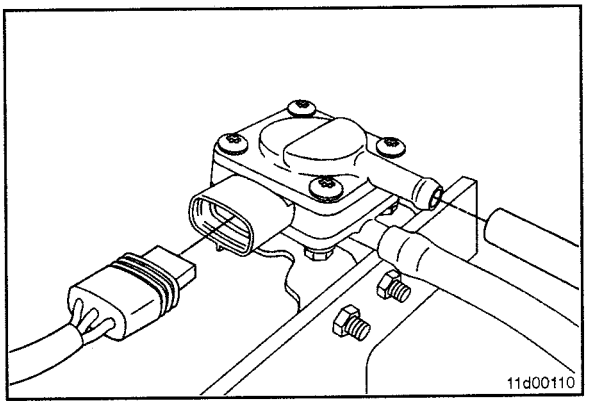
Exhaust Gas Pressure Sensor (011-039)

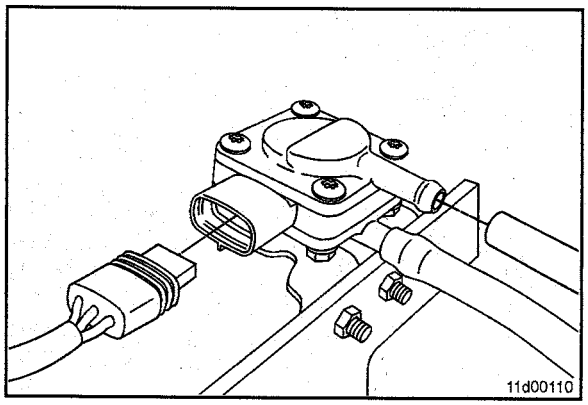
Remove

Push down on the locking tab and pull the connector apart.

Disconnect the hose from the inlet fitting.

Remove the sensor from the mounting location. Refer to the vehicle manufacturer's service manual.





Install

Push the connectors together until they lock.

Connect the hose to the inlet fitting.

Connect the sensor to the exhaust gas treatment monitor unit harness.

Attach the sensor to the mounting location. Refer to the vehicle manufacturer's service manual.

Reset the exhaust gas treatment monitor unit. Refer to Procedure 011-035.

Section 12 - Compressed Air System - Group 12

Section Contents

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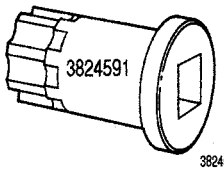
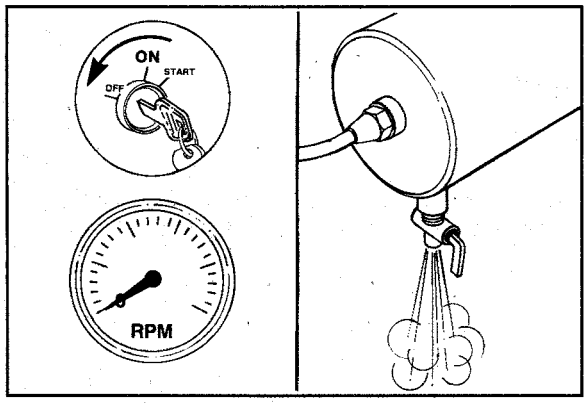
Service Tools

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
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591



Air Compressor Carbon Buildup (012-003)

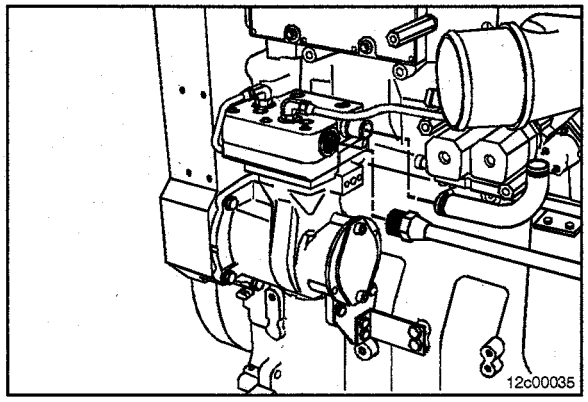
Initial Check

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Shut off the engine.

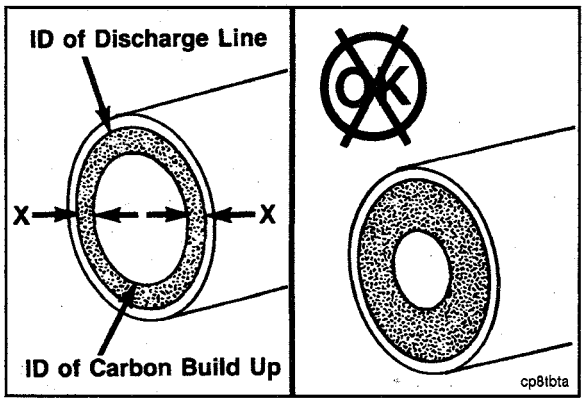
Open the drain cock on the wet tank to release compressed air from the system.



⚠WARNING⚠

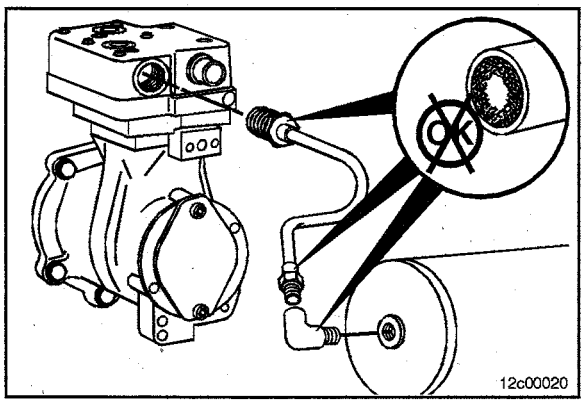
Air discharge lines can be very hot. Be sure the lines are cool before handling to prevent personal injury.

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.

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.

Clean

⚠WARNING⚠
Use skin and eye protection when handling caustic solutions to reduce the possibility of personal injury.

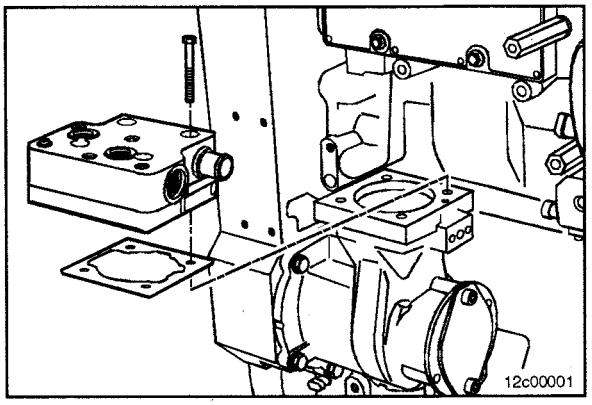
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠CAUTION⚠
Do not use a sharp object to remove carbon. The sealing surfaces can be damaged.

⚠CAUTION⚠
Avoid getting debris and solvents into the clearance between the piston and bore.

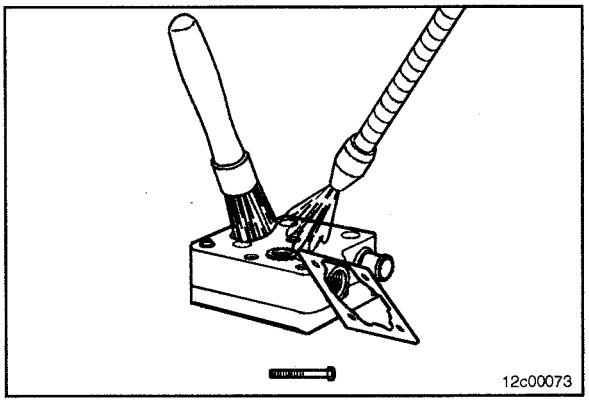
⚠CAUTION⚠
Avoid the use of abrasive products similar to "Scotch Brite™" because any abrasive grit left after cleaning will shorten the life of your air compressor.

Remove the compressor head and valve assembly. Refer to Procedure 012-007.



Clean the compressor head and valve assembly components with solvent and a nonmetallic brush to remove carbon.

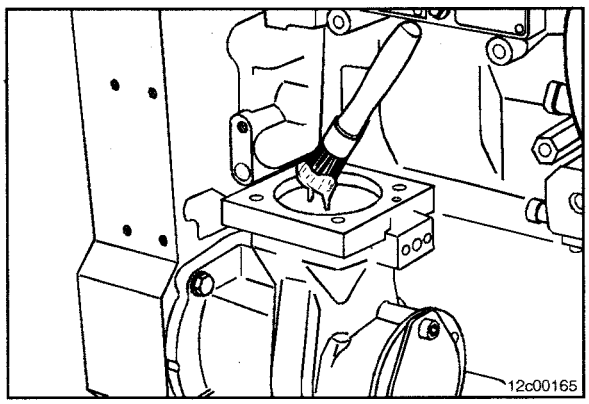
Blow out passages with compressed air.

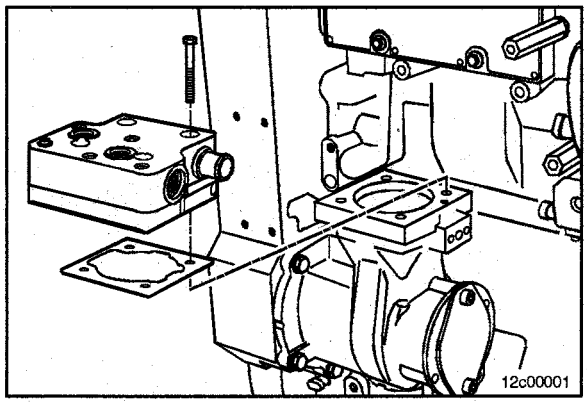


Clean the compressor cylinder.

Rotate the crankshaft until the piston is at the top of the cylinder bore.

Remove any accumulated carbon and varnish by carefully scraping and with light application of solvents.





Install the compressor head and valve assembly. Refer to Procedure 012-007.

Air Compressor Coolant Lines (012-004)

Preparatory Steps

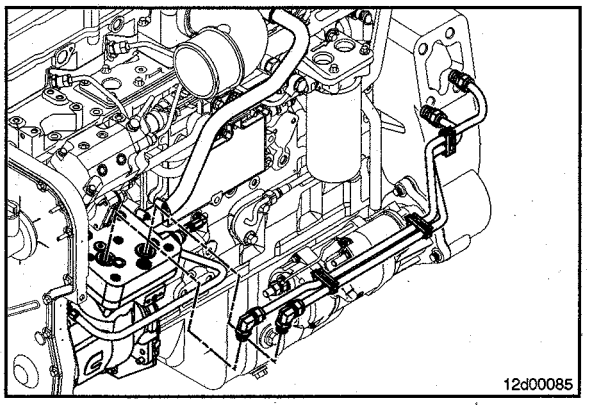
⚠WARNING⚠

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.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain the cooling system. Refer to Procedure 008-018.



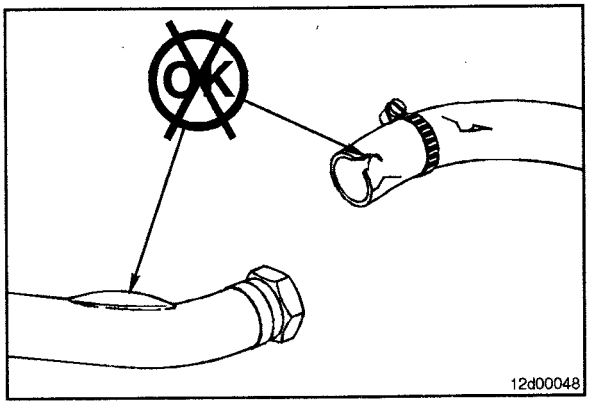
Remove

Remove the coolant lines from the air compressor.

Inspect for Reuse

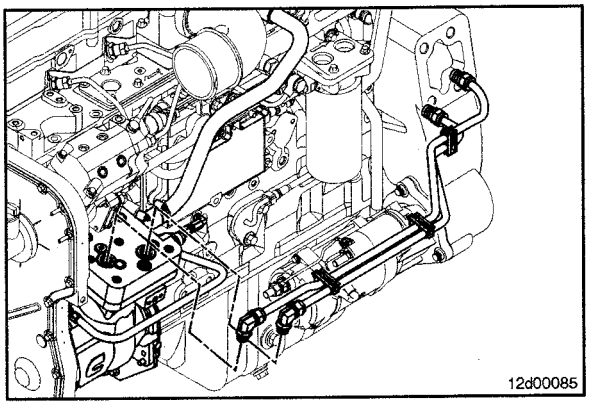
Inspect the drive clips or connectors for damaged threads.

Inspect the coolant hoses and coolant lines for restriction of coolant flow.



Install

Install the coolant lines.



Finishing Steps

Fill the cooling system. Refer to Procedure 008-018.

Operate the engine and check for leaks.

Air Compressor Cylinder Head, Single Cylinder (012-007)

Preparatory Steps

⚠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.

⚠WARNING⚠

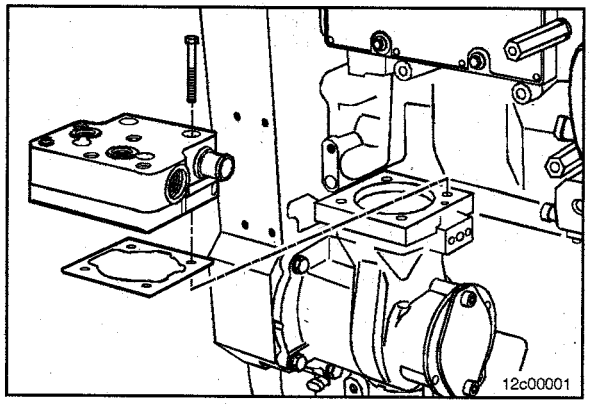
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

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

Remove the coolant lines.

Remove the air governor or air governor signal line (if equipped).

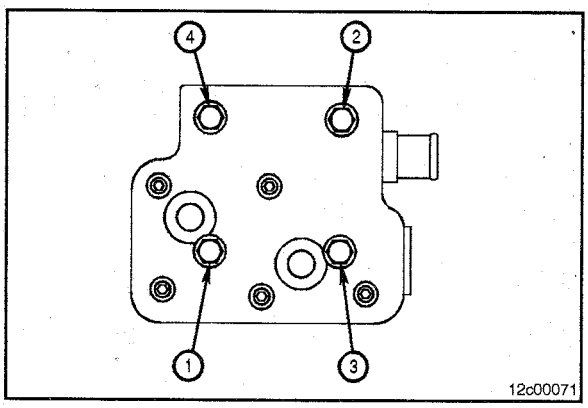
Remove the air inlet and outlet connections from the air compressor.



Remove

Remove the four 8-mm capscrews.

Remove the head and gasket.



Install

Assemble the air compressor using a new gasket.

Install the head and gasket.

Install the four 8-mm capscrews.

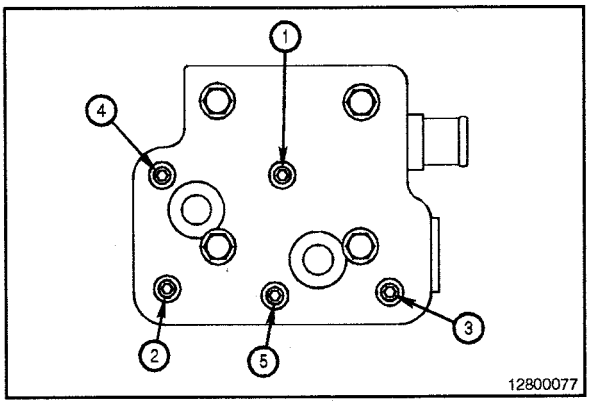
Tighten the capscrews in the sequence shown. Use the torque plus angle method.

Torque Value:	Step1	25 N•m	[18 ft-lb]
	Step2	Rotate capscrews 1, 2, and 3 90 degrees	
	Step3	Rotate capscrew 4 60 degrees	

NOTE: If a new head assembly is being installed, the five small head cover bolts **must** be torqued.

If a new head assembly is being installed, tighten the five small head cover bolts in the sequence shown.

Torque Value: Step1 6 N•m [53 in-lb]
Step2 Rotate 90 degrees.



Finishing Steps

Install the air inlet and outlet connections from the air compressor.

Install the air governor or air governor signal line, if equipped.

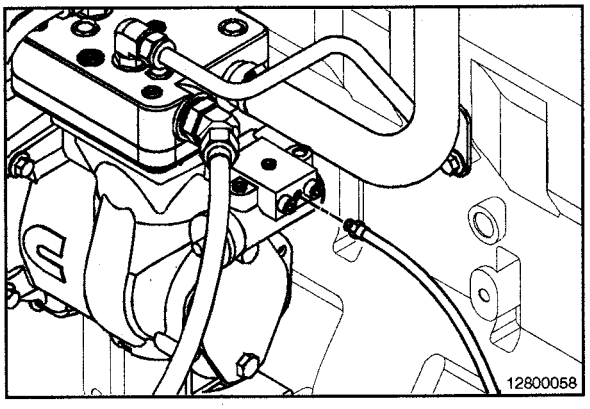
Install the coolant lines.

Fill the cooling system. Refer to Procedure 008-018.

Air Compressor Unloader and Valve Assembly (012-013)

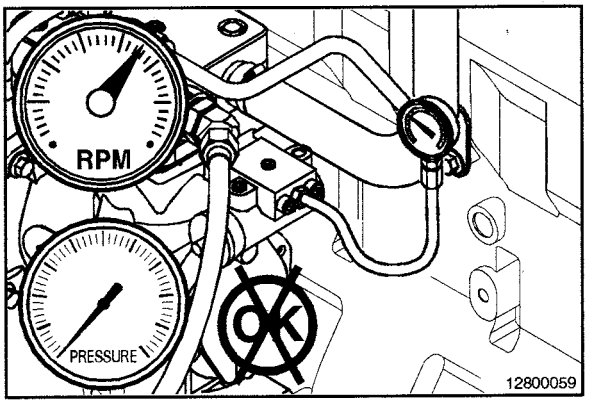
Initial Check

Remove the air governor or air governor signal line from the air compressor.



Operate the engine to activate the air compressor.

If the air compressor is **not** pumping, replace the compressor cylinder head. Refer to Procedure 012-007.



Air Compressor (012-014)

Preparatory Steps

⚠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.

⚠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.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

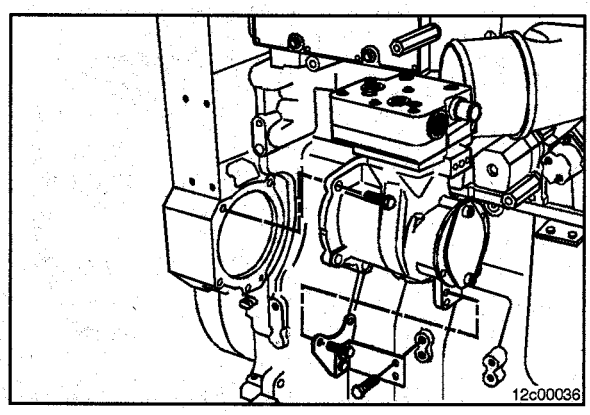
Steam-clean the air compressor.

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

Remove the hydraulic pump, if equipped. Refer to Procedure 009-016 or the OEM service manual.

Remove the coolant lines from the air compressor. Refer to Procedure 012-004.

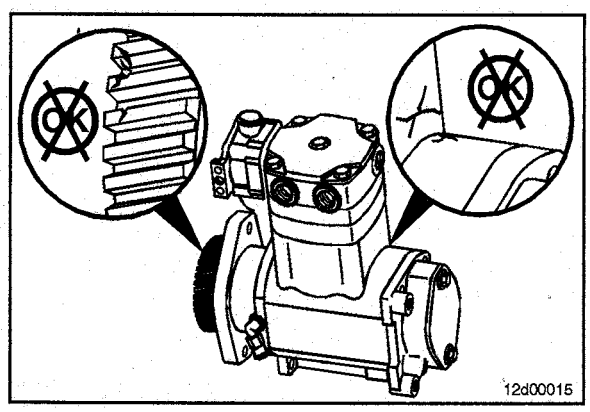
Remove the air connections from the air compressor.



Remove

Remove the air compressor support brackets and capscrews.

Remove the two capscrews and the air compressor.

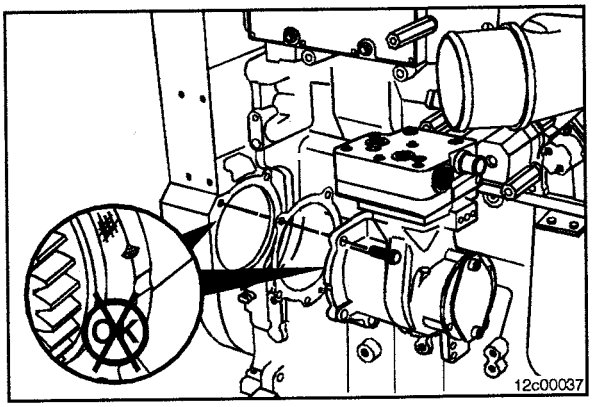


Clean and Inspect for Reuse

Inspect the compressor housing for cracks or damage.

Inspect the drive gear for cracks or damage.

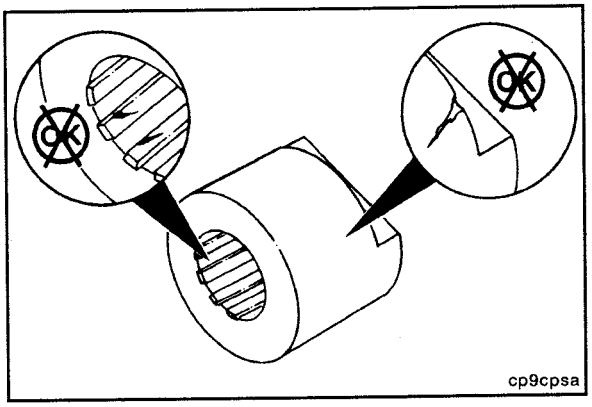
Be sure the gasket surfaces of the front gear housing and the air compressor are clean and **not** damaged.



Power Steering Coupling (if Applicable)

Inspect the power steering coupling for wear or cracks.

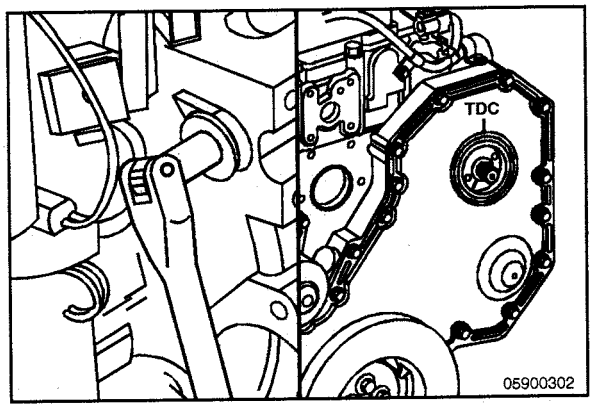
Replace the coupling if damaged. Refer to the OEM repair manual.



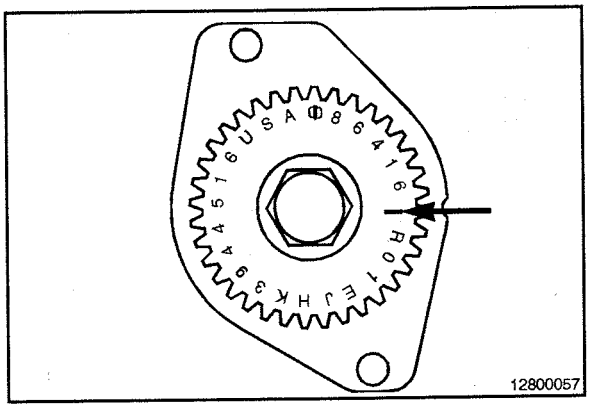
Install

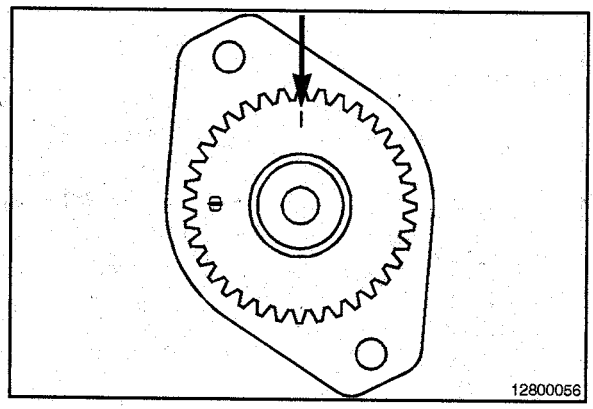
Air Compressor Timing (for Single-Cylinder Air Compressor **Only**)

Rotate the engine so that the number 1 cylinder is at top dead center on the compression stroke. This is done by aligning the timing mark on the fuel pump gear with the TDC mark.



NOTE: There are two similar marks on the air compressor gear that look like "[I]" and "I". The timing mark that is to be used when timing the air compressor to the engine is "I".

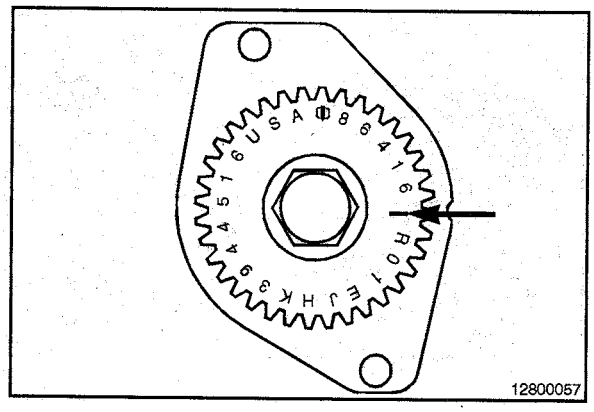




Holset® Air Compressors

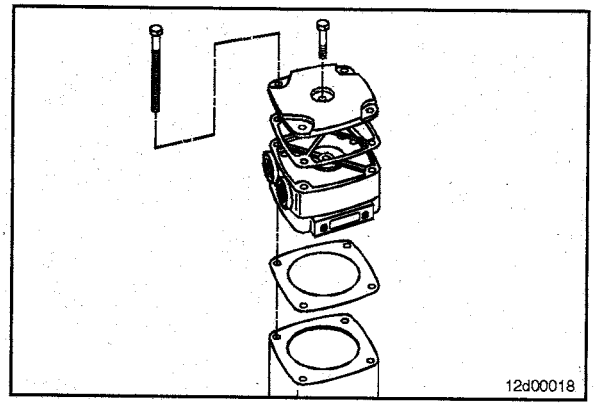
Viewing the compressor from the gear end (with the compressor n a vertical position), rotate the gear so the "I" timing mark is at the 12-o'clock position. This will set the compressor at 60-degrees before top dead center of the compressor's compression stroke.

NOTE: Some Holset® compressors have a divot or drilling on the housing at the 10-o'clock position; IGNORE this mark.



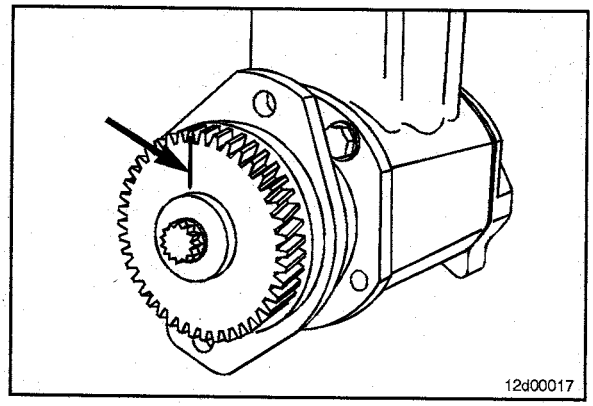
Cummins Single-Cylinder Air Compressors

Viewing the compressor from the gear end (with the compressor in a vertical position), rotate the gear so the "I" timing mark is at the 3-o'clock position. The Cummins single-cylinder air compressor will have a divot on the housing at the 3-o'clock position to aid in timing the compressor. Once the timing mark is at the 3-o'clock position, this will set the compressor at 60-degrees before top dead center of the compressor's compression stroke.



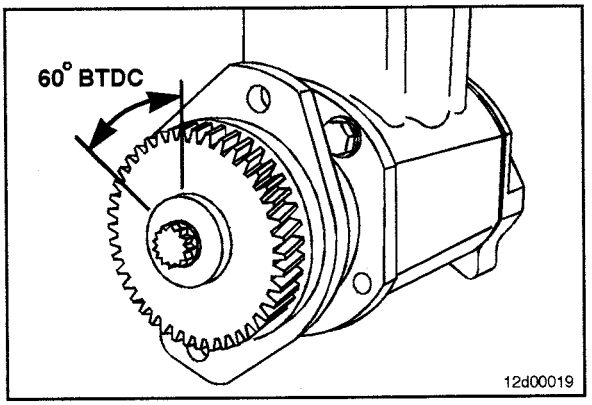
Air Compressor Timing (for Single-Cylinder Air Compressor **Only**, Other than Holset® or Cummins)

Locate TDC on the compressor crankshaft by removing the unloader valve or head. Refer to the respective air compressor manual. TDC does **not** have to be exact. The system is tolerant of some misalignment.



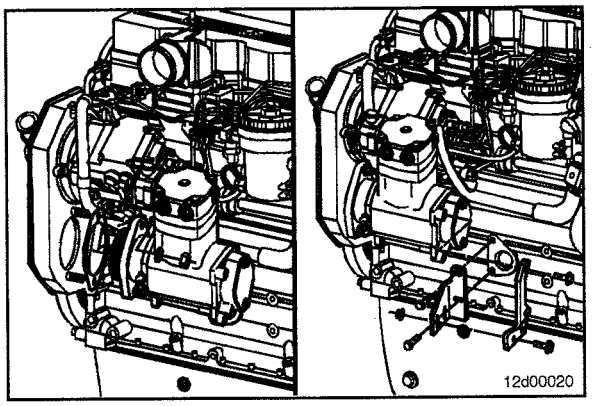
Use ink or dykem to mark the air compressor gear face at TDC (12-o'clock position when viewed from the front).

Rotate the compressor TDC mark to 60-degrees, or six teeth on a 36-tooth gear, before TDC. This is approximately 10-o'clock when viewed from the front of the air compressor.



Install the air compressor and new gasket to the gear housing.

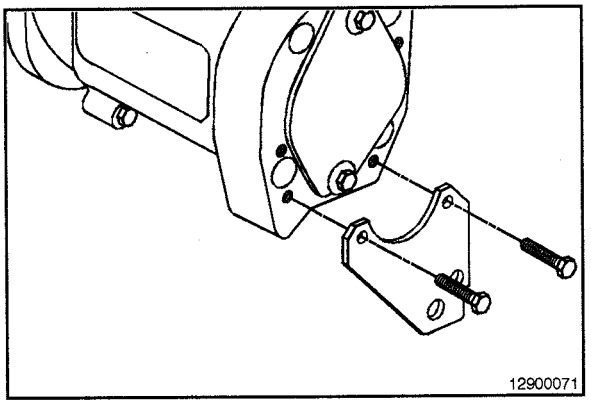
Torque Value: 77 N•m [57 ft-lb]



Install the brace to the air compressor.

Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]

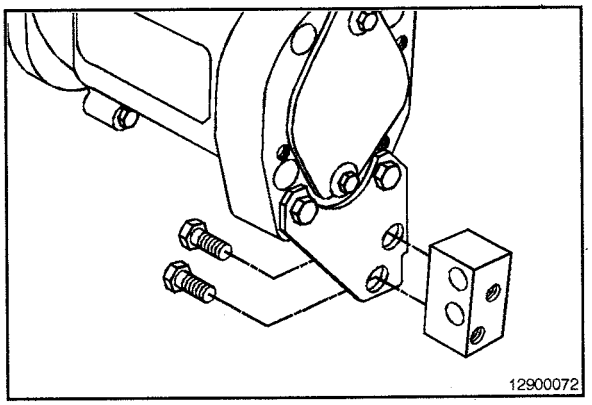


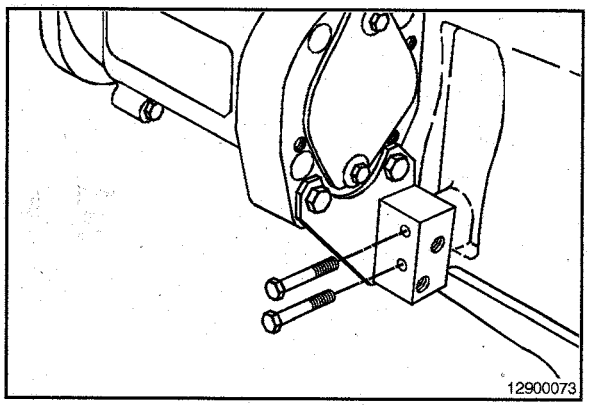
Install the spacer to brace capscrews and finger-tighten.

Make sure there are no gaps between the spacer and the brace, and no gaps between the spacer and the cylinder block.

Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]





Install the capscrews that connect the spacer to the cylinder block and finger-tighten.

Make sure there are no gaps between the spacer and the brace, and no gaps between the spacer and the cylinder block.

Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]

Finishing Steps

Install the oil supply line.

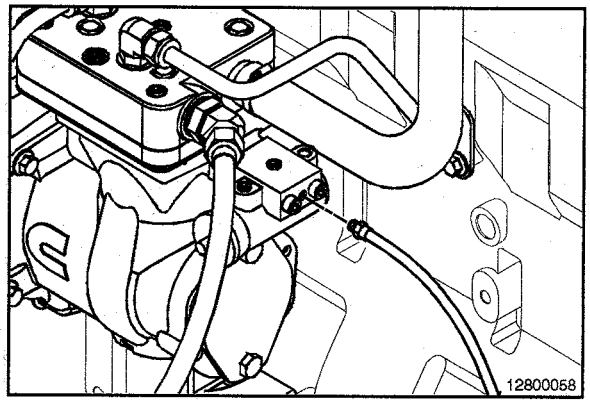
Install the coolant lines. Refer to Procedure 012-004.

Install the air lines.

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

Operate the engine and check for leaks.

Operate the engine to activate the air compressor.



Air Governor (012-016)

Measure

The air compressor governor location can vary. The air governor can be air compressor mounted or chassis mounted.

If the air pressure is being governed at either a higher or lower pressure than the equipment manufacturer's specification, connect a regulated shop air pressure line to the air compressor governor air signal port.

NOTE: Be positive that the 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.

NOTE: When performing the test, be sure that the air system pressure does **not** exceed the manufacturers maximum allowable pressure.

Run the engine and increase the signal pressure to the air governor to determine when the air compressor will stop pumping (system pressure stops rising at this point).

Reduce the signal pressure to determine when system pressure starts the air compressor pumping again (system pressure will begin to rise again at this point).

Compare these pressures with the manufacturer's specifications. If these pressures do **not** meet the specifications, the governor is malfunctioning and will need to be repaired, replaced, or adjusted. Refer to the manufacturer's instructions.

Air Leaks, Compressed Air System (012-019)

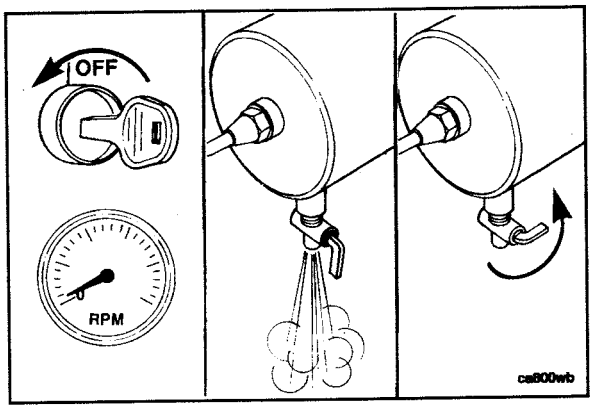
Initial Check

⚠WARNING⚠

Wear appropriate eye and face protection when releasing air pressure from the compressed air system. Flying debris and dirt can cause personal injury.

Shut off the engine.

Open the drain cock on the wet tank to release air from the system. Close the draincock after the pressure is released.

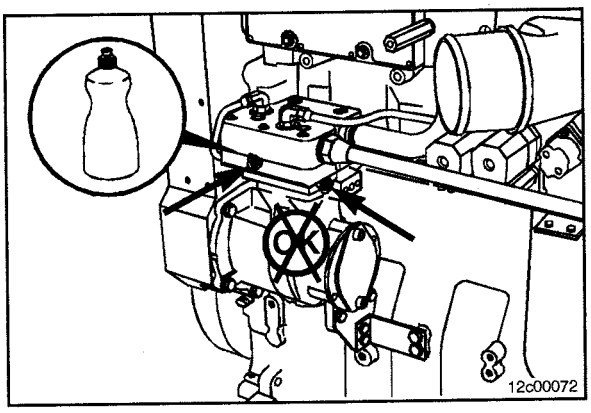


Operate the engine to activate the air compressor.

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 head gasket
- Air compressor cover gasket
- Hose and fitting leaks.

If air leaks are found, verify that the air compressor head and cover bolts are torqued properly. Make sure hoses and fittings are tight. Replace if necessary.

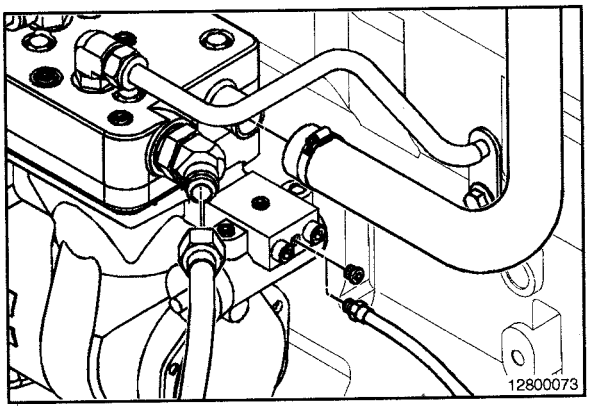


Air Pressure Relief Valve (012-024)

Test

Remove the air governor or air governor line from the air compressor.

Remove the air intake line from the air compressor cylinder head.



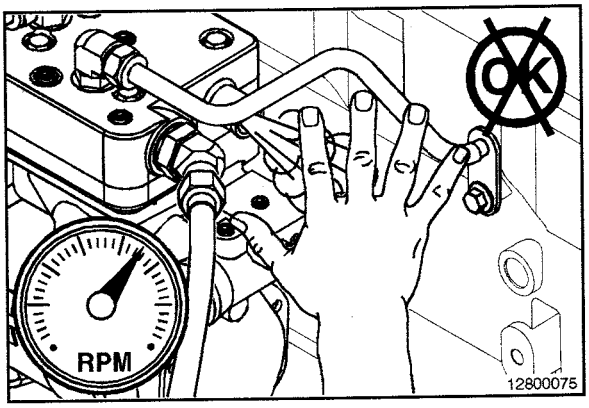
⚠WARNING⚠

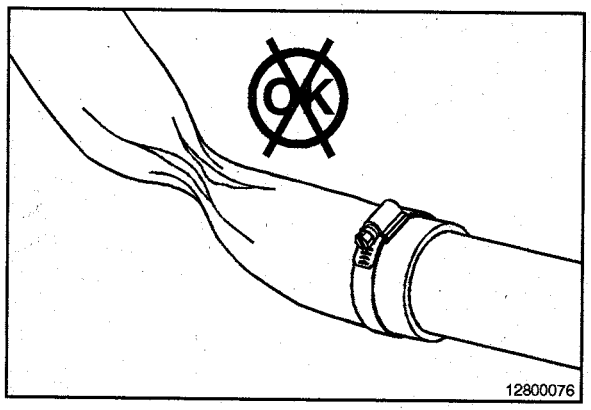
To avoid personal injury, do not hold your hand tool close to the intake port of the air compressor.

Operate the engine to activate the air compressor.

Hold your hand 5 cm [2 in] from the air compressor intake port. If air is coming out of the intake port, the pressure relief valve is malfunctioning and the air compressor cylinder head **must** be replaced.

Refer to Procedure 012-007.





If no air is felt from the intake port, check downstream air system components for damage or restrictions.

Section 13 - Electrical Equipment - Group 13

Section Contents

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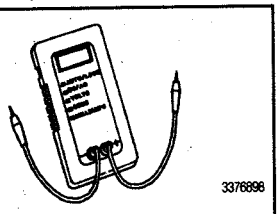
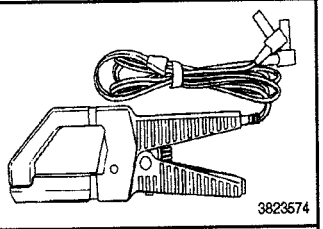
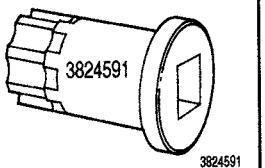
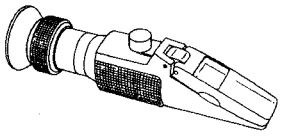
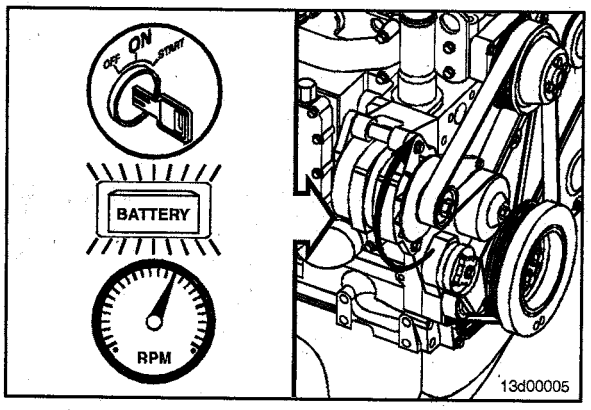
Service Tools

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.

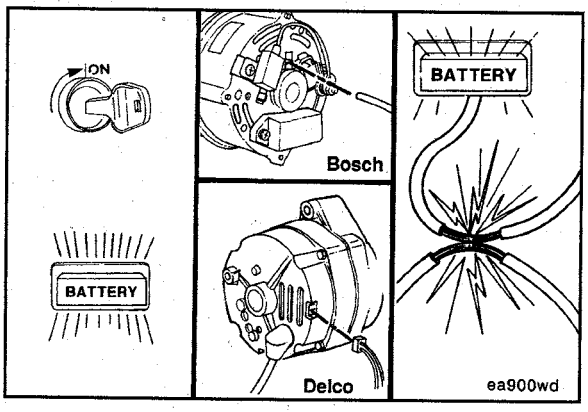
Tool No.	Tool Description	Tool Illustration
3164488	**Digital Multimeter** Used to measure voltage (volts) and resistance (ohms) in a circuit.	
3823574	**Clamp-on Current Probe** Used to measure current flow.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
CC-2800	**Refractometer** Used for Fleetguard® refractometer to check the charge condition of a conventional battery.	



Alternator (013-001)

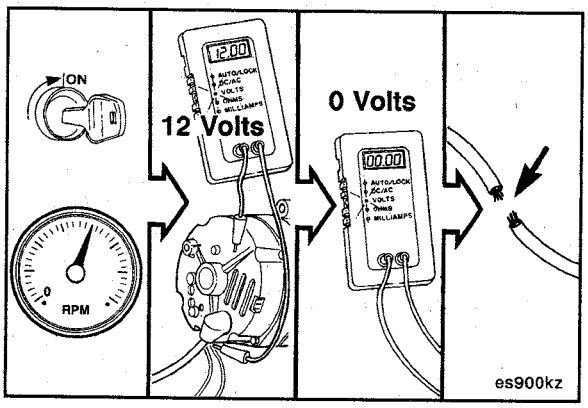
Initial Check

Check the drive belt and alternator pulley to be sure the alternator is rotating.



Check the battery and all wiring.

Inspect the wiring for defects. Check all connections for tightness and cleanliness, including the slip connectors at the alternator and firewall, and connections at the battery.

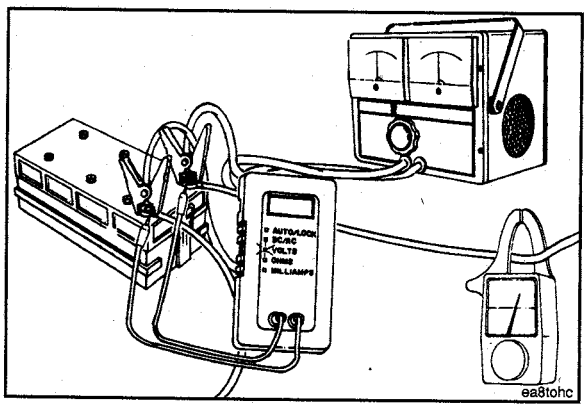


With the ignition switch "ON" and all wiring harness leads connected, connect a voltmeter from:

- Alternator "BAT" "B+" (Bosch®) terminal to ground
- Alternator Number 1 to ground
- Alternator Number 2 to ground
- Alternator D+ (Bosch® K1) to ground.

A zero reading indicates an open circuit between the alternator connections and the battery.

Locate and repair the open circuit.



Digital Multimeter, Part Number 3164488; Clamp-on Current Probe, Part Number 3823574:

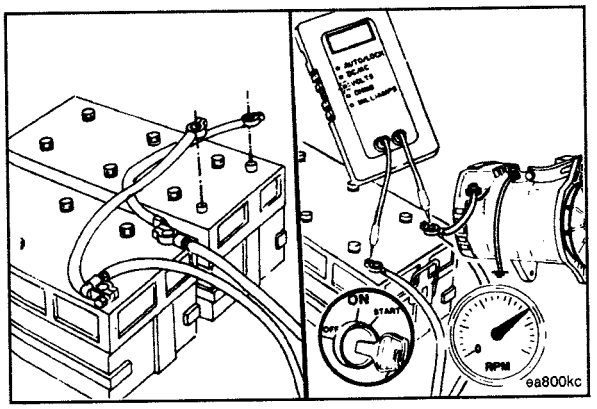
Connect a carbon pile load (battery tester) across the battery posts of the battery boxes.

Clamp an induction pickup type amp meter around the battery cable, or use the digital multimeter, Cummins Part Number 3164488, with the clamp-on current probe, Cummins Part Number 3823574.

Digital Multimeter, Part Number 3164488:

Disconnect any cables that lead to any other battery boxes in the circuit, negative (-) cables first.

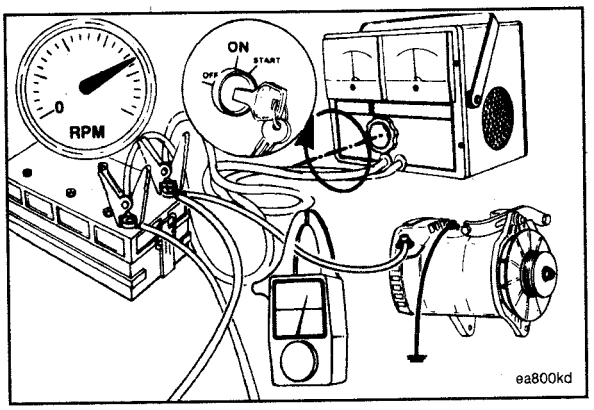
Operate the engine at high idle and measure the alternator voltage output to the batteries with digital multimeter, Part Number 3164488. Refer to the alternator manufacturer's specifications.



Operate the engine at high idle and adjust the systems analyzer/battery tester to apply the maximum rated amperage load to the alternator. Refer to the alternator manufacturer's specifications.

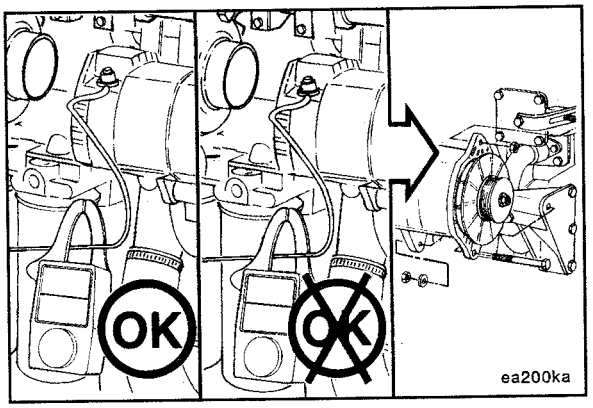
NOTE: The alternator maximum rated amperage output is normally stamped or labeled on the alternator.

Measure the alternator amperage output. Refer to the alternator manufacturer's specifications.



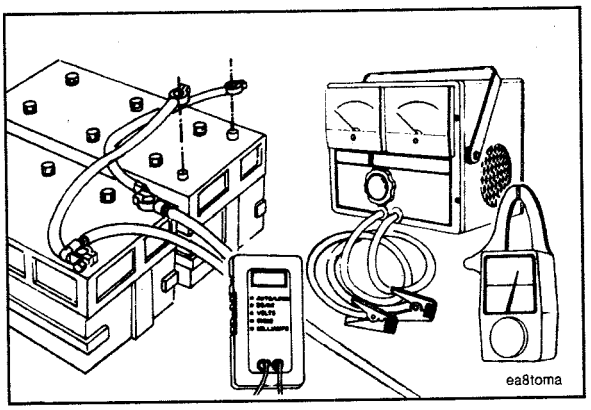
If the gauge on the carbon pile load testing equipment does **not** indicate approximately the same output as the induction-type ampmeter, determine which is defective and replace it. Refer to the alternator manufacturer's specifications.

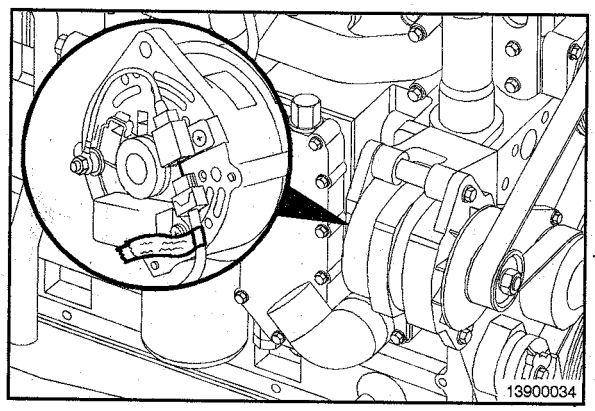
If the alternator output (amps) is **not** within 10 percent of rated output, repair or replace the alternator. Refer to the alternator manufacturer's instructions for repair procedures.



Shut off the engine and remove the test equipment.

Connect all battery cables, negative (-) cable last.





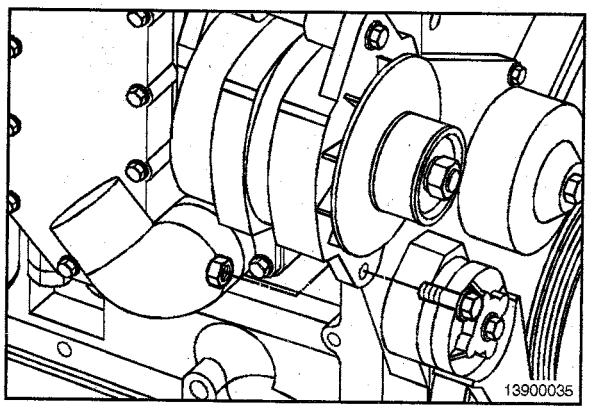
Remove

⚠WARNING⚠

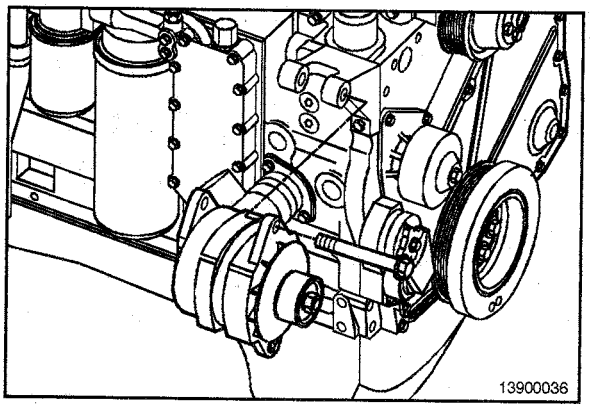
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Remove and tag all wires and complete the following steps:

- Disconnect the ground cable from the battery terminal.
- Remove the drive belt from the alternator pulley. Refer to Procedure 013-005.

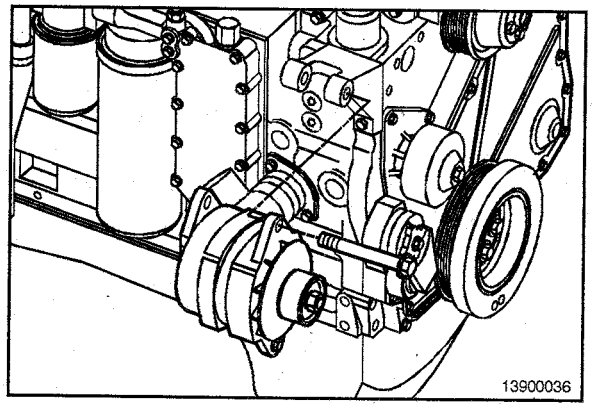


Remove the alternator link capscrew.



Remove the alternator mounting capscrew.

Remove the alternator.



Install

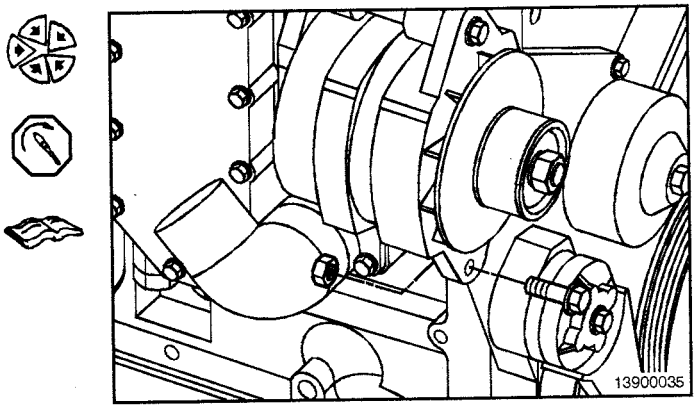
Install the alternator and alternator capscrews in the reverse order of removal.

Torque Value: 43 N•m [32 ft-lb]

Install the alternator link capscrew.

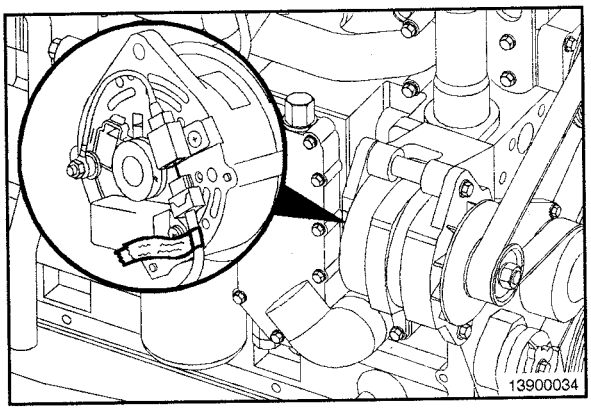
Torque Value: 24 N•m [18 ft-lb]

Install the drive belt. Refer to Procedure 008-002.



Connect all wires to the alternator.

Connect the battery ground cable.

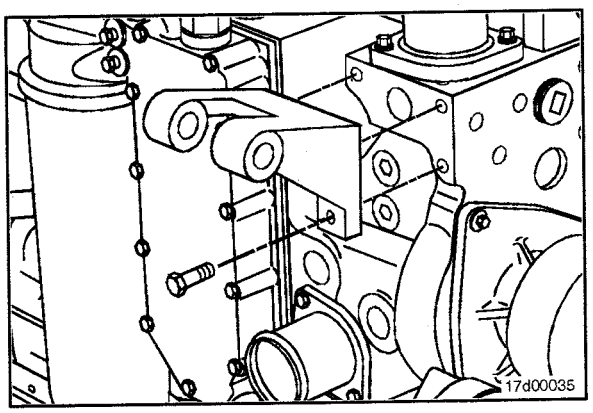


Alternator Bracket (013-003)

Remove

Remove the alternator. Refer to Procedure 013-001.

Remove the alternator bracket mounting capscrews and bracket.

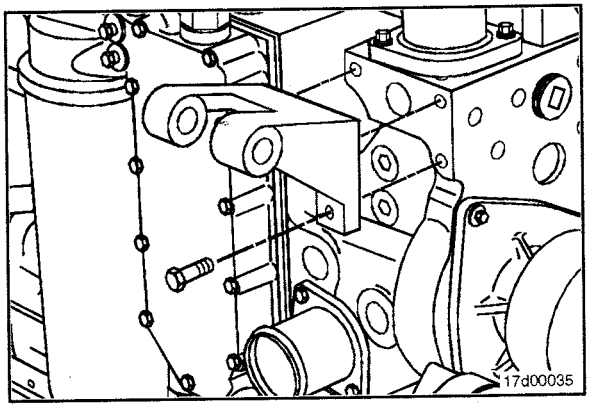


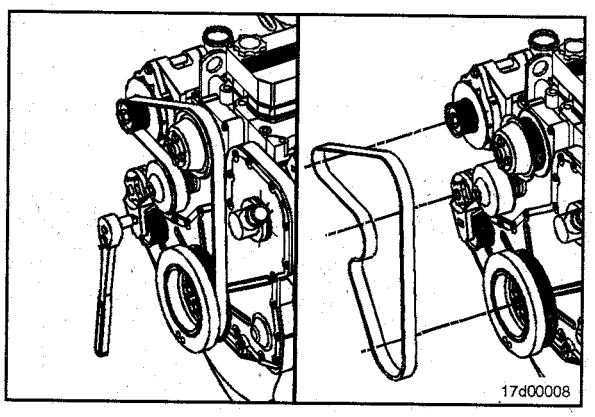
Install

Install the mounting bracket and bracket mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]

Install the alternator. Refer to Procedure 013-001.



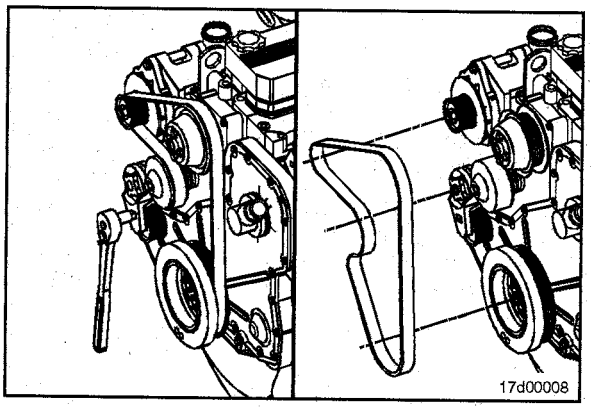


Drive Belt, Alternator (013-005)

Remove

Lift the tensioner to relieve tension on the belt and remove the belt.

Refer to Procedure 008-002.

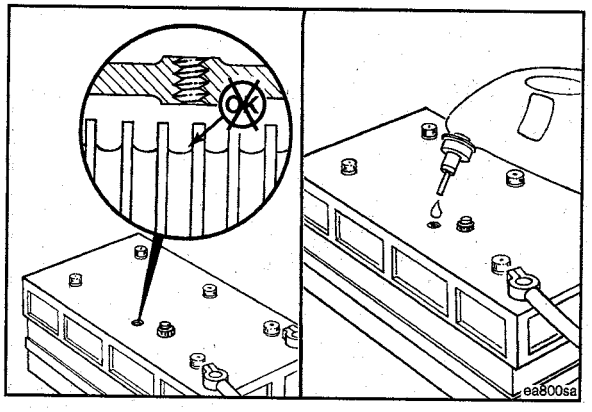


Install

Lift and hold the belt tensioner. Install the drive belt and release the tensioner.

Refer to Procedure 008-002.

NOTE: If difficulty is experienced installing the drive belt (i.e., the belt seems too short), position the belt over the grooved pulleys first and then, while holding the tensioner up, slide the belt over the water pump pulley.



Batteries (013-007)

Initial Check

⚠WARNING⚠

Acid is 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 reduce the possibility of serious personal injury.

If conventional batteries are used, remove the cell caps or covers and check the electrolyte level.

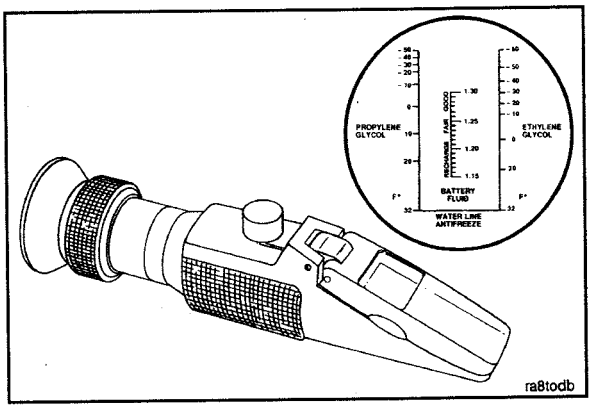
NOTE: Maintenance-free batteries are sealed and do **not** require the addition of water.

Fill each battery cell with distilled water. Refer to the battery manufacturer's specifications.

Use the Fleetguard® Refractometer, Part Number 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.

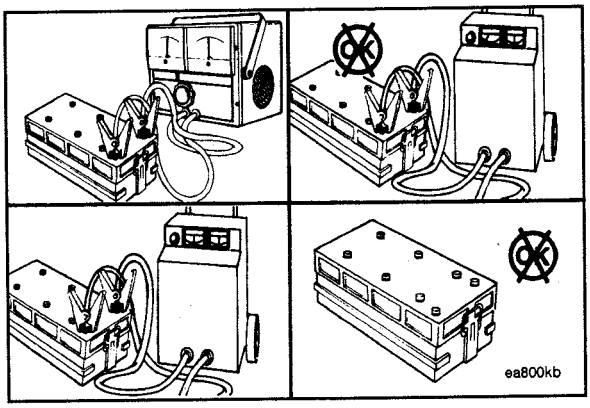
If water has been added to a dry cell, recharge the battery to mix the added water with the existing battery electrolyte to prevent inaccurate readings.



Use a battery tester 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's instructions.

Replace the battery if it will **not** charge to the manufacturer's specifications, or will **not** maintain a charge.



Battery Cables and Connections (013-009)

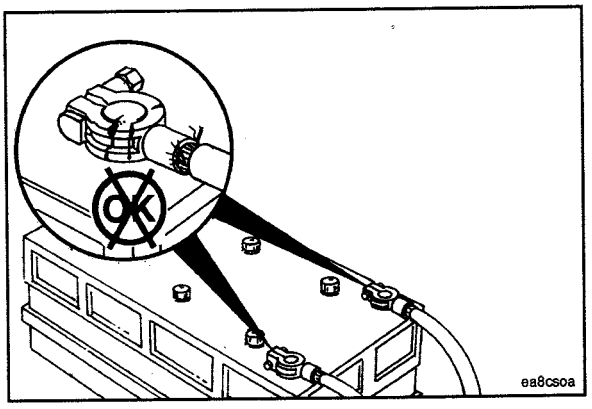
Initial Check

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Inspect the battery terminals for loose, broken, or corroded connections.

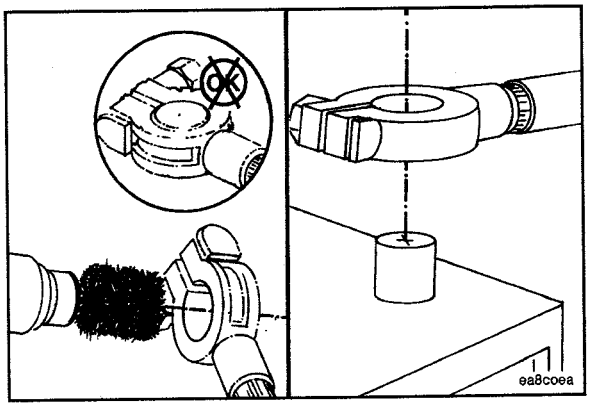
Repair or replace broken cables or terminals.

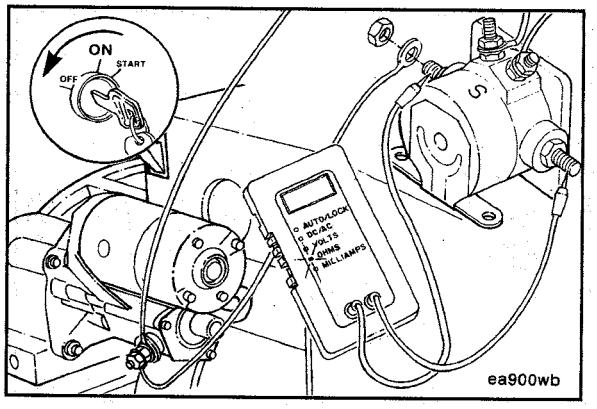


If the connections are corroded, remove the cables and use a battery brush to clean the cable and battery terminals.

Install and tighten the battery cables.

Use grease to coat the battery terminals to prevent corrosion.



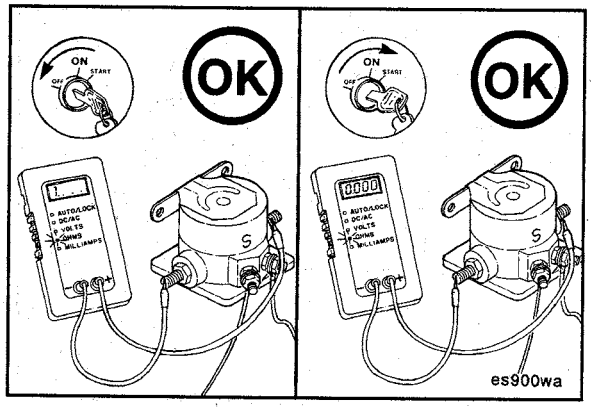


Starter Magnetic Switch (013-017)

Resistance Check

Remove the cable connecting the magnetic switch to the starting motor solenoid, from the magnetic switch terminal.

Set the digital multimeter, Cummins Part Number 3164488, to measure resistance (ohms).

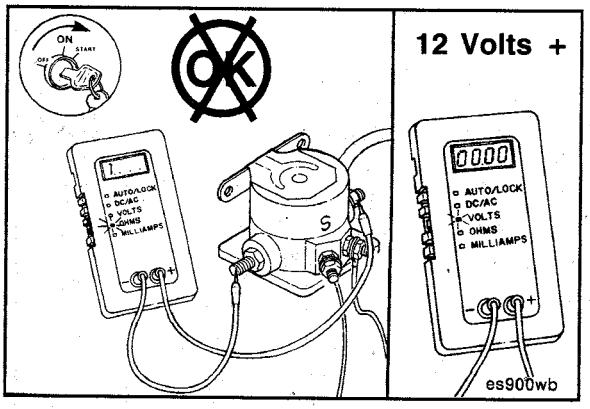


Connect the leads to the two large switch terminals.

With the starting motor switch in the OFF position, the multimeter **must** indicate resistance greater than 100k ohms.

Turn the starting motor switch to the START position.

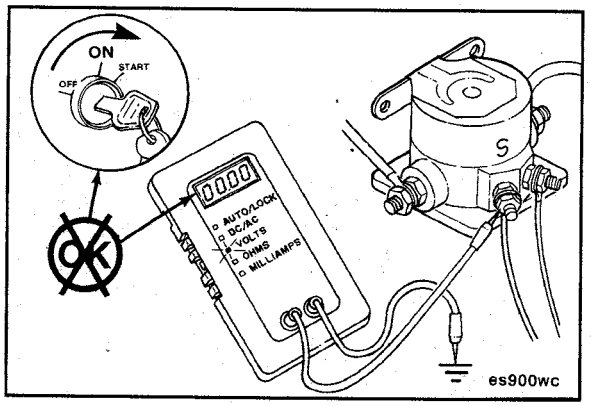
The multimeter **must** indicate less than 10 ohms. If **not** within specifications, replace the starter magnetic switch according to the manufacturer's instructions.



Voltage Check

If the multimeter indicates resistance at greater than 100k ohms with the starting motor switch in the "START" position, turn the starting motor switch to the "OFF" position.

Set the multimeter scale to read DC voltage.



Connect one multimeter lead to the magnetic switch terminal marked "S" and the other lead to the ground.

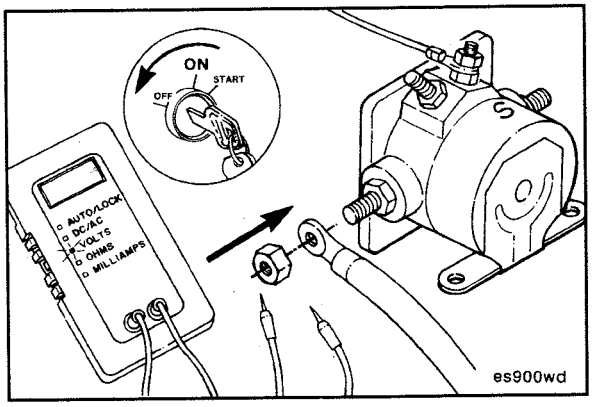
Turn the starting motor switch to the "START" position.

If the multimeter indicates no voltage, the magnetic switch is **not** the cause of the complaint. Refer to Procedure 013-018.

If the starter magnetic switch is **not** within specification, replace the switch according to the manufacturer's instructions.

Turn the starting motor switch to the "OFF" position.

Remove the multimeter leads and connect the magnetic switch to the starting motor solenoid wire.



Starter Switch (013-018)

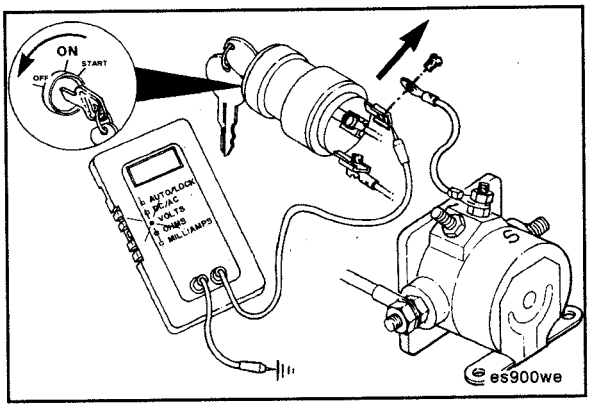
Voltage Check

⚠WARNING⚠

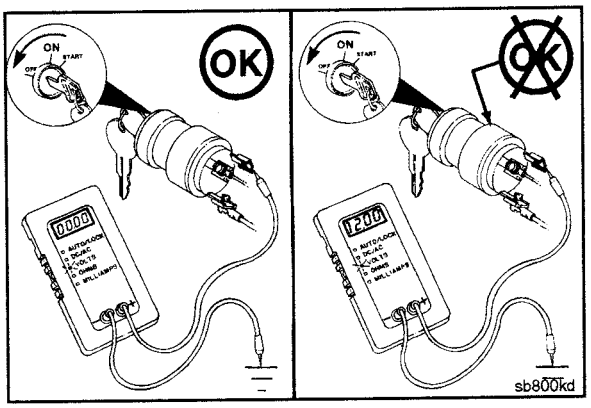
Be sure the starting motor switch is in the "OFF" position to prevent electrical shock and personal injury.

Remove the wire connecting the starting motor switch to the magnetic switch (marked "S" or "START") from the starter switch terminal.

Connect the positive (+) lead of the digital multimeter, Cummins Part Number 3164488, or equivalent to the starter switch terminal and the negative (-) lead to a chassis or engine ground location.

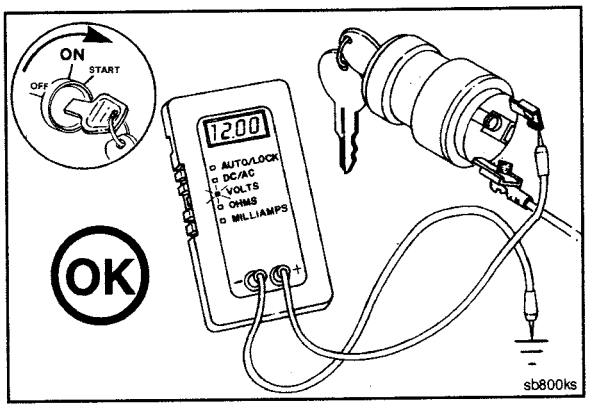


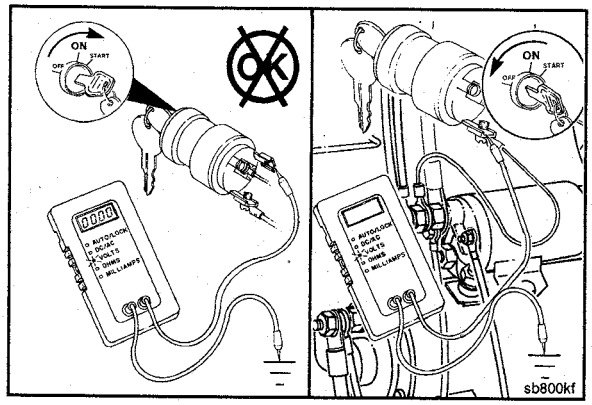
NOTE: Set the multimeter to indicate DC volts with the starting motor switch in the "OFF" position, there must **not** be voltage at the starter switch terminal. If the meter indicates voltage, the starter switch is malfunctioning and **must** be replaced.



Turn the starting motor switch to the "START" position.

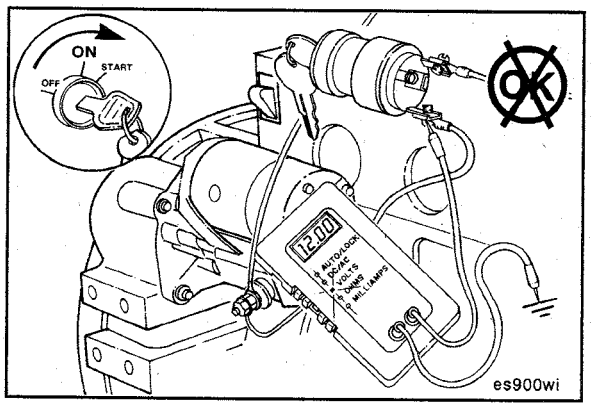
The multimeter **must** indicate system voltage.





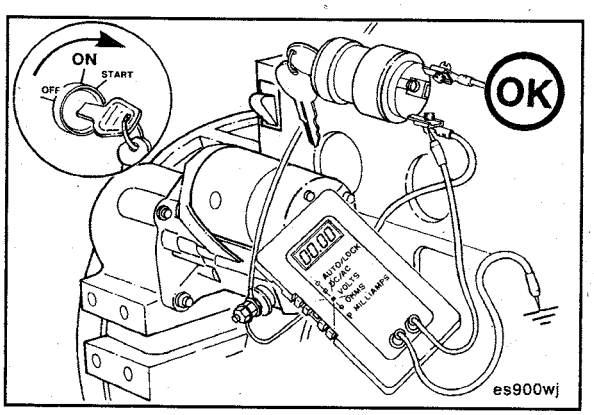
If there is **no** voltage, turn the starting motor switch to the "OFF" position.

Connect the multimeter positive (+) lead to the starter switch terminal having a wire connecting the starter switch to the starting motor solenoid B terminal.



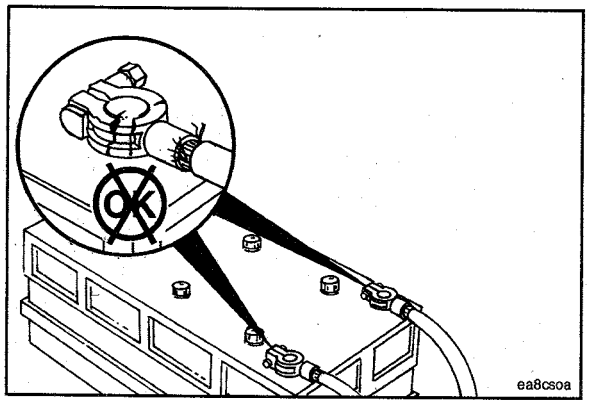
Turn the starting motor switch to the "START" position.

If the meter indicates system voltage at the starter switch input terminal, the starter switch is defective and **must** be replaced. Refer to the manufacturer's procedure for replacement.



If the meter indicates no voltage, the switch is **not** the cause of the complaint.

Check the wiring from the starter switch to the starting motor solenoid B terminal and from the starting motor solenoid to the battery for broken or damaged wires.

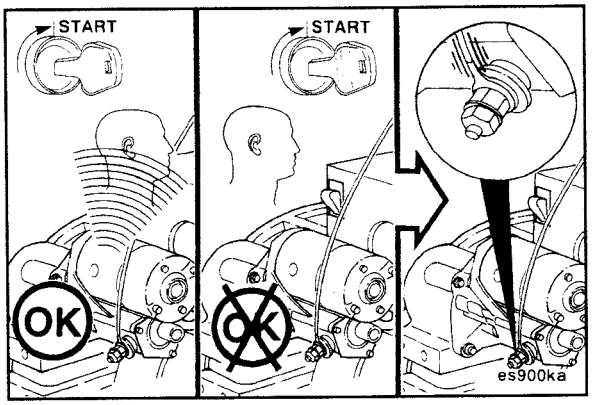


Starter Solenoid (013-019)

Initial Check

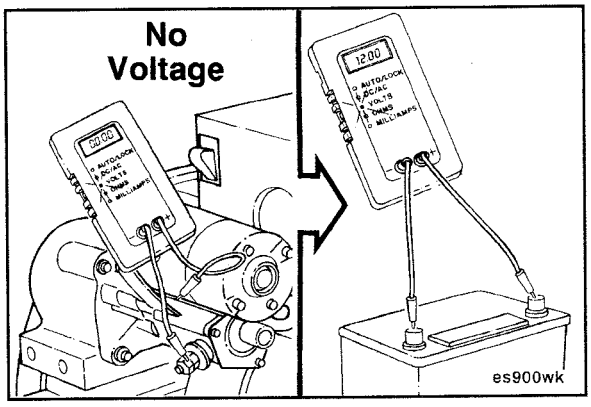
Before troubleshooting the starting motor, make sure the battery terminals are **not** loose or corroded.

If the starting motor solenoid does **not** make an audible sound, check for loose wiring connections.



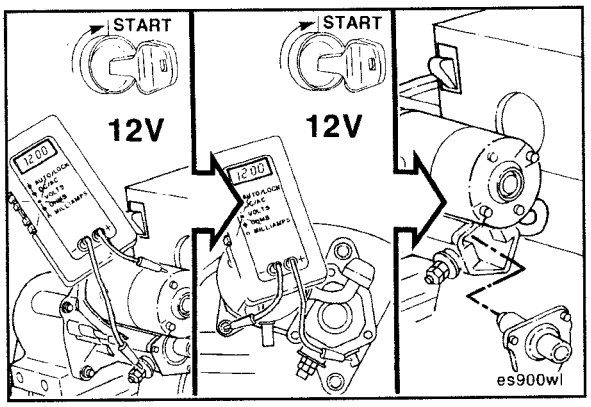
Use a digital multimeter, Cummins Part Number 3164488, or equivalent, to set the voltage scale.

Check for system voltage at the starting motor solenoid battery terminal.



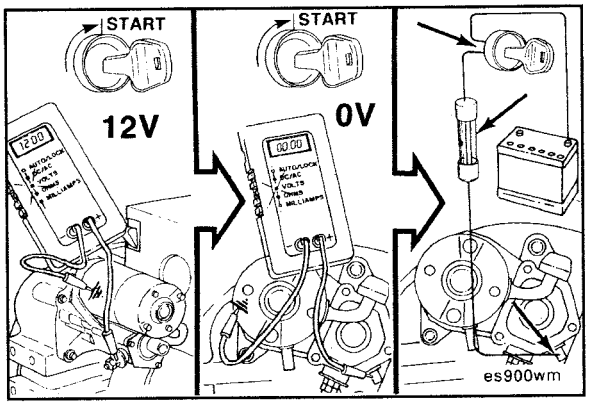
If the multimeter indicates system voltage at the starting motor battery terminal, check the voltage at the starting motor solenoid S terminal, when the starting switch is energized.

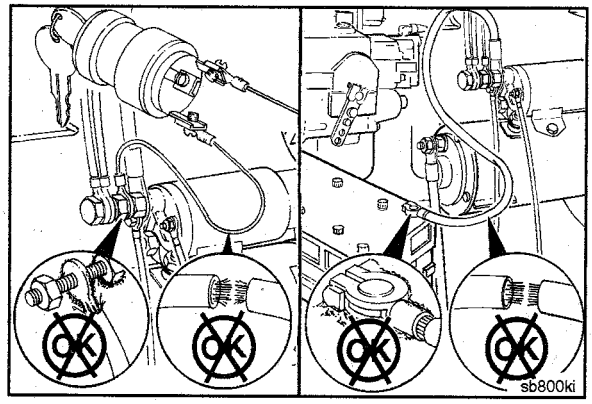
If the multimeter indicates system voltage at the S terminal, but the starter does **not** engage, the starting motor solenoid is malfunctioning and the starter **must** be replaced. Refer to Procedure 013-020.



If the multimeter does **not** indicate system voltage at the S terminal, check:

- Fuses
- Voltage to the ignition switch and magnetic switch. Refer to "Starting Motor Switch and Magnetic Switch - Checking" in this section. Refer to Procedures 013-017 and 013-018
- Application safety shutoff systems



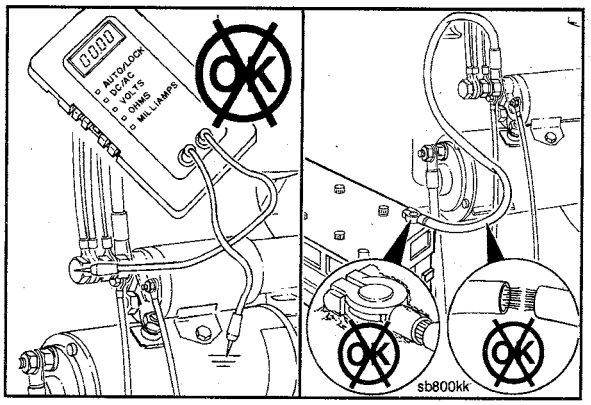


Voltage Check

Set the digital multimeter, Part Number 3164488, to measure DC voltage.

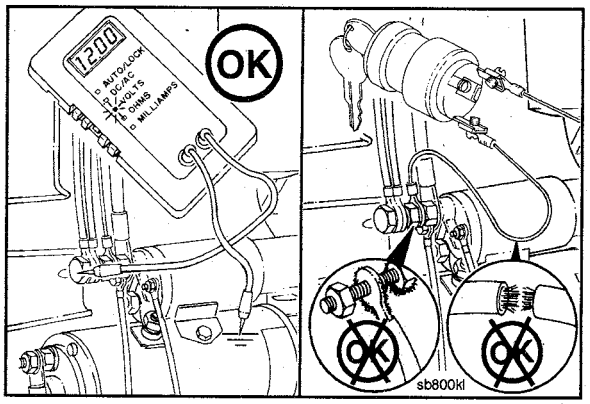
Connect the multimeter positive (+) lead to the starter solenoid positive cable terminal and the negative (-) lead to a chassis or engine ground location.

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.

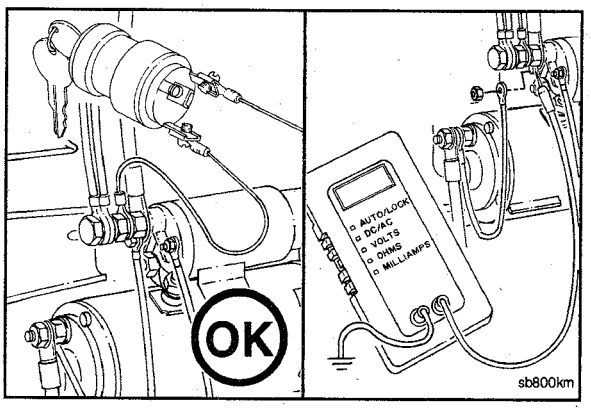


If the multimeter indicates a voltage, but the starter will **not** operate, check the wire connecting the starter solenoid to the starter switch for breaks.

Also check for loose or corroded connections.

Be sure to check for:

- Fuses
- Application engine shutoff systems.

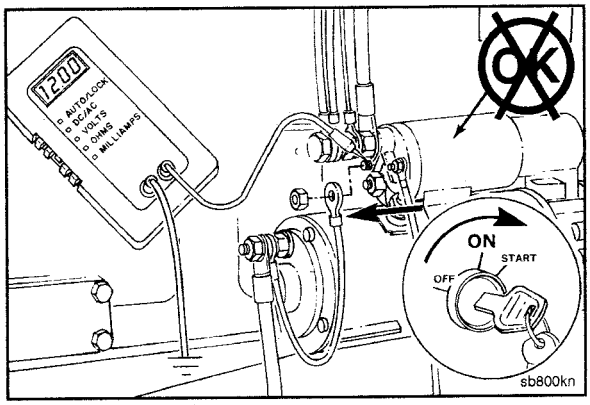


If the wire connecting the starter solenoid and starter switch is **not** loose or damaged, and the starter will **not** operate, remove the cable connecting the starter and starter solenoid from the solenoid terminal.

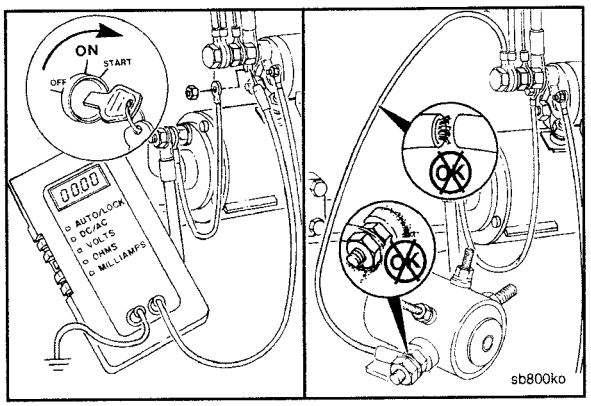
Connect the multimeter positive (+) lead to the solenoid positive (+) terminal and the negative (-) lead to the chassis or an engine ground location.

Turn the starter switch to the "START" position.

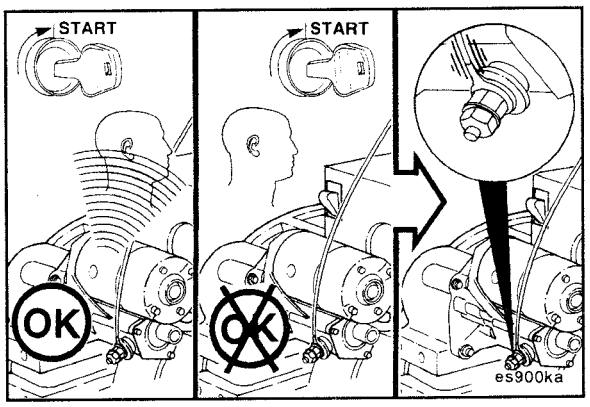
If the multimeter indicates a voltage, the starter solenoid is malfunctioning and **must** be replaced.



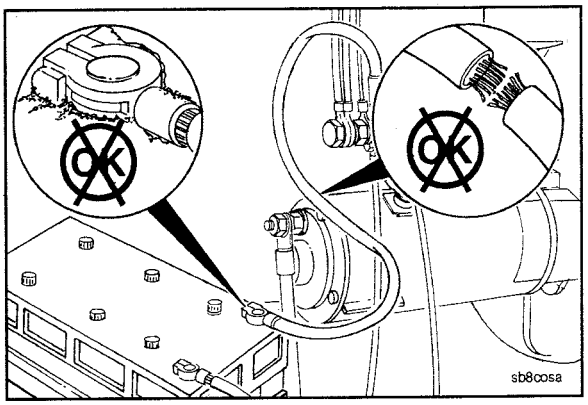
If the multimeter does **not** indicate a voltage, check the wire connecting the starter solenoid to the magnetic switch for breaks, and for loose or corroded connections.

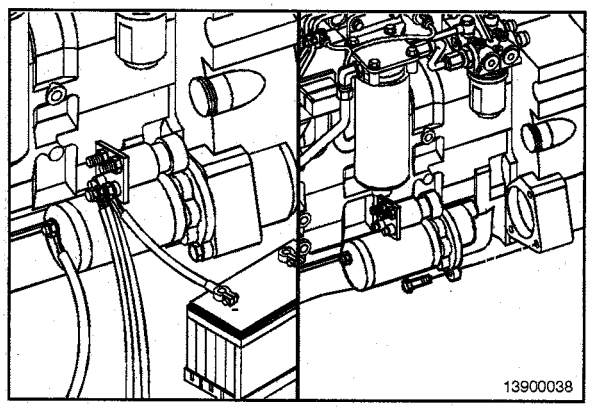


If the wire connecting the starter solenoid to the magnetic switch is **not** loose or damaged and the starter will **not** operate, check the cable connecting the starter solenoid to the starting motor for breaks, and for loose or corroded connections.

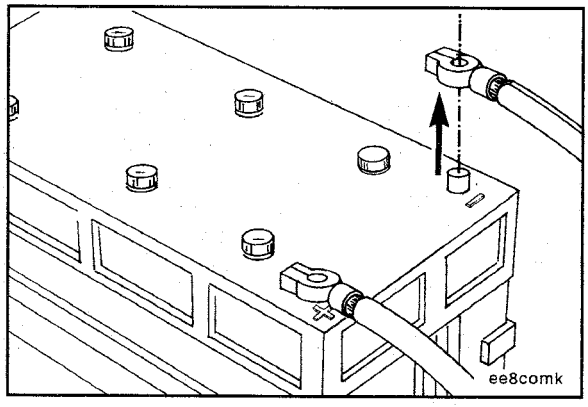


Check the cable connecting the starting motor to the battery for breaks, and for loose or corroded connections.





If the cables are **not** loose or damaged, the starting motor is defective and **must** be replaced. Refer to Procedure 013-020.



Starting Motor (013-020)

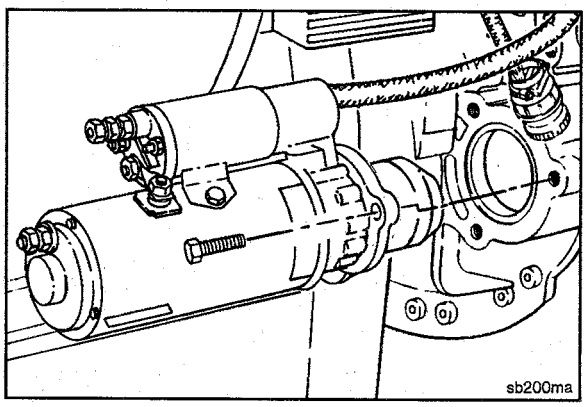
Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the ground cable from the battery terminal.

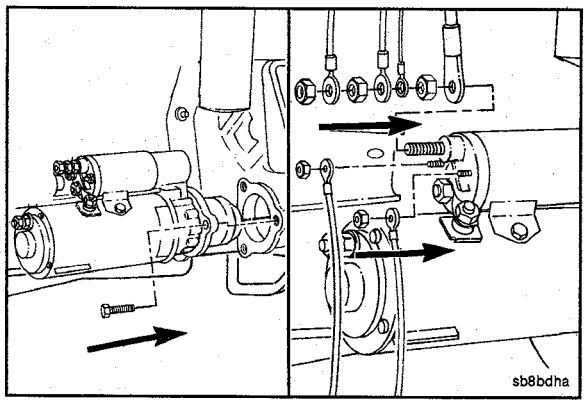
Remove and tag all wires.



Remove

Remove the three capscrews and the starting motor.

If equipped with a starting motor spacer, remove the spacer and clean all surfaces between the starting motor, starting motor spacer, and flywheel housing with a wire brush.



Install

Install the starting motor in the reverse order of removal.

Torque Value: 43 N•m [32 ft-lb]

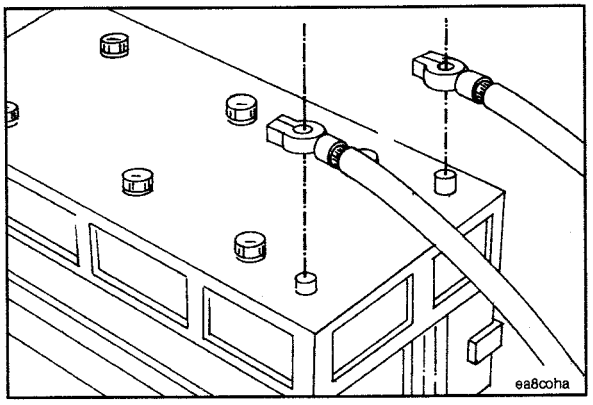
Connect all electrical connections to the starting motor.

Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

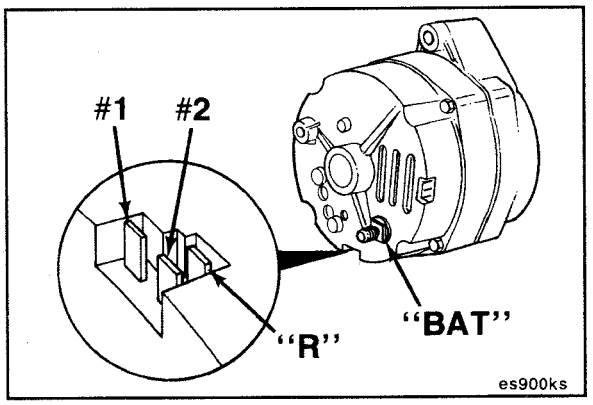
Install and tighten the battery electrical connections. Connect the negative (-) cable last.



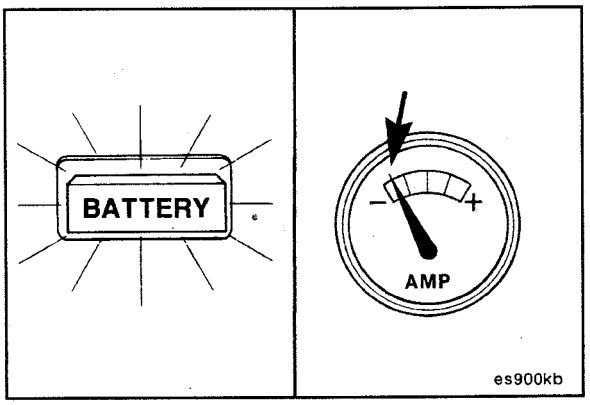
Charging System Indicator (013-023)

Initial Check

Be sure the correct terminals are being used on the alternator. The R terminal (Delco®) or W terminal (Bosch® K1) provide half of the system voltage and is used to operate accessories such as the tachometer on generator sets.

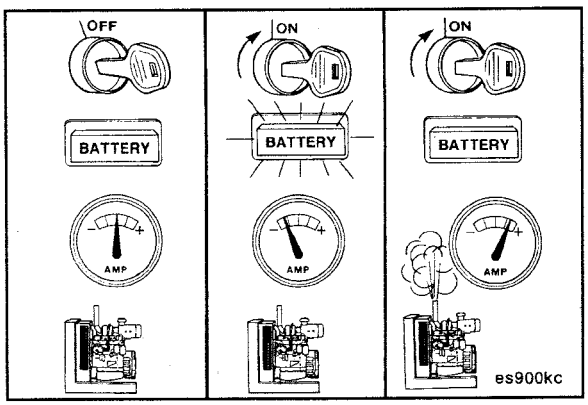


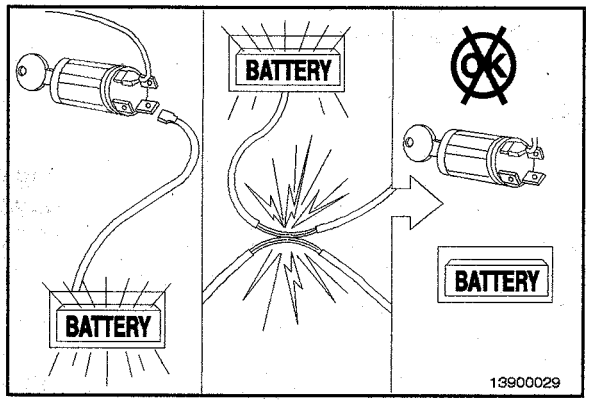
Trouble with the starting system can be indicated by the indicator lamp or ampmeter.



Check the indicator lamp for normal operation as shown below:

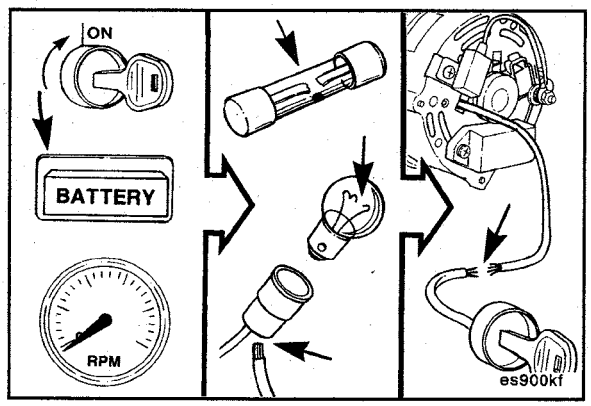
Engine	Switch	Lamp	Ampmeter
Stopped	OFF	OFF	0
Stopped	ON	ON	-
Running	ON	OFF	+





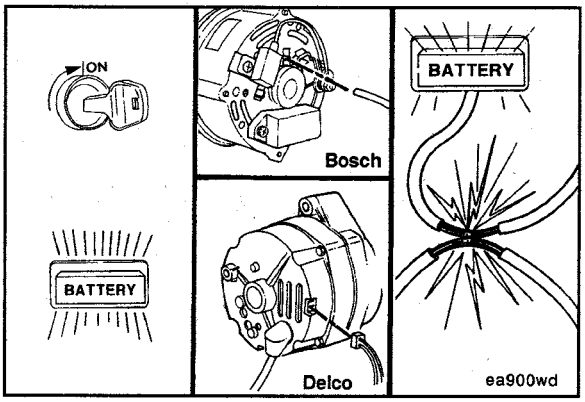
If the lamp is on when the switch is OFF and the engine is **not** running, disconnect the lamp lead at the ignition switch.

- If the lamp stays on, there is a short to a positive wire.
- If the lamp goes out, there is a short in the switch.



If the lamp goes off when the switch is ON and the engine is **not** running, there can be an open in the circuit.

Check for a blown fuse, a burned out bulb, defective bulb socket, or an open in the No. 1 or D (+) lead circuit between alternator and ignition switch.



If the lamp is on when the switch is ON and the engine is running, disconnect the lead to the alternator.

- If the lamp stays on, there is a short to the ground in the lamp circuit.
- If the lamp goes out, inspect the alternator.

Section 14 - Engine Testing - Group 14

Section Contents

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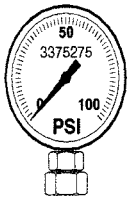
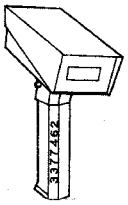
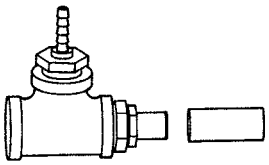
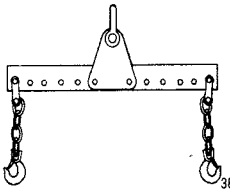
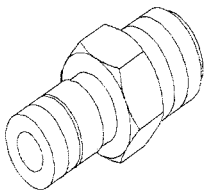
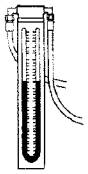
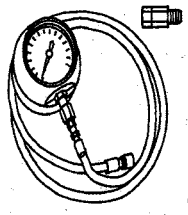
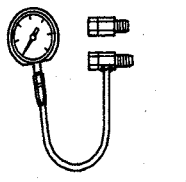
Service Tools

Engine Testing

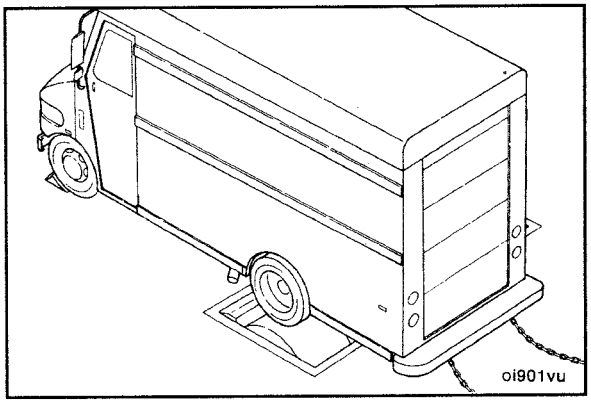
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3375275	**Pressure Gauge (0 to 1103 kPa [0 to 160 psi])** Used to measure lubricating oil pressure.	 3375275
3377462	**Digital Optical Tachometer** Used to measure engine speed (rpm)	 3377462
3822566	**Blowby Checking Tool** Used to check engine crankcase blowby.	 eg8loge
3162871	**Engine Lifting Fixture** Used to remove and install the engine.	 3822512
3824843	**Compuchek® Fitting** Used for connection to diagnostics machine.	 3824813
ST-1111-3	**Manometer** Used with the blowby check tool to measure engine crankcase pressure.	 st-1111-3

Tool No.	Tool Description	Tool Illustration
ST-1273	**Pressure Gauge** Used to measure engine intake manifold pressure, exhaust restriction, lift pump output pressure, and pressure drop across fuel filter.	
ST-434	**Vacuum gauge** Used to measure lift pump inlet restriction. Hose adapter, Cummins Part Number ST-434-2, and Vacuum Gauge, ST-434-12, are used to perform the test.	

Engine Testing (Chassis Dynamometer) (014-002)

Setup



The performance of an engine installed in on-highway vehicles can be tested on a chassis dynamometer.

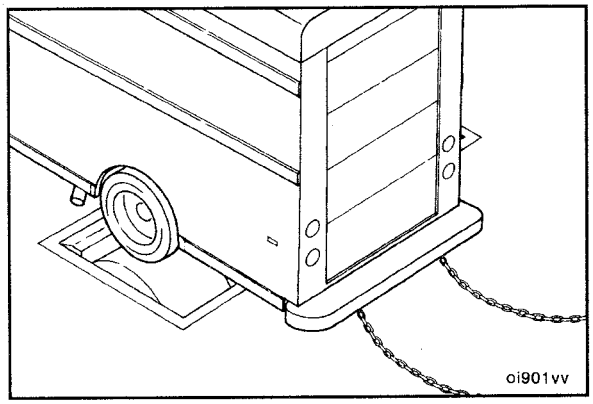
NOTE: Because of driveline efficiency and engine-driven accessories, the engine horsepower when measured at the rear wheels will be reduced by approximately:

- 20 percent for single-axle vehicles
- 25 percent for tandem-axle vehicles
- 35 percent for recreational vehicles.

NOTE: These percentages are used for engine run-in **only** and are **not** to be used as absolute figures.

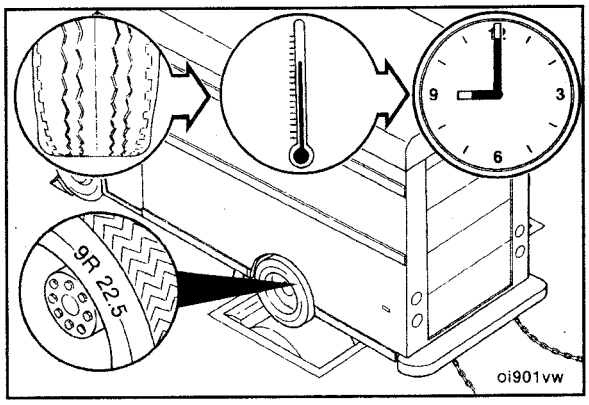
⚠WARNING⚠

Follow all of the vehicle manufacturer's safety precautions before installing or operating a vehicle on a chassis dynamometer. Failure to do so can cause damage to the vehicle and/or harm personnel.



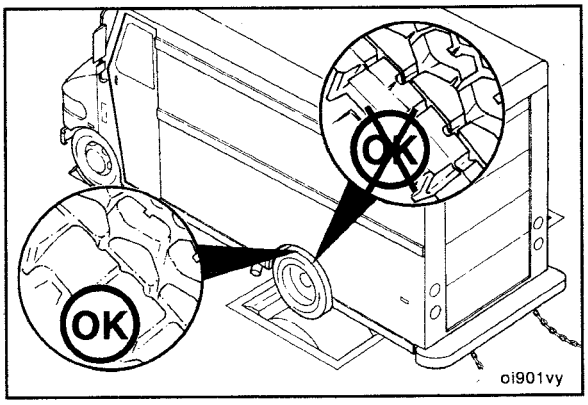
⚠CAUTION⚠

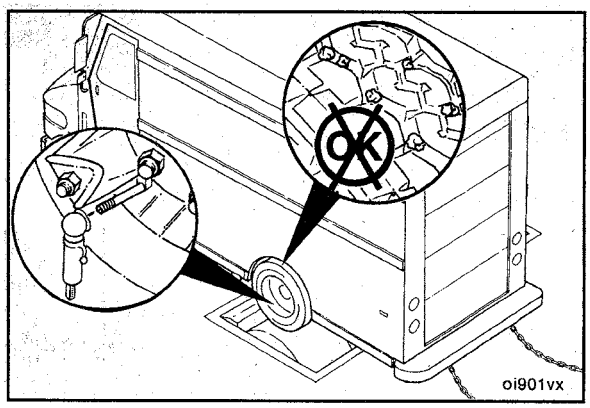
Low-profile tires are more sensitive to heat than bias ply tires. Excessive operating time at full load can damage the tires due to overheating. Check the tire manufacturer's recommendations for the maximum allowable chassis dynamometer operating time.



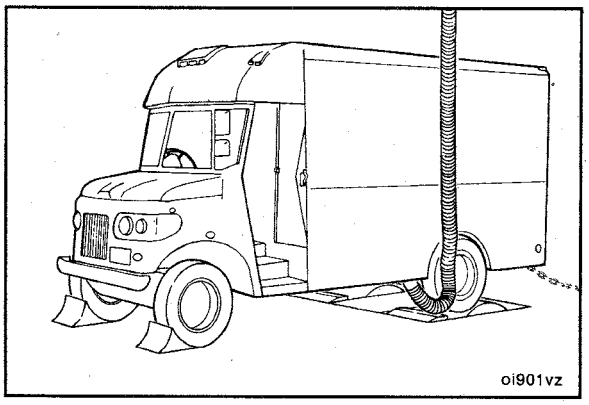
While operating the chassis dynamometer, follow the general safety precautions listed below:

Use tires that have more than 160 km [100 mi] of use.
Do **not** use new tires.
Do **not** use recapped tires or tires of different sizes or designs.

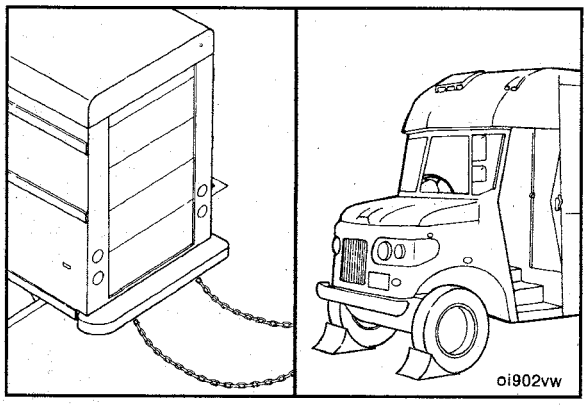




Make sure the tires are inflated to the manufacturer's specifications.
Remove all rocks or other materials from the treads of the tires that will be rotating on the dynamometer rollers.



Make sure there is correct overhead clearance for exhaust stacks, air deflectors, or other attachments above the cab.



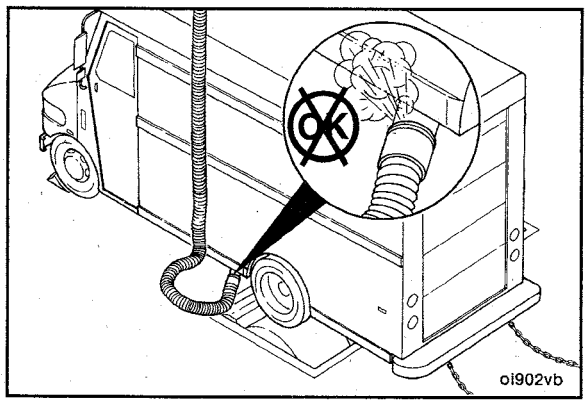
Carefully position the vehicle on the rollers.

△CAUTION△

To prevent damage to the chassis dynamometer, make sure there is enough slack in the tie-down chains.

Attach the tie-down chains to the rear of the vehicle.

Place wheel chocks in front of the front tires.



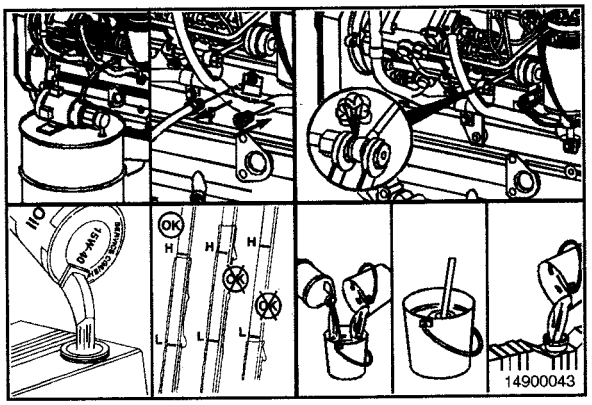
⚠WARNING⚠

Some exhaust gas constituents may be toxic and/or carcinogenic. Make sure the ventilation hose does not leak.

Adjust the vehicle and dynamometer room exhaust system to make sure all the exhaust gases are removed from the room.

Read the chassis dynamometer and vehicle manufacturer's recommendations and specifications for testing procedures.

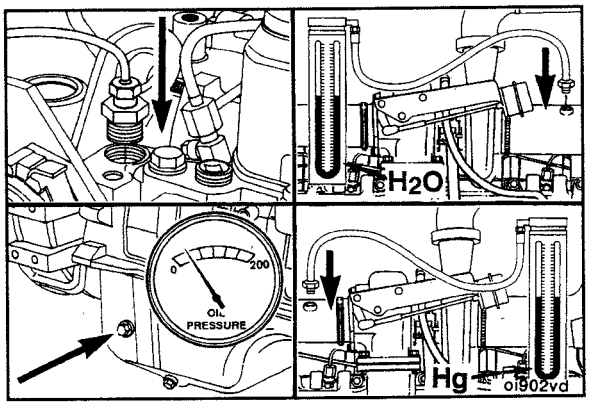
Test



⚠ 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.

The following procedure assumes that the lubricating oil and fuel systems were correctly primed, the dipstick calibrated, and the engine filled to the correct levels with lubricating oil and coolant during installation of the engine into the chassis. If these systems were **not** serviced during installation of the engine, Refer to Procedure 014-006 in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193, or Procedure 014-006 in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087, or Procedure 014-006 in the Troubleshooting and Repair Manual, ISC, ISC^e, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418, or Procedure 014-006 in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003, or Procedure 014-006 in the Troubleshooting and Repair Manual, ISB, ISB^e 4 and 6 Cylinder, Bulletin 4021271, or Procedure 014-006 in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207, for instructions on priming the lubricating oil and the fuel system and calibrating the dipstick. Refer to the Operation and Maintenance Manual for instructions on filling the lubricating oil and the cooling systems.



The number of instruments and gauges required to perform a chassis dynamometer test will vary according to type and the capability of the test equipment used.

See the service tools listed at the beginning of this section.

To correctly monitor an engine's performance, record the following parameters:

- Lubricating oil pressure (vehicle instrument panel)
- Engine speed (rpm) (vehicle instrument panel)
- Wheel horsepower (whp) (dynamometer controls)
- Blowby, refer to Procedure 014-010
- Exhaust back pressure, refer to Procedure 011-009 in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193, or Procedure 011-009 in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087, or Procedure 011-009 in the Troubleshooting and Repair Manual, ISC, ISC^e, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418, or Procedure 011-009 in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003, or Procedure 011-009 in the Troubleshooting and Repair Manual, ISB, ISB^e 4 and 6 Cylinder, Bulletin 4021271, or Procedure 011-009 in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207.
- Coolant temperature (vehicle instrument panel), refer to Procedure 008-018 in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193, or Procedure 008-018 in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087, or Procedure 008-018 in the Troubleshooting and Repair Manual, ISC, ISC^e, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418, or Procedure 008-018 in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003, or Procedure 008-018 in the Troubleshooting and Repair Manual, ISB, ISB^e 4 and 6 Cylinder, Bulletin 4021271, or Procedure 008-018 in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207.
- Coolant pressure, refer to Procedure 008-018 in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193, or Procedure 008-018 in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087, or Procedure 008-018 in the Troubleshooting and Repair Manual, ISC, ISC^e, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418, or Procedure 008-018 in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003, or Procedure 008-018 in the Troubleshooting and Repair Manual, ISB, ISB^e 4 and 6 Cylinder, Bulletin 4021271, or Procedure 008-018 in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207.
- Intake manifold pressure, refer to Procedure 010-057 in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193, or Procedure 010-057 in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087, or Procedure 010-057 in the Troubleshooting and Repair Manual, ISC, ISC^e, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418, or Procedure 010-057 in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003, or Procedure 010-057 in the Troubleshooting and Repair Manual, ISB, ISB^e 4 and 6 Cylinder, Bulletin 4021271, or Procedure 010-057 in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207.
- Inlet air restriction, refer to Procedure 010-031 in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193, or Procedure 010-031 in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087, or Procedure 010-031 in the Troubleshooting and Repair Manual, ISC, ISC^e, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418, or Procedure 010-031 in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003, or Procedure 010-031 in the Troubleshooting and Repair Manual, ISB, ISB^e 4 and 6 Cylinder, Bulletin 4021271, or Procedure 010-031 in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207.
- Fuel supply pressure, refer to Procedure 006-024 in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193, or Procedure 006-024 in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087, or Procedure 006-024 in the Troubleshooting and Repair Manual, ISC, ISC^e, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418, or Procedure 006-024 in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003, or Procedure 006-024 in the Troubleshooting and Repair Manual, ISB, ISB^e 4 and 6 Cylinder, Bulletin 4021271, or Procedure 006-024 in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207.

Engine Run-in (Chassis Dynamometer) (014-003)

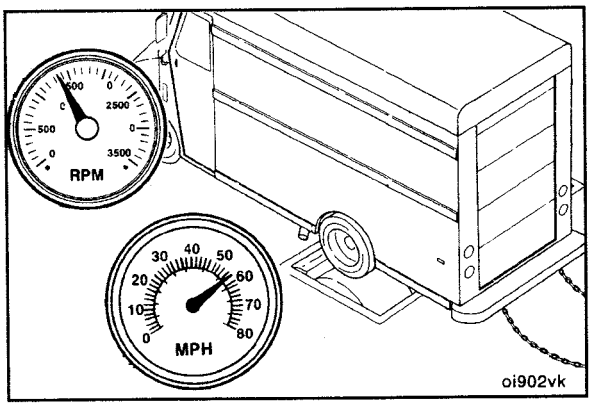
Test

⚠CAUTION⚠

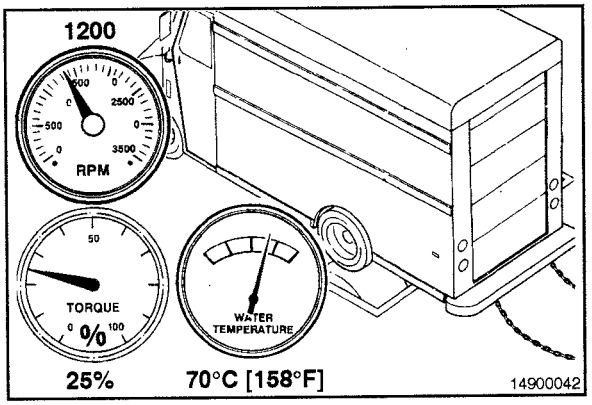
Refer to General Engine Test Procedures - (Chassis Dynamometer) (014-002) before operating the engine to avoid internal component damage.

NOTE: Refer to Chassis Dynamometer Operation, Procedure 014-005, for general operating procedures and safety precautions.

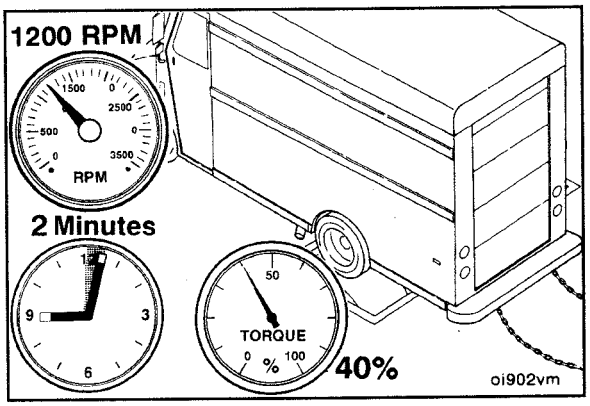
NOTE: Operate the vehicle in a gear that produces a road speed of 90 to 95 kph [55 to 60 mph].



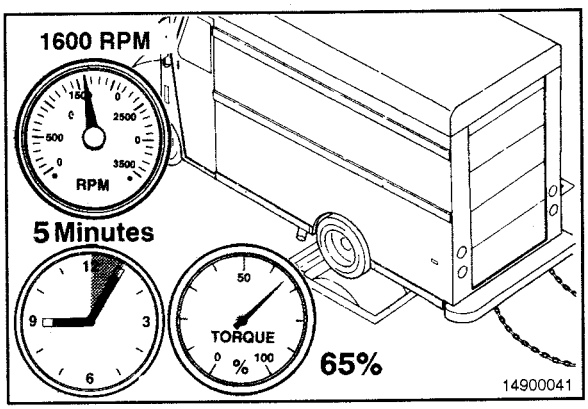
Operate the engine at 1200 rpm and 25 percent of torque peak load until the water temperature reaches 70°C [160° F].

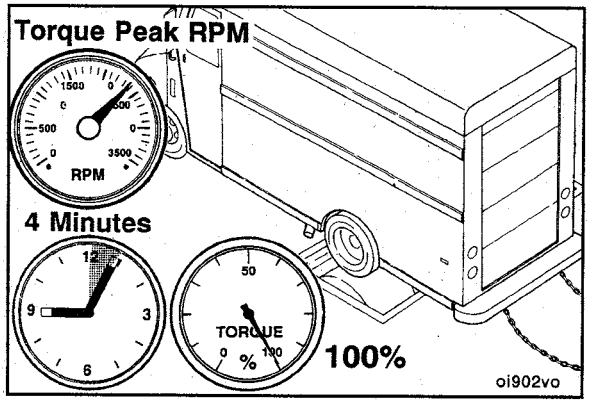


Operate the engine at 1200 rpm and 40 percent of torque peak load for 2 minutes. Check the gauges and record the readings.



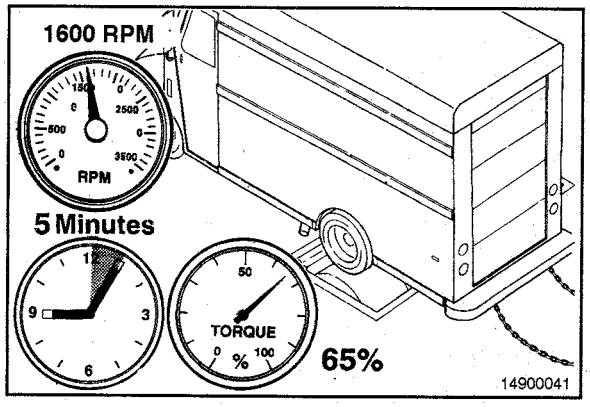
Operate the engine at 1600 rpm and 65 percent of torque peak load for 5 minutes. Check the gauges and record the readings.



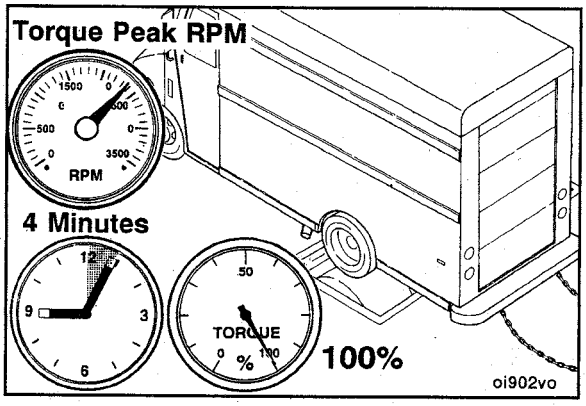


Operate the engine at torque peak rpm and full load for 4 minutes. Check the gauges and record the readings.

NOTE: Refer to the engine data sheet for the torque peak rpm of the engine model being tested.

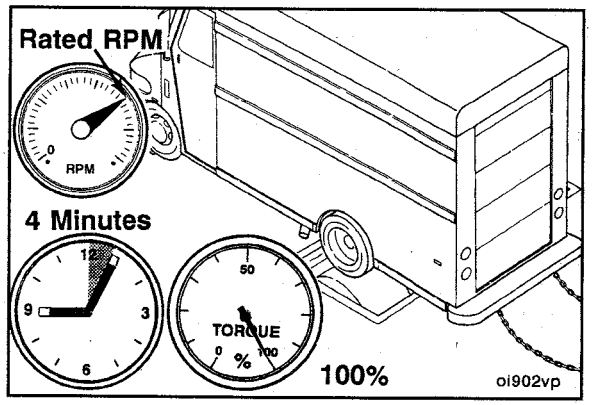


Operate the engine at 1600 rpm and 65 percent of torque full load for 5 minutes. Check the gauges and record the readings. Compare the readings to those published in the appropriate engine data sheet.



Operate the engine at torque peak rpm and full load for 4 minutes. Check the gauges and record the readings.

NOTE: Refer to the engine data sheet for the torque peak rpm of the engine model being tested.

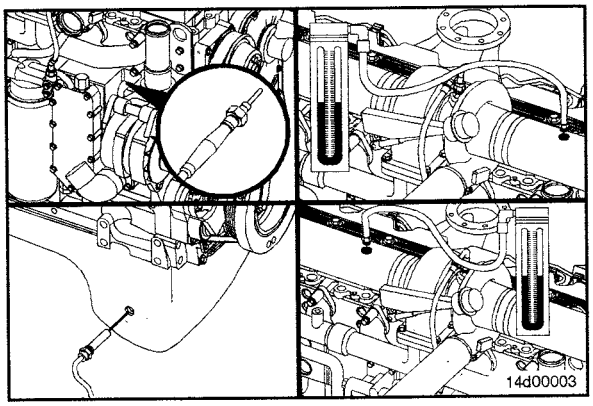


⚠CAUTION⚠

Do not shut off the engine immediately after the run-in is complete. Allow the engine to cool by operating it at low idle for a minimum of 3 minutes to avoid internal component damage.

Operate the engine at rated speed (rpm) and full load for 4 minutes. Check the gauges and record the readings. Compare the readings to those published in the appropriate engine data sheet.

Make sure to remove all dynamometer instrumentation from the vehicle.



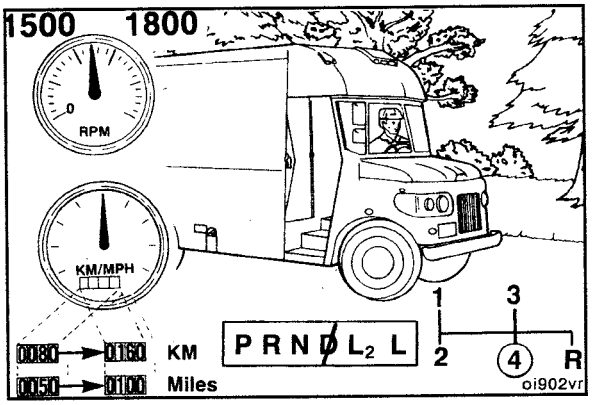
Engine Run-in (Without Dynamometer) (014-004)

Test

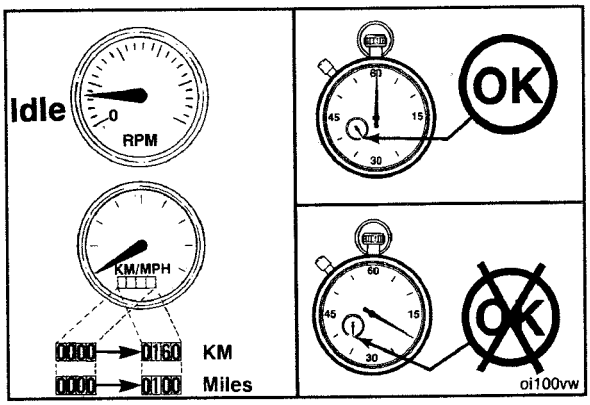
⚠CAUTION⚠

Refer to Engine Test (Engine Dynamometer) (014-005) before operating the engine to avoid internal component damage.

Operate the engine at 1500 to 1800 rpm in high gear for the first 80 to 160 km [50 to 100 mi] after rebuild.



NOTE: Do **not** idle the engine for more than 5 minutes at any one time during the first 160 km [100 mi] of operation.

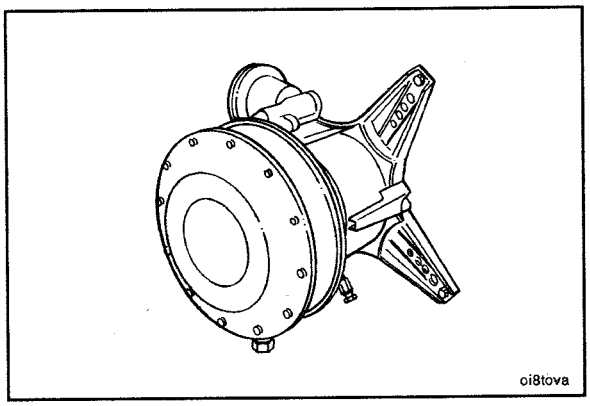


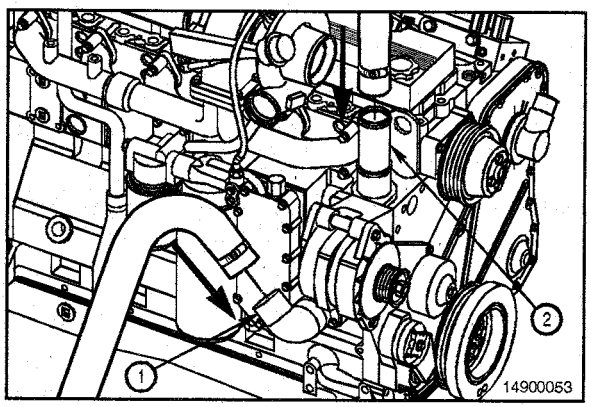
Engine Testing (Engine Dynamometer) (014-005)

Setup

Use engine lifting fixture, Part Number 3162871, to install the engine to the test stand. Align and connect the dynamometer. Refer to the manufacturer's instructions for aligning and testing the engine.

NOTE: Make sure the dynamometer capacity is sufficient to permit testing at 100 percent of the engines rated horsepower. If the capacity is **not** enough, the testing procedure **must** be modified to the restrictions of the dynamometer.

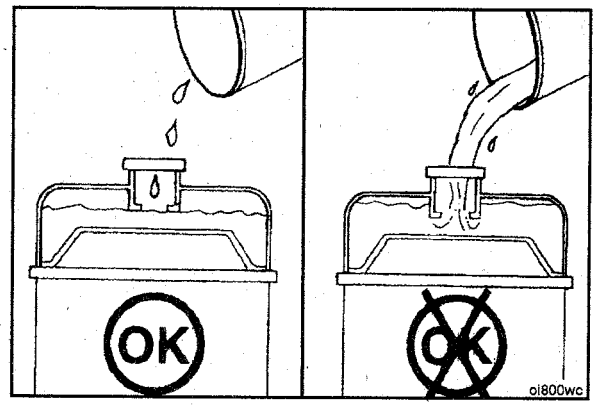




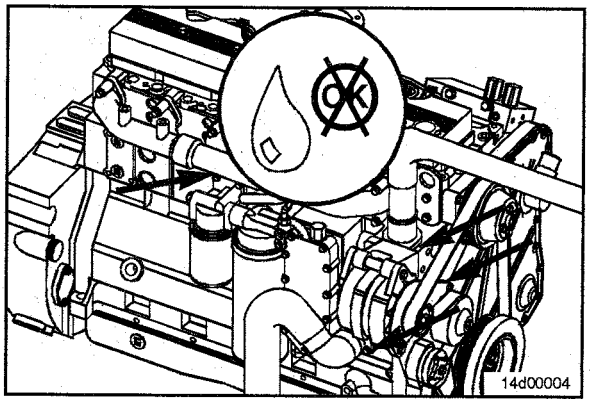
Connect the coolant supply to the water inlet connection (1).

Connect the coolant return to the water outlet connection (2).

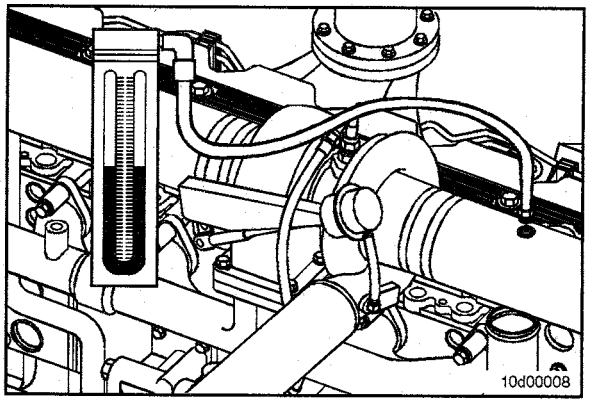
Install the drain plugs, close all the water drain cocks, and make sure all the clamps and fittings are tight.



Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill (or expansion) tank.



Inspect the engine for coolant leaks at connections, fittings, plates, and plugs. Repair if necessary.



Air Inlet Restriction

Connect a water manometer, Part No. ST-1111-3, to the turbocharger air inlet pipe to test air restriction.

NOTE: The manometer connection **must** be installed at a 90-degree angle to the airflow in a straight section of pipe, one pipe diameter before the turbocharger.

NOTE: A vacuum gauge, Part No. ST-434, can be used in place of the water manometer.

Minimum Gauge Capacity 760 mm H_2O [30 in H_2O]

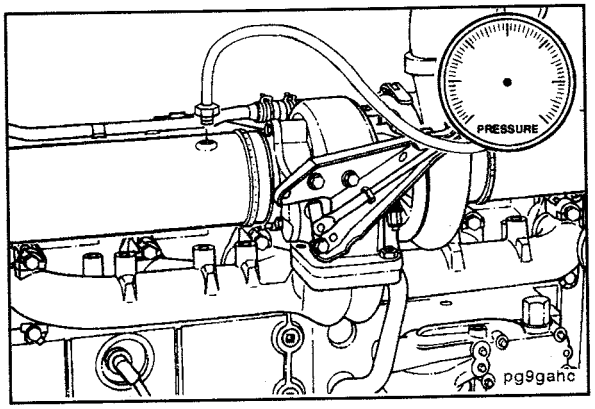
Exhaust Restriction

Connect a mercury manometer to a straight section of the exhaust piping near the turbocharger outlet to check exhaust restriction.

NOTE: A pressure gauge, Cummins Part Number ST-1273, can be used in place of the mercury manometer.

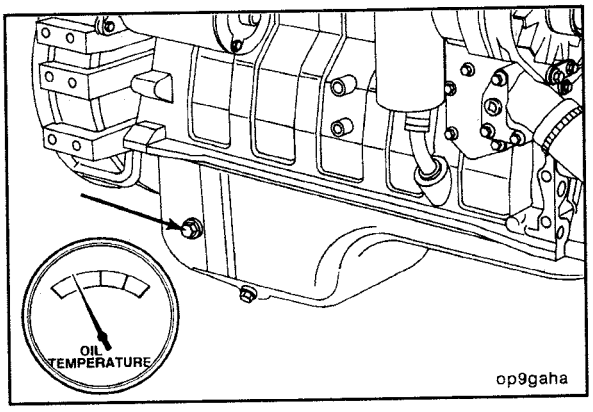
NOTE: For automotive applications, a tapped hole is provided on the inlet side of the catalyst for checking exhaust restrictions.

Minimum Gauge Capacity 254 mm Hg [10 in Hg]



Attach the lubricating oil temperature sensor in the location shown.

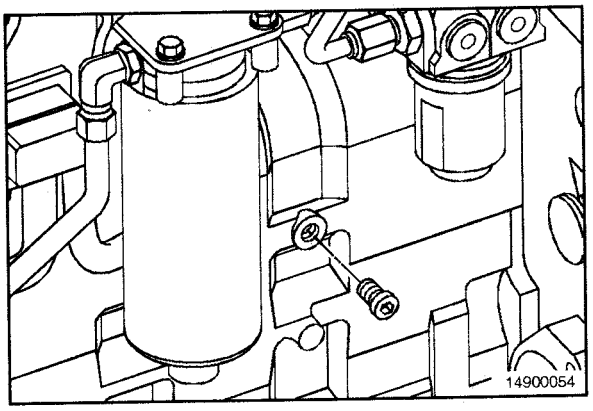
Minimum Gauge Capacity 150 °C [300 °F]



⚠CAUTION⚠

The lubricating oil system must be primed before operating the engine after if has been rebuilt to avoid internal damage.

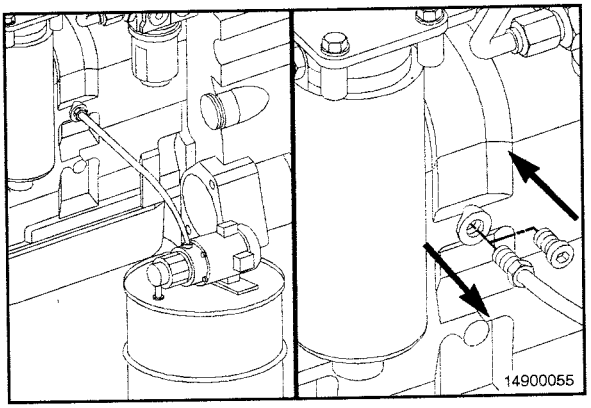
To prime the lubricating oil system using external pressure, connect the supply to a tapped hole in the main lubricating oil rifle.

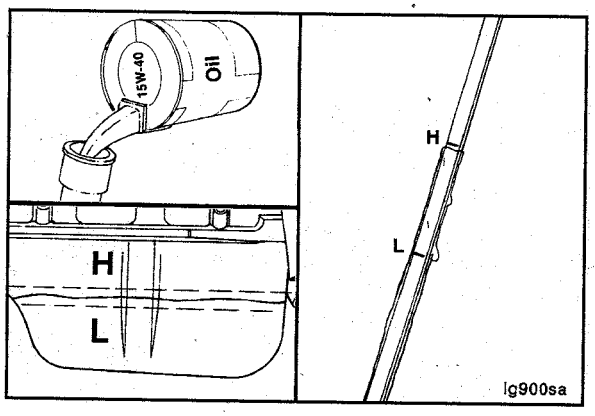


Use a pump capable of supplying 210 kPa [30 psi] of continuous pressure. Connect the pump to the port on the main lubricating oil rifle as shown.

Use clean lubricating oil to prime the system until the oil pressure registers on the gauge.

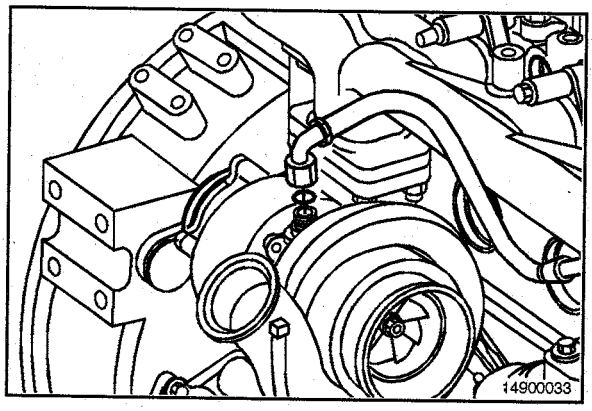
Remove the lubricating oil supply tube and install the plug.





Make sure the lubricating oil has had time to drain to the lubricating oil pan and fill the engine to the high mark as measured on the dipstick.

Use the correct lubricating oil as specified in the Operation and Maintenance Manual.



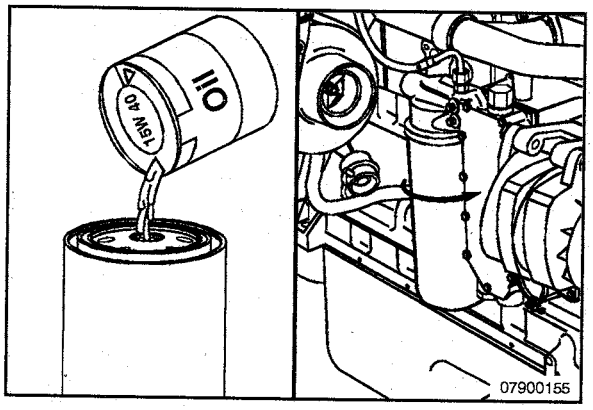
If an external pressure pump is **not** available, prime the lubricating system according to the following procedure.

Fill the engine with lubricating oil to the high-level mark on the dipstick.

Disconnect the turbocharger lubricating oil supply tube.

Pour 50 to 60 cc [2.0 to 3.0 fl oz] of clean 15W-40 lubricating oil into the turbocharger lubricating oil supply hole.

Connect the lubricating oil supply tube to the turbocharger.



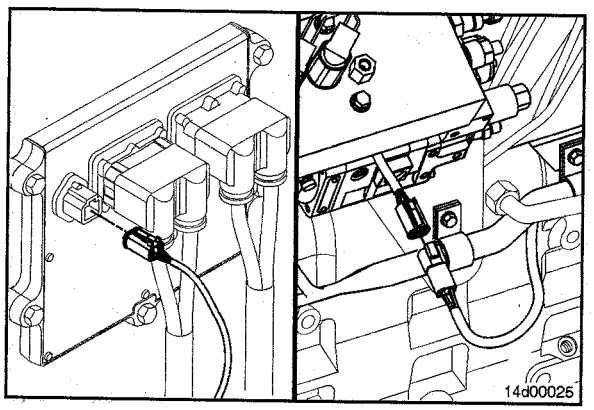
△CAUTION△

Mechanical overtightening can distort the threads or damage the filter element seal.

Fill the lubricating oil filters with clean 15W-40 lubricating oil.

Screw the filters onto the filter head fitting until the gasket contacts the filter head surface.

Tighten the filter as specified by the manufacturer.



CM850 Control Module

Disconnect the 4-pin power connector from the ECM to prevent the engine from starting.

CM554 Control Module

Disconnect the CAPS injection control valve connector so that the engine does **not** start.

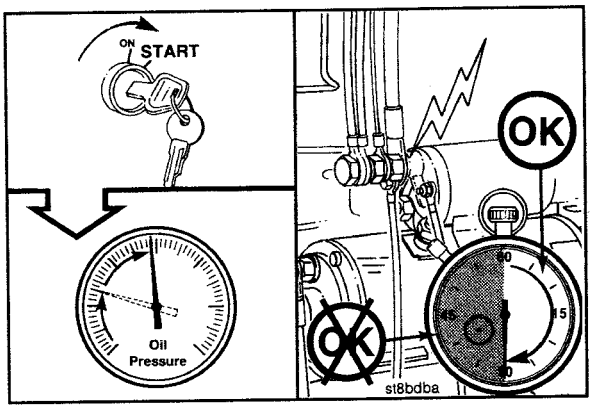
⚠CAUTION⚠

Do not crank the starting motor for periods longer than 30 seconds. Excessive heat will damage the starting motor.

Crank the engine until the lubricating oil pressure gauge indicates system pressure.

NOTE: Allow 2 minutes between the 30-second cranking periods so the starter motor can cool.

NOTE: If pressure is **not** indicated, find and correct the problem before continuing.

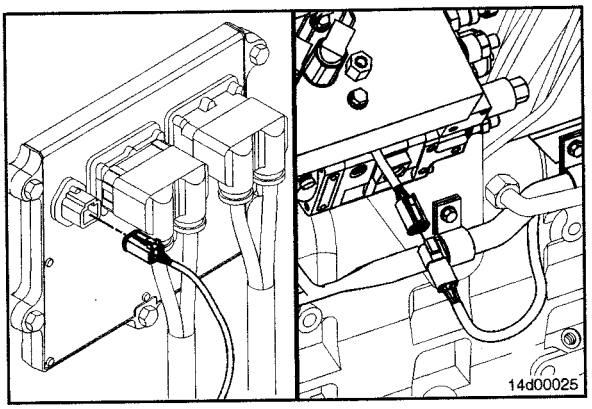


CM850 Control Module

Reconnect the 4-pin power connector to the ECM.

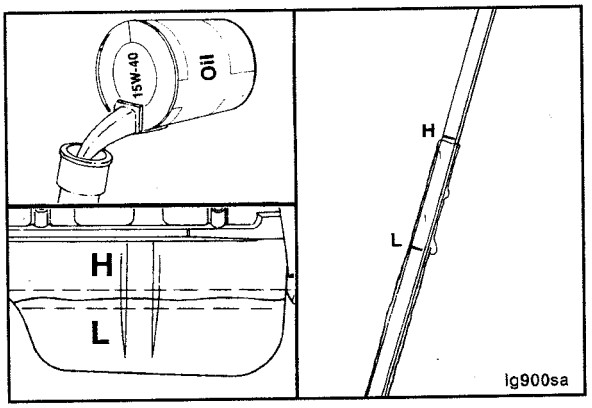
CM554 Control Module

Reconnect the injection control valve connector.

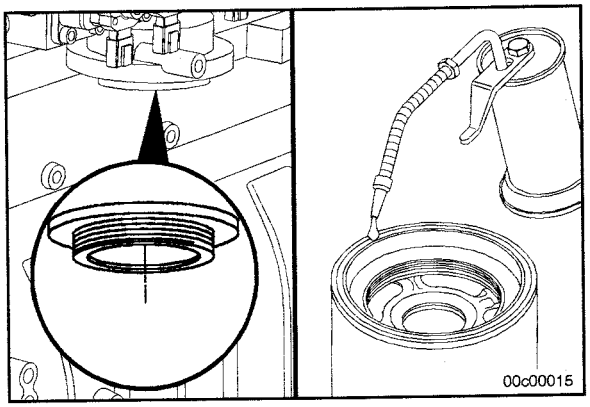


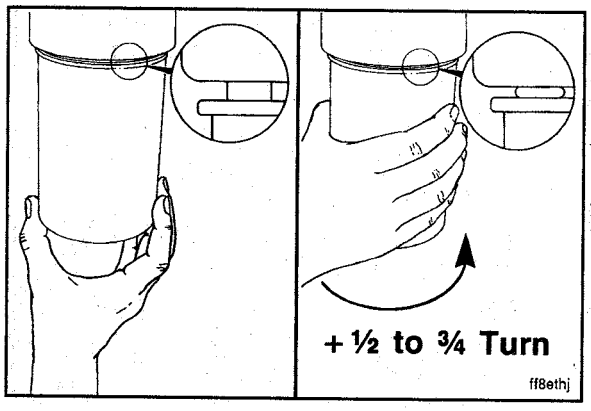
Allow the lubricating oil to drain into the lubricating oil pan and measure the lubricating oil level with the dipstick.

Add lubricating oil as necessary to bring the level to the high-level mark.



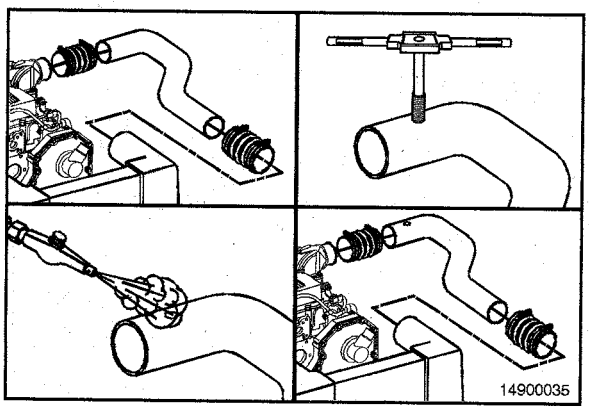
Lubricate the gasket on the fuel filter with clean 15W-40 lubricating oil.





Screw the fuel filter onto the filter head until the gasket contacts the filter head surface.

Tighten the filter as specified by the manufacturer.



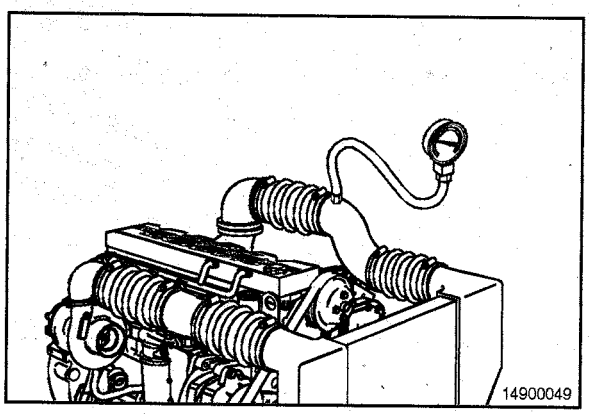
⚠CAUTION⚠

Do not attempt to install pipe thread fittings in plastic or rubber intake piping.

If INSITE™ is available, use it to monitor intake manifold pressure during the test. This eliminates the need to install a gauge as shown below.

If the air crossover tube does **not** have a pipe plug and tapped hole, perform the following procedure:

- Remove the charge air cooler air crossover tube from the engine.
- Drill and tap a 1/8-inch pipe thread hole in the tube 4 to 6 inches from intake opening.
- Clean all metal shavings from the air crossover tube.
- Install the crossover tube.



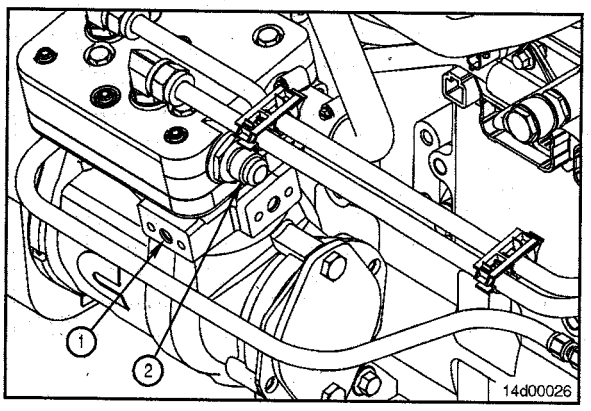
To determine the amount of turbocharger boost, remove the pipe plug in the air crossover tube and install the intake manifold pressure sensor or pressure gauge, Part No. ST-1273.

Minimum Gauge Capacity 1905 mm Hg [75 in Hg]

For an accurate engine crankcase blowby measurement, insert a blowby checking tool in the crankcase breather vent.

Connect a water manometer to the blowby tool. A pressure gauge can be used in place of the manometer.

Minimum Gauge Capacity 1270 mm H_2O [50 in H_2O]



To be able to unload the compressor, connect a source of compressed air to the unloader (1). This air line **must** contain a valve between the source and the unloader.

NOTE: All air compressors manufactured by Cummins Inc. **must** be loaded during engine run-in. All air compressors **must** be unloaded during the engine performance check.

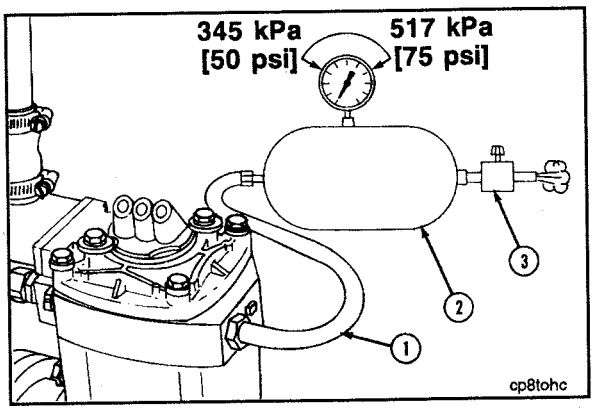
NOTE: The compressed air load in the accompanying illustration **must** be attached to the air compressor outlet (2).

To provide a load on the air compressor, connect an air tank (2) to the compressor outlet, use steel tubing or a high-temperature hose (1).

Install an air regulator (3) that can maintain tank air pressure of 345 to 517 kPa [50 to 75 psi] at both the minimum and the maximum engine rpm.

Hose Temperature (Minimum) 260 °C [500 °F]

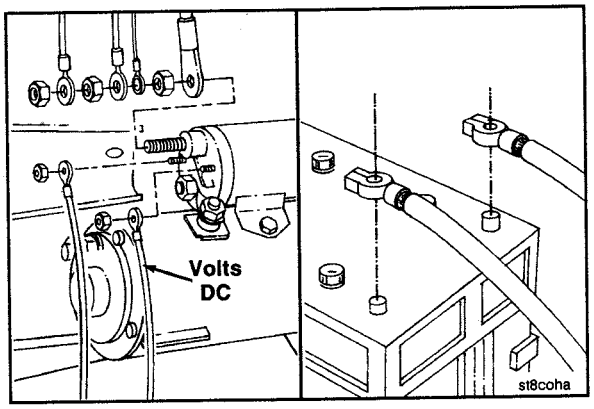
NOTE: If the engine is equipped with a variable geometry turbocharger, the turbocharger control valve will require a continous air supply of at least 621 kPa [90 psi].



Inspect the voltage rating on the starter motor before installing the electrical wiring.

Attach electrical wires to the starter motor and the batteries, if used.

NOTE: If another method of starting the engine is used, follow the manufacturer's instructions to make the necessary connections.

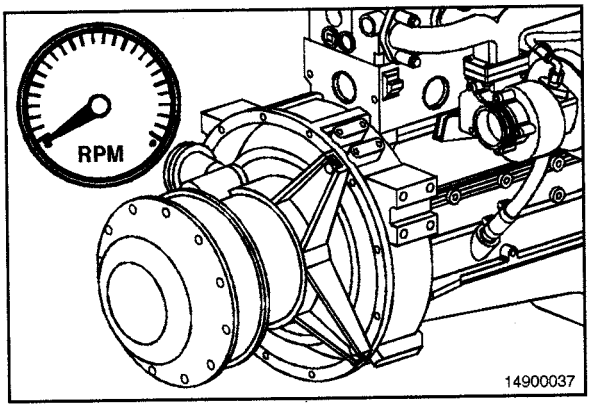


Engine Run-in (Engine Dynamometer) (014-006)

Run-In Instructions

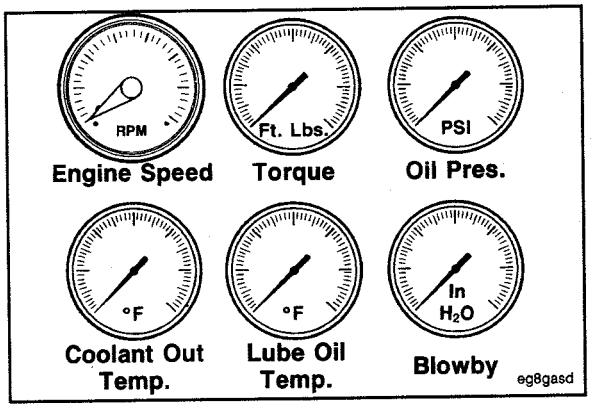
The engine run-in period allows the tester to detect assembly errors and to make final adjustments needed for performance that meets specifications.

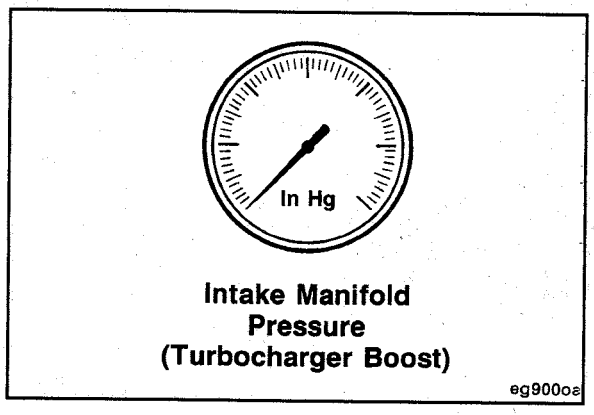
NOTE: The amount of time specified for the following engine run-in phases are minimums. Additional time can be used, if desired, at each phase except engine idle periods.



Measurements from these indicators and gauges **must** be observed closely during all phases of the engine run-in period.

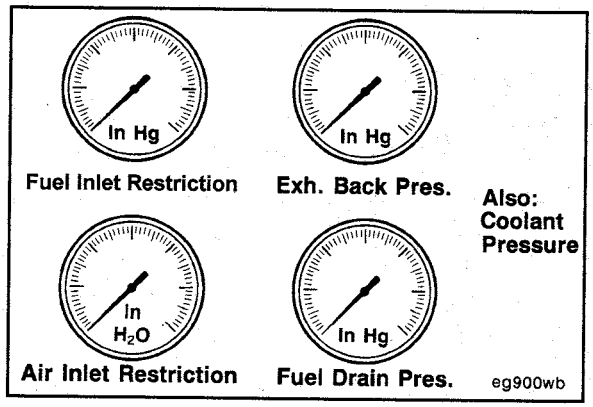
- Engine speed
- Torque
- Oil pressure
- Coolant outlet temperature
- Lube oil temperature
- Blowby.





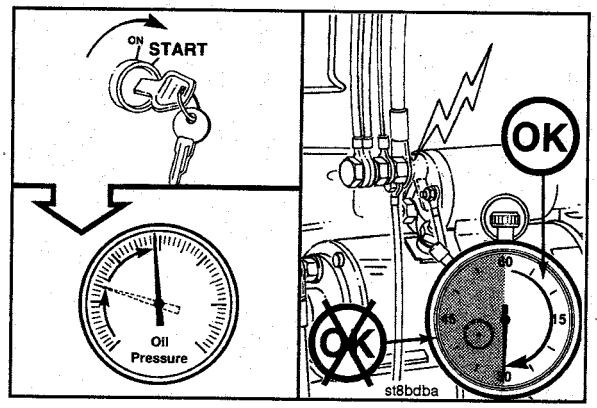
To evaluate the engine performance correctly, this additional measurement **must** be observed during engine run-in phases:

- Intake manifold pressure.



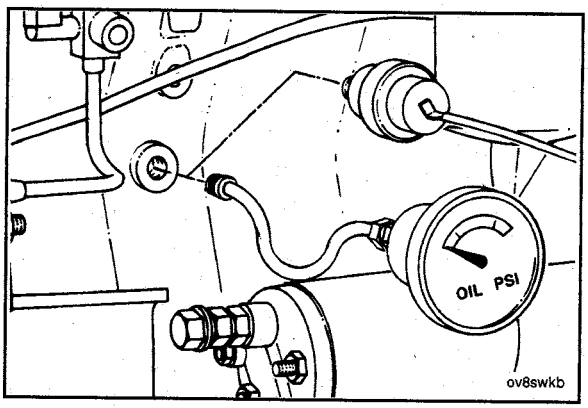
It is good practice to observe these measurements even if engine performance meets specifications. If engine performance does **not** meet specifications, these measurements can indicate possible reasons for underperformance.

- Fuel inlet restriction
- Exhaust back pressure
- Air inlet restriction
- Fuel drain pressure
- Coolant pressure.



⚠CAUTION⚠
Do not crank the engine for more than 30 seconds. Excessive heat will damage the starting motor.

Crank the engine and observe the lubricating oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starting motor to cool for 2 minutes before cranking the engine again.



Engine lubricating oil pressure **must** be at least 70 kPa [10 psi] at 700 rpm.

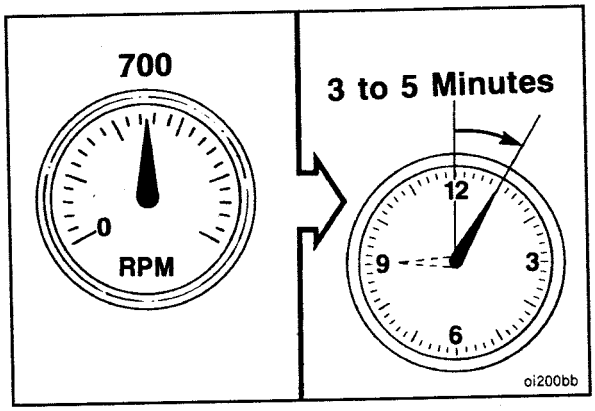
⚠CAUTION⚠
If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage.

Correct the problem if the lubricating oil pressure is **not** within specifications.

⚠CAUTION⚠

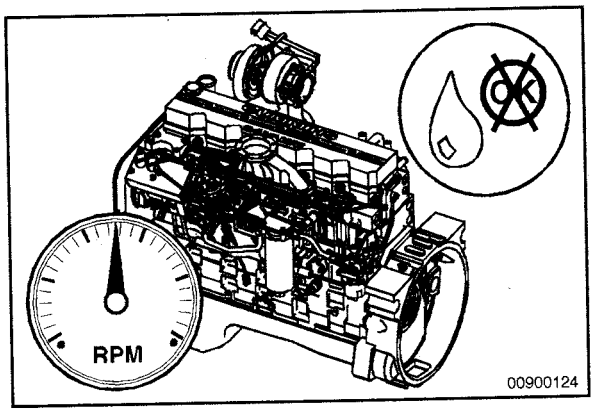
Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation will cause damage to the engine.

Operate the engine at approximately 700 rpm for 3 to 5 minutes.



Listen for unusual noises; watch for coolant, fuel, and lubricating oil leaks; and check for correct engine operation in general.

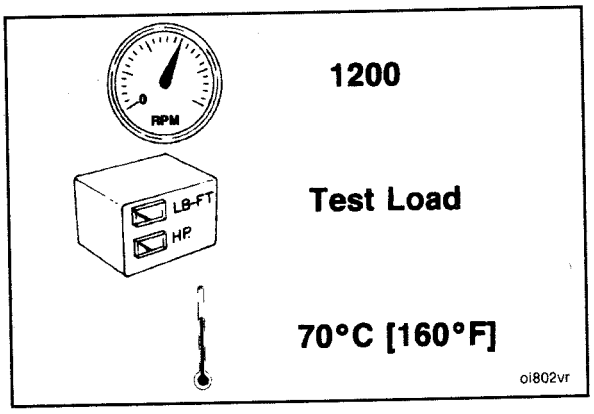
NOTE: Repair all leaks or component problems before continuing the engine run-in.



Move the throttle to obtain 1200-rpm engine speed, and set the test load to 25 percent of the rated load.

Operate the engine at this speed and load level until the coolant temperature is 70°C [160°F]. Check all gauges and record the data.

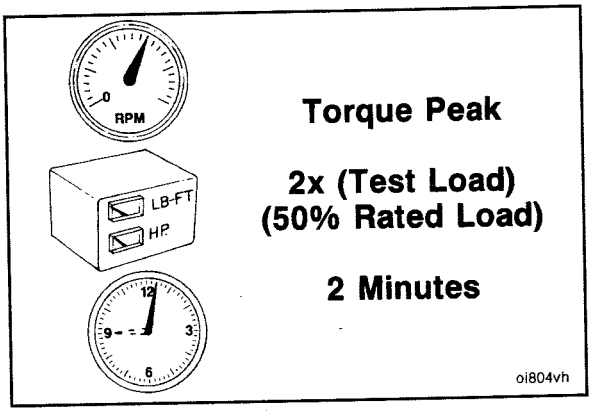
NOTE: Do **not** proceed to the next step until a steady blowby reading is obtained.

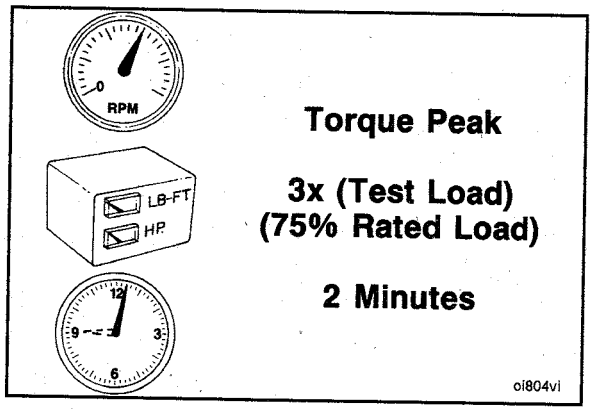


Open the throttle to the speed that peak torque occurs, and adjust the dynamometer load to 50 percent of torque peak load. Operate the engine at this speed and load level for 2 minutes.

Check all gauges and record the data.

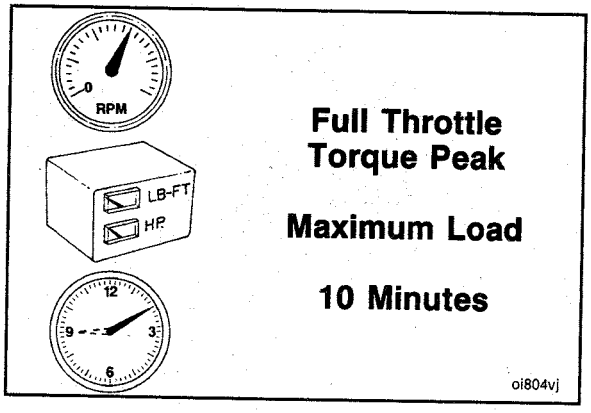
NOTE: Do **not** proceed to the next step until blowby is stable within specifications.





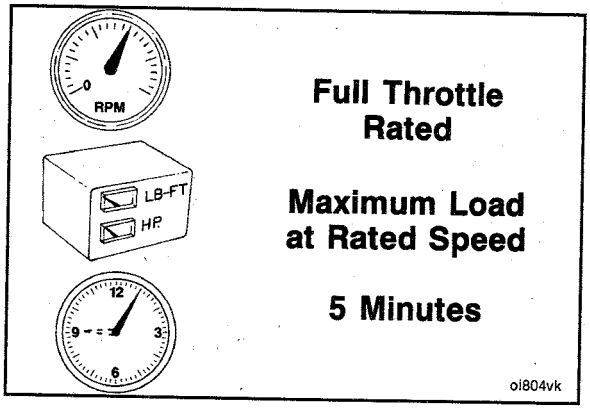
With the engine speed remaining at torque peak rpm, increase the dynamometer load to 75 percent of torque peak load. Operate the engine at this speed and load level for 2 minutes. Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until blowby is stable within specifications.



Move the throttle lever to its fully opened position, and increase the dynamometer load until the engine speed is at torque peak rpm. Operate the engine at this speed and load level for 10 minutes or until the blowby becomes stable within specifications.

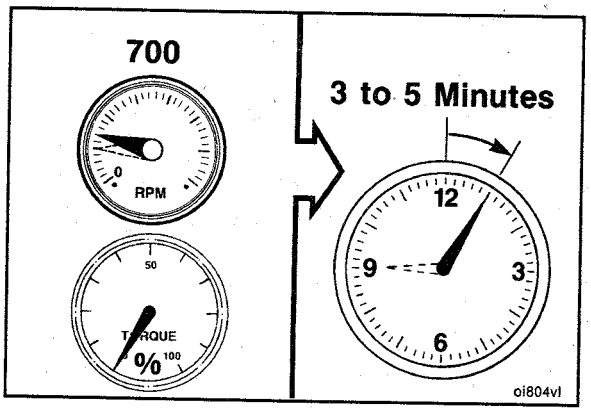
Check all gauges and record the data.



Reduce the dynamometer load until the engine speed increases to the engine's rated rpm.

Operate the engine at rated rpm for 5 minutes.

Check all gauges and record the data.

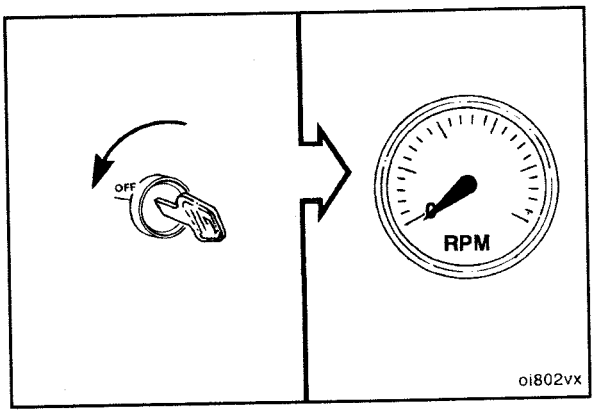


⚠CAUTION⚠

Shutting off the engine immediately after operating at full load will damage the turbocharger and internal components. Always allow the engine to cool before shutting it off.

Remove the dynamometer load completely, and operate the engine at 700 rpm for 3 to 5 minutes. This period will allow the turbocharger and other components to cool.

Shut off the engine.

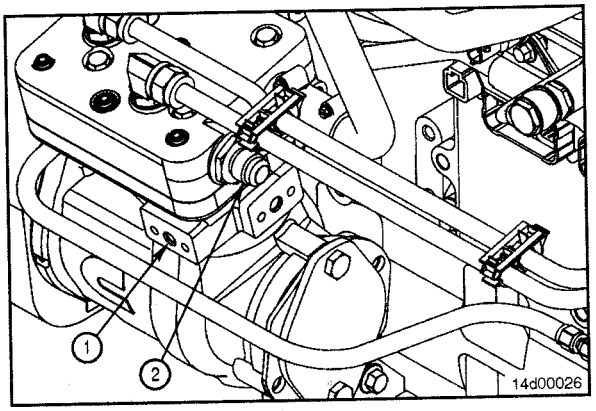


Engine Dynamometer Test - Performance Checking

Make sure the air compressor is unloaded during the performance check.

Apply regulated air pressure of 655 kPa [95 psi] to the air compressor unloader (1).

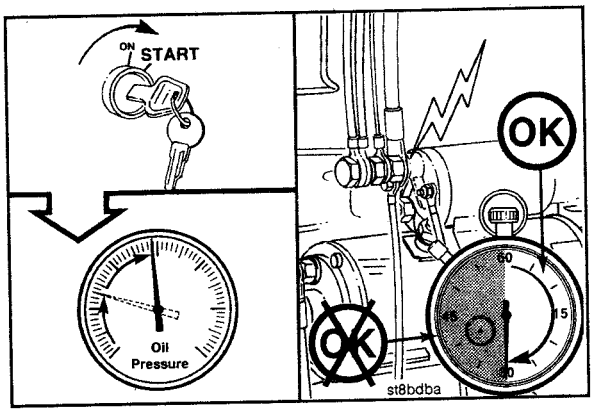
NOTE: If the engine is equipped with a variable geometry turbocharger, the turbocharger control valve will require a continous air supply of at least 621 kPa [90 psi].



⚠CAUTION⚠

Do not crank the engine for more than 30 seconds. Excessive heat will damage the starter motor.

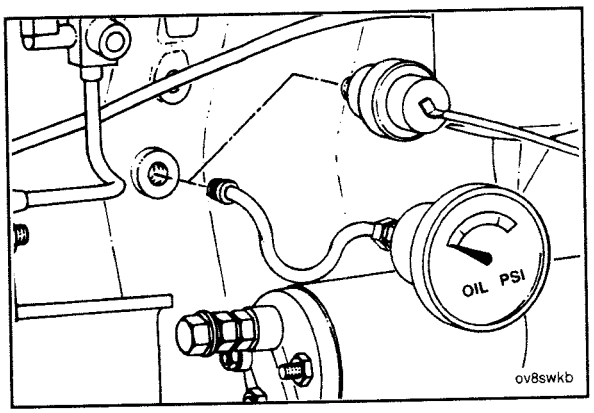
Crank the engine and observe the oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starter motor to cool for 2 minutes before cranking the engine again.

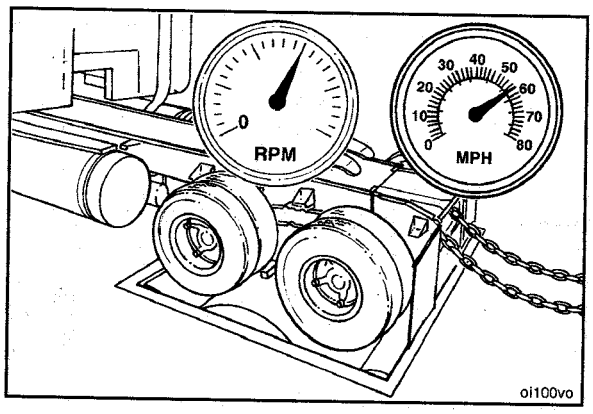


⚠CAUTION⚠

If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage. Correct the problem if lubricating oil pressure is not within specifications.

Engine lubricating oil pressure **must** be at least 69 kPa [10 psi] at approximately 700 rpm.





Make sure the engine is at operating temperature.

Move the throttle to the fully depressed position. Adjust the dynamometer load until the engine maintains the rated rpm.

Allow the readings to stabilize. Read the horsepower.

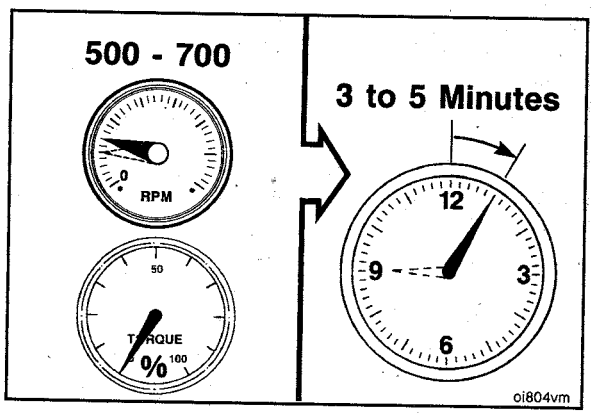
Check all the gauges and record the readings.

NOTE: The horsepower reading will **not** be accurate if the lubricating oil temperature and fuel temperature are **not** within specifications.

Lubricating Oil Temperature		
°C		°F
90	MAX	194

Fuel Temperature		
°C		°F
65	MAX	149

Check all gauges and record the data.

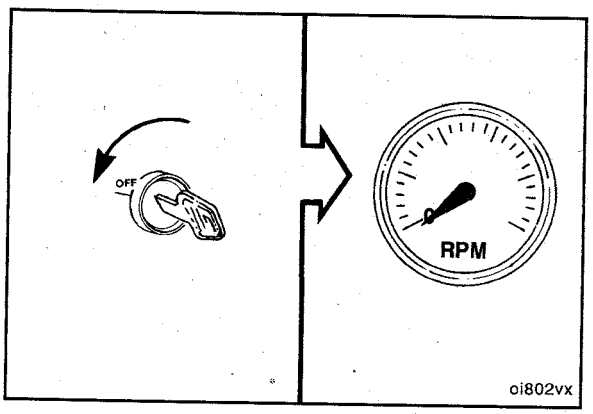


△CAUTION△

Do not shut off the engine immediately after it has been loaded. It must be allowed to sufficiently cool.

Remove the dynamometer load completely, and operate the engine at idle speed for 3 to 5 minutes. This will allow the turbocharger and other components to cool.

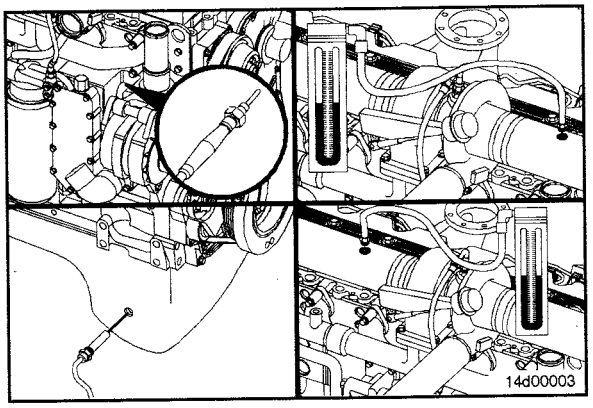
NOTE: Idle periods longer than 5 minutes are to be avoided.



Shut off the engine after the cooldown period.

Remove all test instrumentation. Remove the engine from the dynamometer.

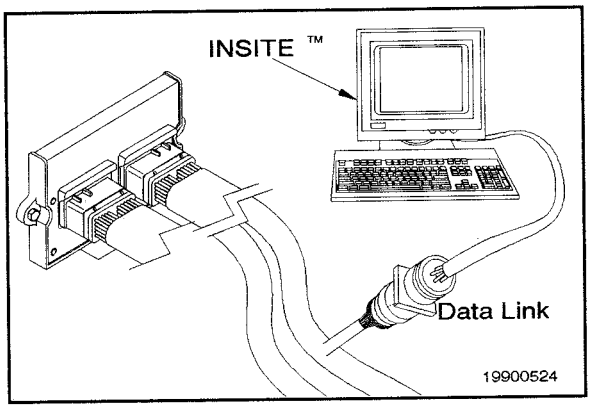
NOTE: If the engine is to be stored temporarily and does **not** have permanent-type antifreeze, it is necessary to drain all coolant. Drain locations are identified on the engine side views. Refer to Procedures 008-018.



Engine Testing (In Chassis) (014-008)

Setup

The Setup for Dynamometer function is used to prepare the attached electronic control module (ECM) for advanced diagnostic tests run on the dynamometer. For purposes of this test, the Maximum Engine Speed without a vehicle speed sensor (VSS), the Maximum Vehicle Speed in Top Gear, and the Maximum Vehicle Speed in Lower Gear are set to their maximum values. The idle shutdown feature is disabled. All of these values are automatically reset to their previous values when the engine keyswitch is turned off.



Settings

Maximum Engine Speed without VSS: For testing purposes, this speed is temporarily set to the maximum value allowed (3000 rpm).

Maximum Vehicle Speed in Top Gear: For testing purposes, this speed is temporarily set to the maximum value allowed (120 mph).

Maximum Vehicle Speed in Lower Gear: For testing purposes, this speed is temporarily set to the maximum value allowed (120).

Idle Shutdown: This feature is temporarily disabled for testing purposes (Disable).

Some J1939 electronic subsystems **must** be disabled. The user has the ability to enable or disable the J1939 datalink with the service tool.

Refer to the INSITE™ user's manual for detailed setup for Dynamometer Instructions.

Automated Cylinder Performance Test

The automated cylinder performance test is the most thorough test of cylinder performance (versus the single-cylinder cutout test, which tests the performance of individual cylinders **only**). The service tool **must** be attached to an electronic control module (ECM) to perform this test. Follow the steps outlined in Preparing to Run the Automated Cylinder Performance Test, to make sure the best possible outcome is achieved.

This test is automated in the sense that, once the test is started, the service tool controls what cylinders are disabled or enabled, what ECM values are recorded, and what information displays as a result of the test. Once the test is finished, follow the steps outlined in After Running the Automated Cylinder Performance Test to make sure the engine returns to its original state.

This test will produce a Pass or Fail message for each cylinder. Its percent contribution value is also displayed.

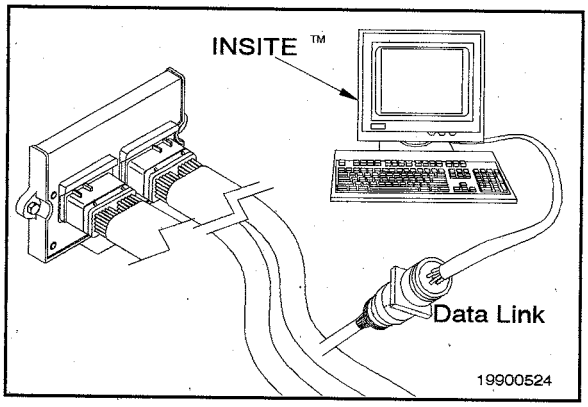
Cylinder	% Contribution	
1	66	Is Not OK
2	101	Is OK
3	98	Is OK
4	101	Is OK
5	101	Is OK
6	101	Is OK

19800469

Preparing to Run the Automated Cylinder Performance Test

Before performing this test, make sure you:

1. . Clear the areas around the engine and the fan, and make sure the exhaust is vented correctly.
2. . Operate the engine until the coolant temperature is a minimum of 76.7°C [170°F].
3. . Shut off the engine.
4. . Lock the fan clutch in the ON position for continuous operation.
5. . Shut off the air conditioning.
6. . Disengage any devices that can cause the load on the engine to vary.
7. . With the vehicle stationary, start the engine and let it idle.
8. . Start the test using INSITE™.



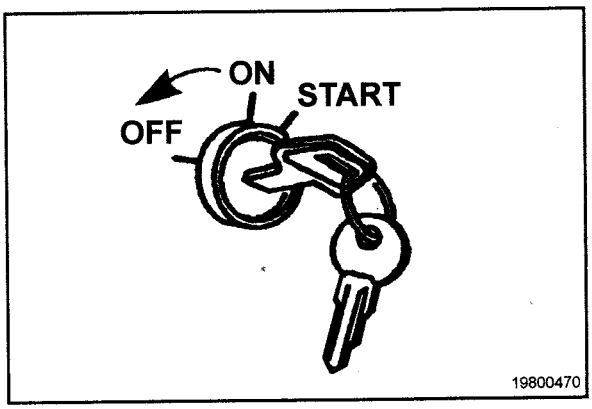
Refer to the INSITE™ user's manual for detailed automated cylinder performance test instructions.

After Running the Automated Cylinder Performance Test

It is normal for the engine rpm to vary during the test, but if the engine rpm goes to high idle for more than 5 seconds at a time, shut off the engine.

Once the test is complete, make sure to:

1. . Shut off engine.
2. . Return the fan to normal operation, if necessary.
3. . Perform the suggested repairs that resulted from the test.
4. . Return any disengaged devices to their normal mode of operation.

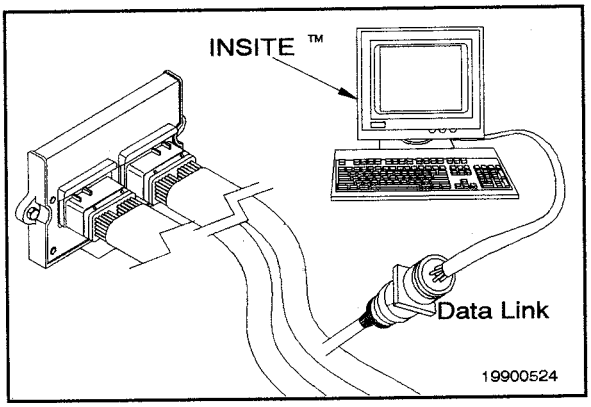


Cylinder Cutout Test

Use the single-cylinder cutout test to remove individual cylinders from the engine firing cycle and to monitor a running engine while the selected cylinder is disabled. The system displays the percent load and rpm values while the cylinder is disabled.

The service tool **must** be attached to a running engine in a nonmoving vehicle to perform this test.

Refer to the INSITE™ user's manual for detailed cylinder cutout test instructions.



Cylinder to be Cut Out

None: Select this option to run all cylinders.

1 through 6: Select one of these options to shut off cylinder Nos. 1 through 6, respectively. **Only** one cylinder can be shut off at a time.

Monitor

Percent Load: The percent of load that the engine is carrying.

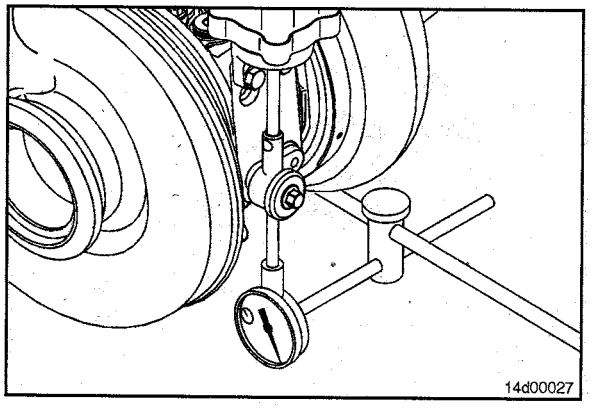
rpm: The engine's revolutions per minute.

Turbocharger Actuator Test

Use the turbocharger actuator test to verify the correct functioning of the variable geometry turbocharger actuator. During the test, air pressure is applied to the actuator and rod travel is measured.

The service tool **must** be attached to an ECM to perform this test.

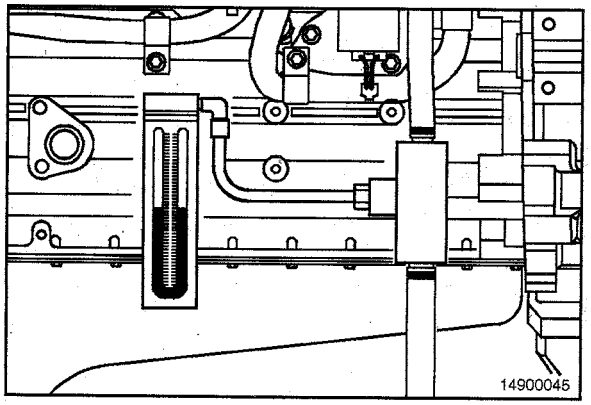
Refer to INSITE™ user's manual for detailed turbocharger actuator test instructions.



Use INSITE™ to extend and retract the turbocharger actuator rod several times.

Measure the distance the actuator rod travels when extended.

Turbocharger Actuator Rod Travel		
mm		in
10.8	MIN	0.40
11.8	MAX	0.46



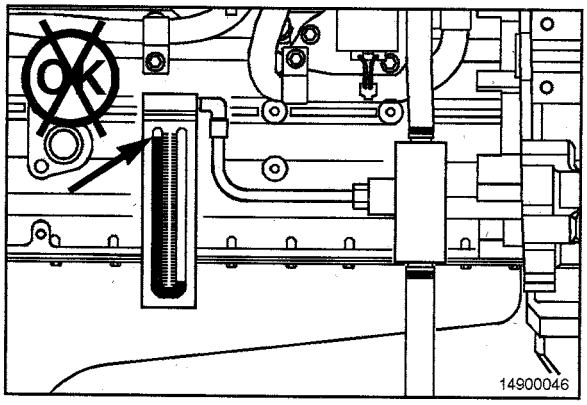
Crankcase Blowby, Measure (014-010)

Measure

Measure the blowby by installing the correct blowby tool in the crankcase breather vent. Refer to Service Tools Procedure 022-001 in Section 14 in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193, or Procedure 022-001 in Section 14 in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087, or Procedure 022-001 in Section 14 in the Troubleshooting and Repair Manual, ISC, ISC^e, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418, or Procedure 022-001 in Section 14 in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207

NOTE: Excessive blowby indicates a turbocharger malfunction or an engine internal component malfunction, allowing combustion gases to enter the crankcase.

Minimum Gauge Capacity: Refer to Procedure 014-005 in the Troubleshooting and Repair Manual ISB and QSB5.9 Engines, Bulletin 3666193, or Procedure 014-005 in the Troubleshooting and Repair Manual B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087, or Procedure 014-005 in the Troubleshooting and Repair Manual, ISB, ISB^e 4 and 6 Cylinder, Bulletin 4021271, or Procedure 014-005 in the Troubleshooting and Repair Manual, ISC, ISC^e, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418.

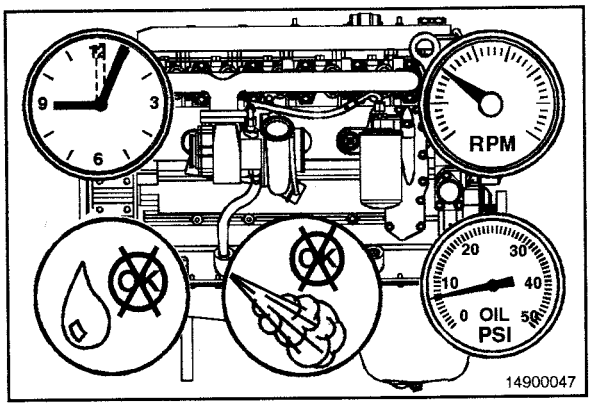


NOTE: If a sudden increase in blowby occurs, or if blowby exceeds the maximum allowable limit during any run-in step, return to the previous step and continue the run-in. If blowby does **not** reach an acceptable level, discontinue the run-in and determine the cause.

⚠CAUTION⚠

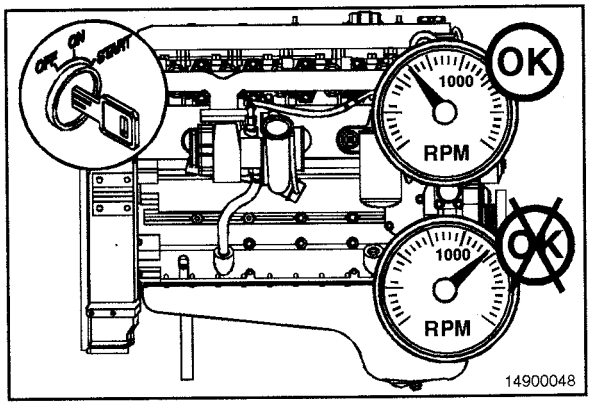
Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation can damage the engine.

NOTE: Avoid long idle periods. Operate the engine at low idle **only** long enough (three to five minutes) to check for correct lubricating oil pressure and any fuel, lubricating oil, water, or air leaks.



⚠CAUTION⚠

Do not allow the engine speed to exceed 1000 rpm before run-in. The internal components can be damaged.

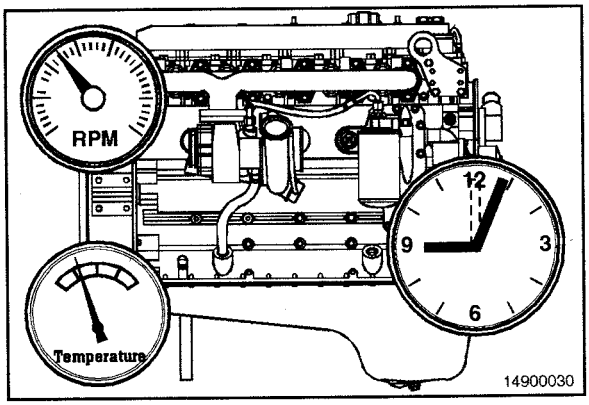


⚠CAUTION⚠

Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation can damage the engine.

⚠CAUTION⚠

Do not shut off the engine immediately after the last step of the run-in is completed. Allow the engine to cool by operating at low idle for a minimum of three minutes to reduce internal component damage.



Notes

Section 16 - Mounting Adaptations - Group 16

Section Contents

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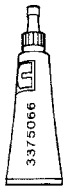
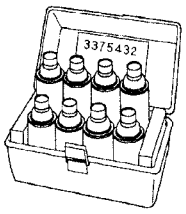
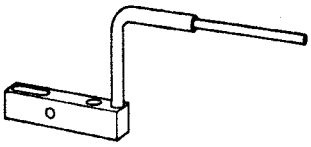
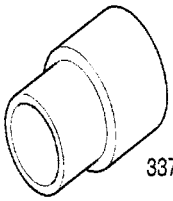
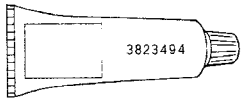
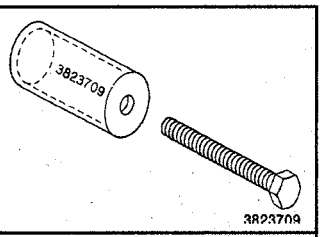
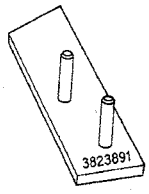
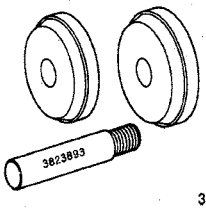
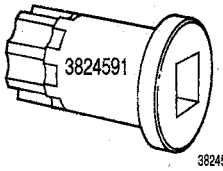
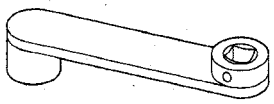
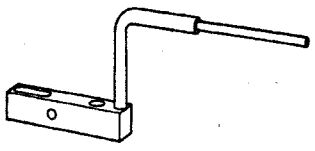
Service Tools

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
3375066	**Pipe Sealant** Used on capscrew threads and pipe plugs.	 3375066
3375068	**Cup Plug Sealant** Used when installing cup plugs.	 3375068
3375432	**Crack Detection Kit** Used to detect cracks.	 3375432
3376050	**Dial Indicator and Sleeve Assembly** Used with dial gauge attachment, Part No. ST-1325, to measure flywheel and flywheel housing run-out.	 fh8togb
3376812	**Cup Plug Driver** Used to install cup plug in flywheel housing.	
3823494	**Three-bond Sealant** Heavy duty silicone-type cup plug sealant.	 3823494

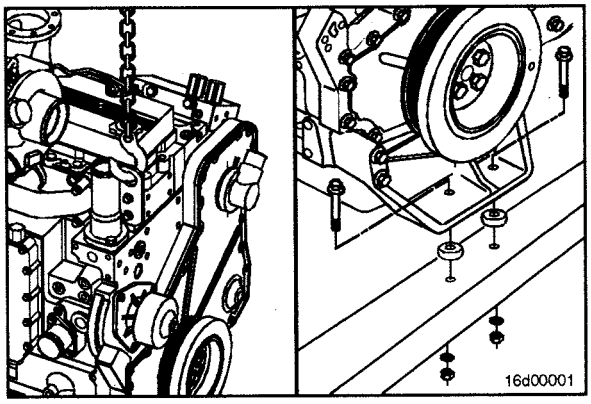
Tool No.	Tool Description	Tool Illustration
3823709	**Idler Shaft Puller and Capscrew** Used to remove idler shaft from idler gear and flywheel housing.	
3823891	**Gear Locking Tool** Used to prevent rotation of the PTO output shaft while tightening the output flange capscrew.	
3823893	**Bearing Race Driver** Used to install output shaft bearing races.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
3824928	**Offset Wrench (C-Series Engine)** Used to tighten the hidden capscrews in the REPTO flywheel housing.	
ST-1325	**Dial Indicator Attachment** Attaches to crankshaft flange to provide measuring of flywheel and flywheel housing runout with dial bore gauge.	

Engine Support Bracket, Front (016-002)

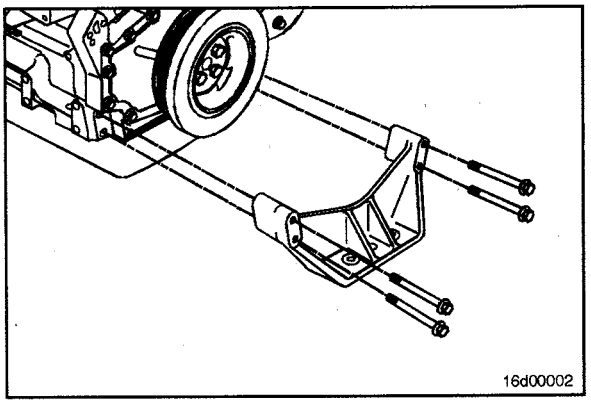
Remove

Use a hoist or lifting fixture to support the front of the engine.

Remove the capscrews from the front engine mount.



Remove the four mounting capscrews and the front engine support.



Clean and Inspect for Reuse

⚠ WARNING ⚠

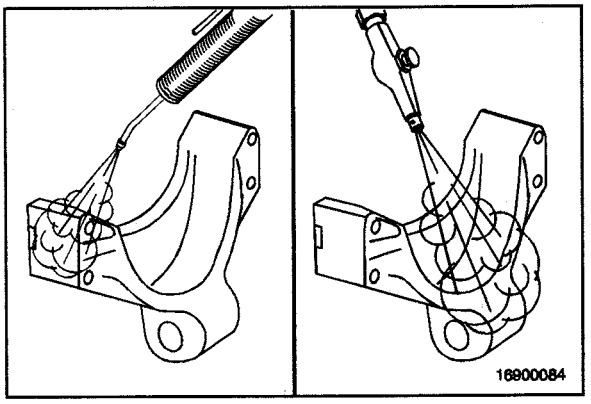
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

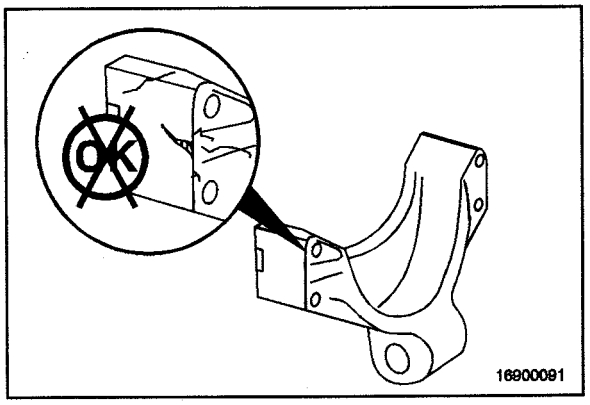
Use steam or solvent to clean the front engine support.

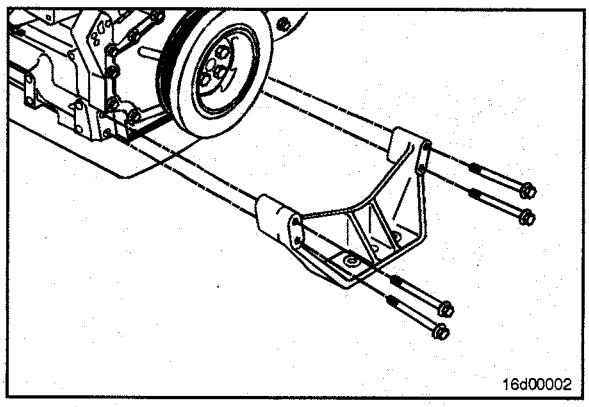
Dry with compressed air.



Inspect the support for cracks or damage.

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

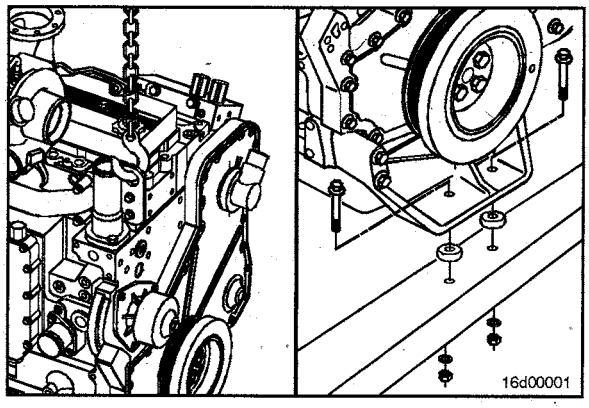




Install

Install the front support and mounting capscrews.

Torque Value: 112 N•m [83 ft-lb]

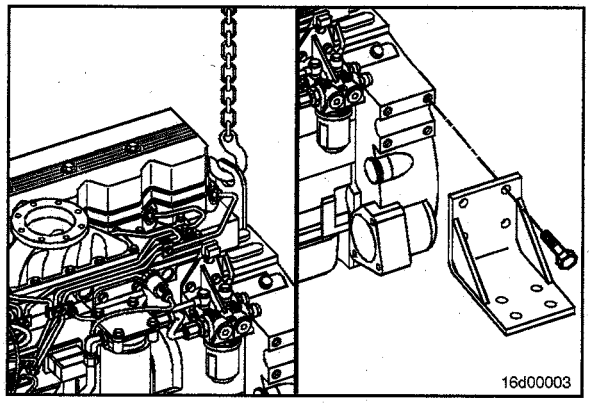


Lower the front of the engine.

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.

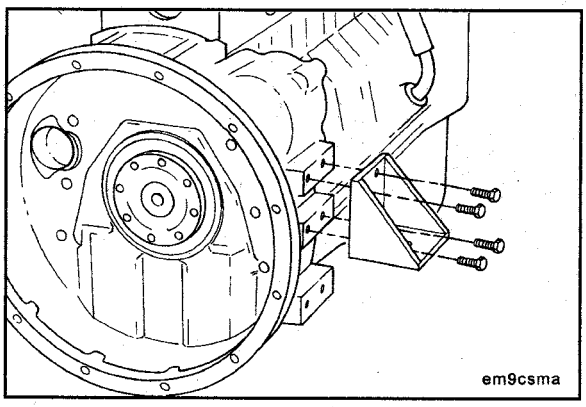


Engine Support Bracket, Rear (016-003)

Remove

Use a hoist or lifting fixture to support the rear of the engine.

Remove the capscrew from the rear engine mount.



Remove the four capscrews and rear support bracket.

Clean and Inspect for Reuse

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ 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.

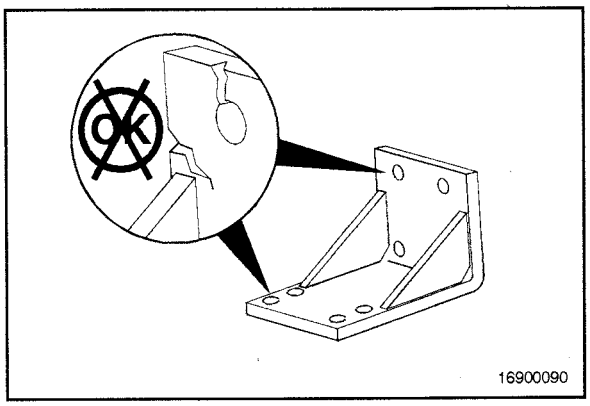
⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use steam or solvent to clean the rear engine support.

Dry with compressed air.

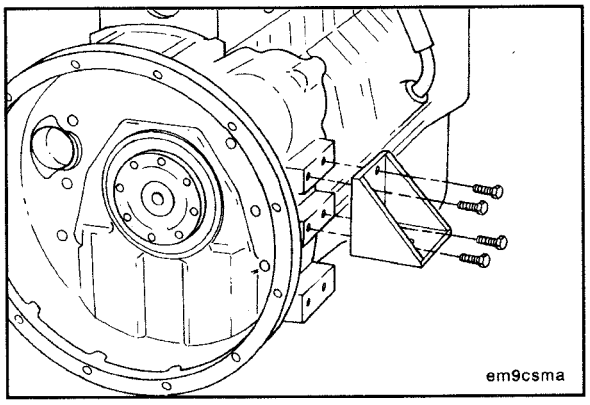
Inspect the support bracket for cracks or damage. If the support bracket is cracked, it **must** be replaced.



Install

Install the support bracket and mounting capscrews.

Torque Value: 71 N•m [52 ft-lb]

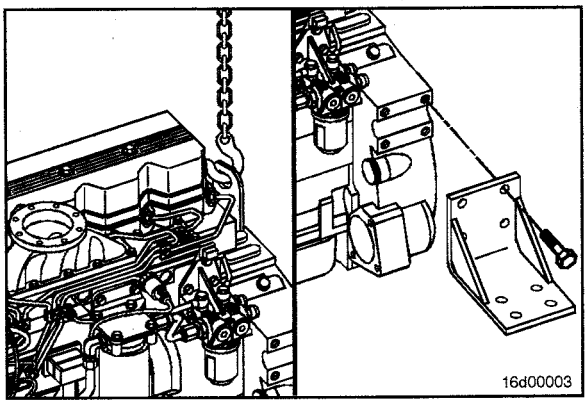


Lower the rear of the engine.

Install the rear engine mount capscrews.

Tighten to the manufacturer's specifications.

Remove the lifting fixture or hoist from the rear of the engine.



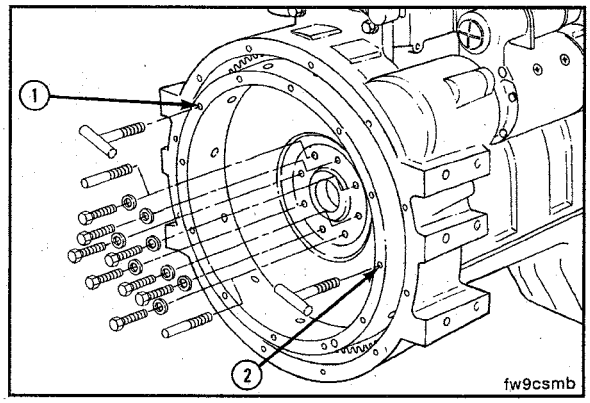
Flywheel (016-005)

Preparatory Steps

Remove the vehicle driveline and transmission. Refer to the manufacturer's instructions.

Remove the clutch discs and the pressure plate.

NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.



Remove

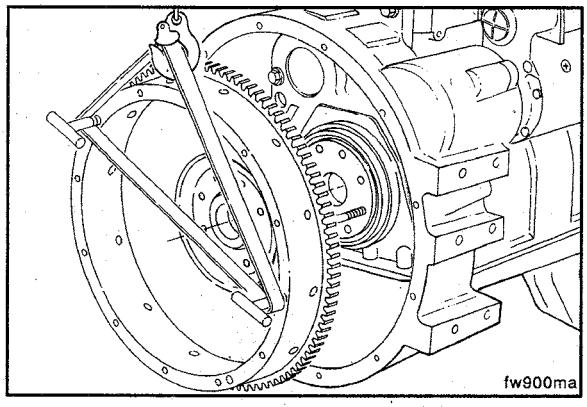
Remove two (2) capscrews 180 degrees apart.

Install two M12 x 1.25 x 90 mm guide pins.

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 (1) and (2).

Remove the remaining six (6) flywheel mounting screws.

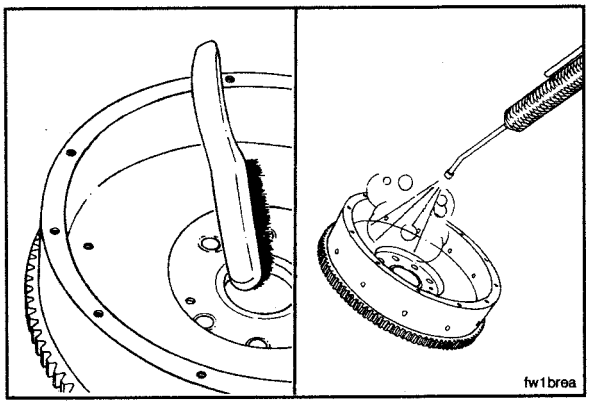


⚠WARNING⚠

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

Remove the flywheel from the guide pins.

Clean and Inspect for Reuse



⚠ 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.

⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

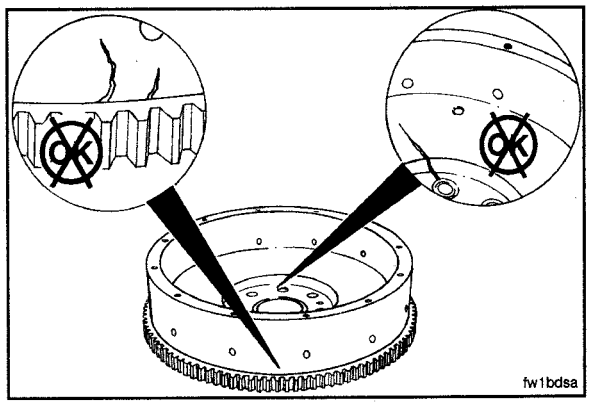
⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Use a wire brush to clean the crankshaft pilot bore.

Use steam or solvent to clean the flywheel.

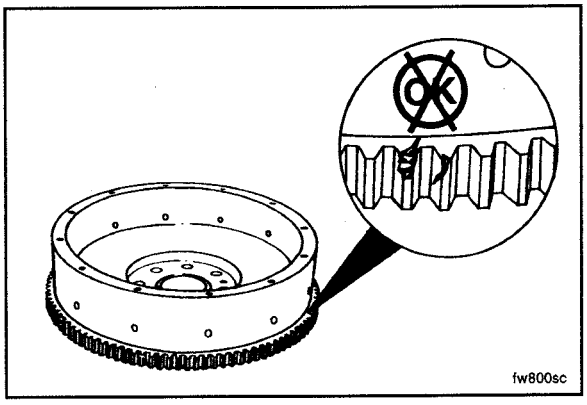
Dry with compressed air.

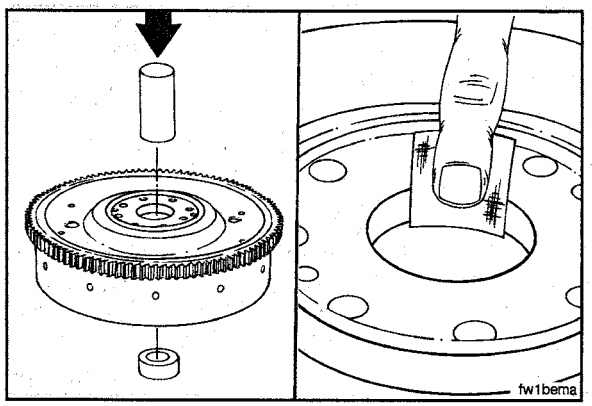
Use the crack detection kit, Part Number 3375432, to check for cracks in the flywheel. Follow the instructions provided with the kit.



Inspect the flywheel ring gear teeth for cracks and chips.

NOTE: If the ring gear teeth are cracked or broken, the ring gear **must** be replaced. Refer to Procedure 016-008.



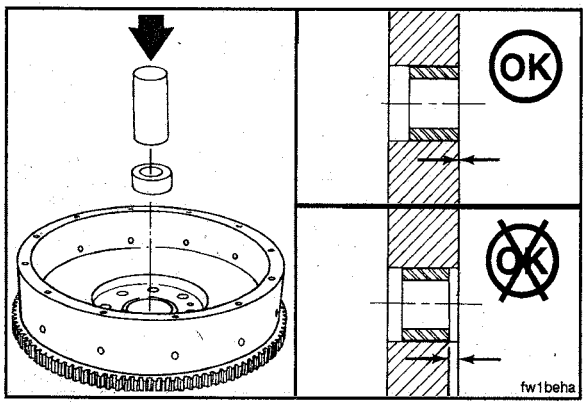


Install

NOTE: Use a new pilot bearing when installing a new or rebuilt clutch.

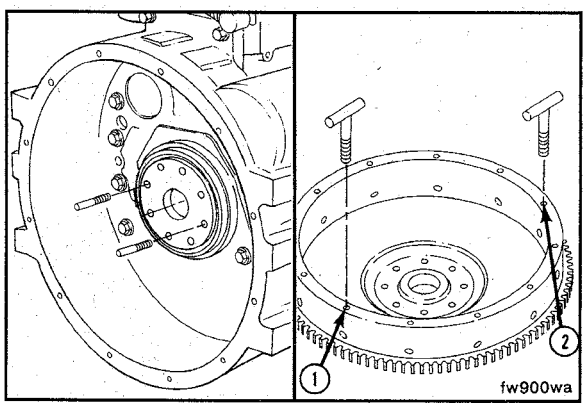
Use a mandrel and a hammer to remove the pilot bearing.

Use Scotch-Brite™ 7448 or equivalent to clean the pilot bore.



Use a mandrel and hammer to install the pilot bearing.

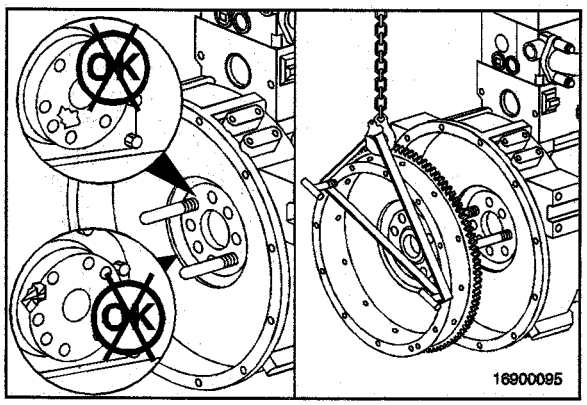
NOTE: The pilot bearing **must** be installed even with the pilot bore surface.



Install two M12 x 1.25 x 90-mm guide pins into the crankshaft flange 180 degrees apart.

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 into the flywheel at points (1) and (2).



⚠WARNING⚠

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

Inspect the rear face of crankshaft and flywheel mounting flange for cleanliness and nicks or burrs.

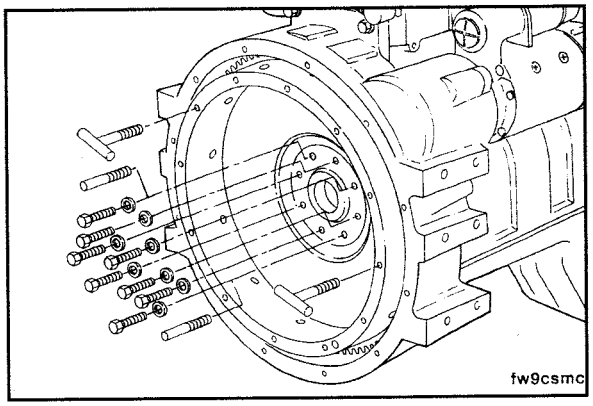
Install the flywheel on the guide pins.

Lubricate the threads of the capscrews and the surface of the washers with 15W-40 lubricating oil.

Install the six capscrews.

Remove the T-handle and guidepins.

Install the remaining capscrews into the holes from where the guide pins were removed.

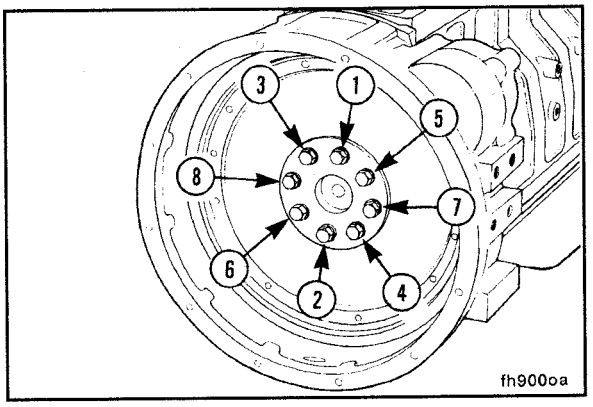


Hold the crankshaft when tightening the flywheel capscrews using the barring tool, Part Number 3824591.

Tighten the capscrews in a star pattern.

Torque Value: 137 N•m [101 ft-lb]

Refer to the equipment manufacturer's procedures to install the transmission clutch and all related components (if equipped).



Measure

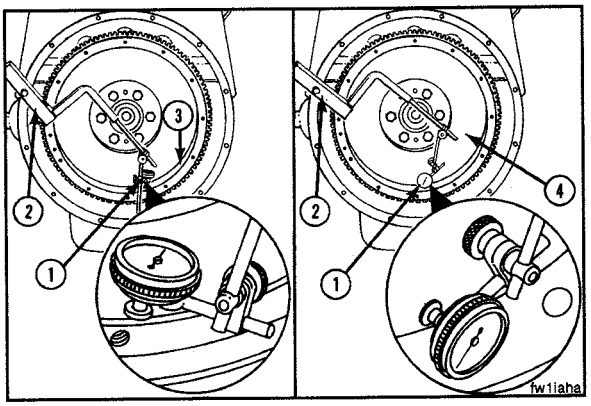
Bore Runout

Use the dial indicator gauge (1), Part Number 3376050, or its equivalent and dial gauge attachment (2), Part Number ST-1325, to inspect the flywheel bore (3) and the surface (4) runout.

Install the attachment to the flywheel housing.

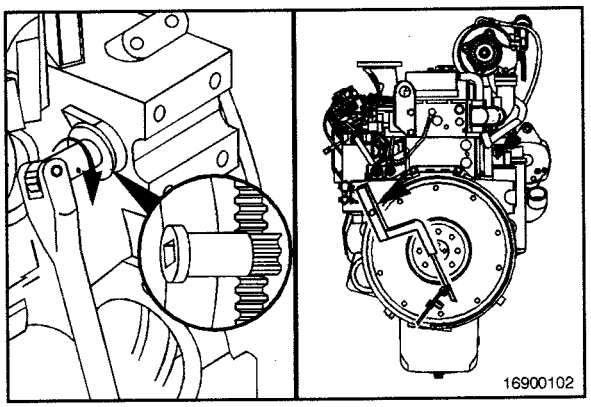
Install the gauge on the attachment.

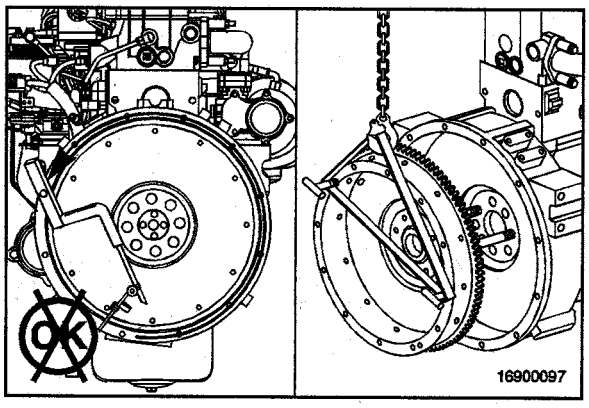
Install the contact tip of the indicator against the inside diameter of the flywheel bore, and set the dial indicator at zero.



Use the barring tool, Cummins Part Number 3374591, to rotate the crank shaft one complete revolution.

NOTE: The total indicator reading (TIR) **must not** exceed 0.127 mm [0.0050 in].

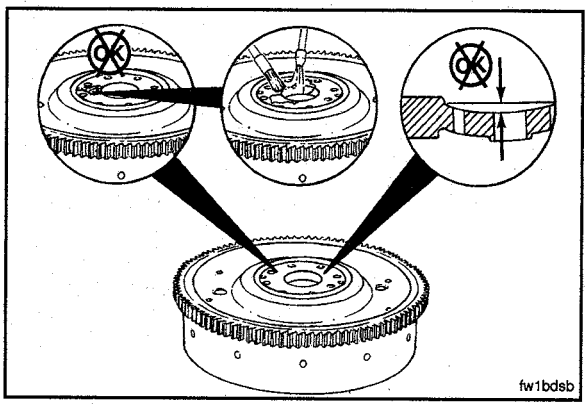




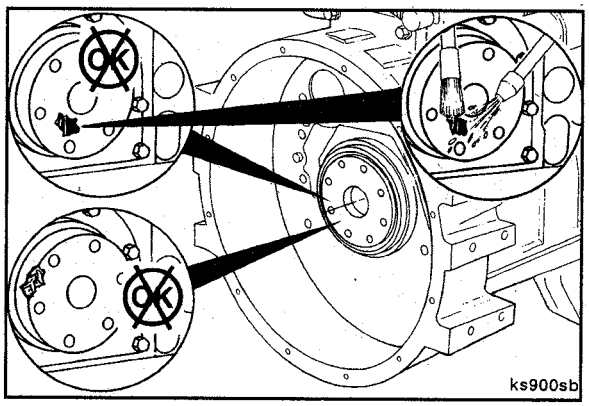
⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

NOTE: If the total indicator reading (TIR) is greater than the specification, do the following:

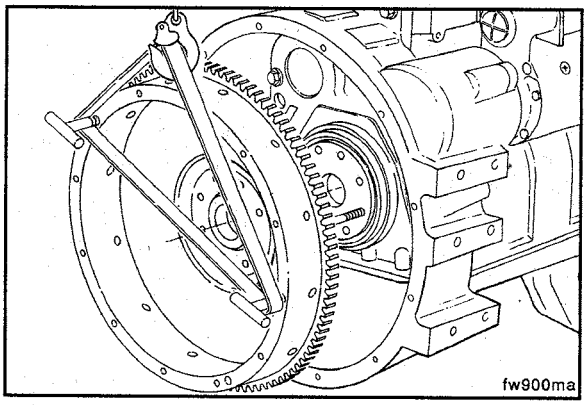
- Remove the flywheel.



- Inspect the flywheel mounting surface for dirt or damage.



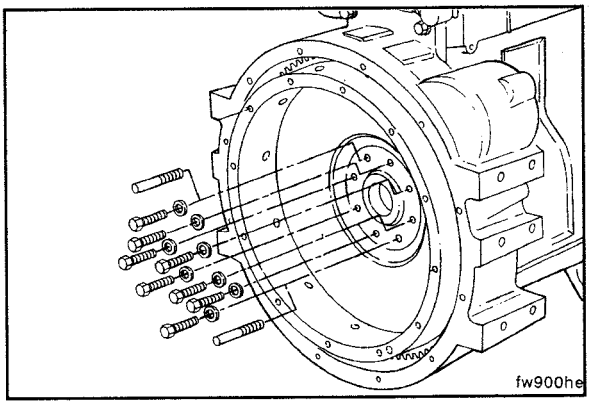
- Inspect the crankshaft for dirt or damage.



⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

- Install the flywheel and inspect the bore runout again.

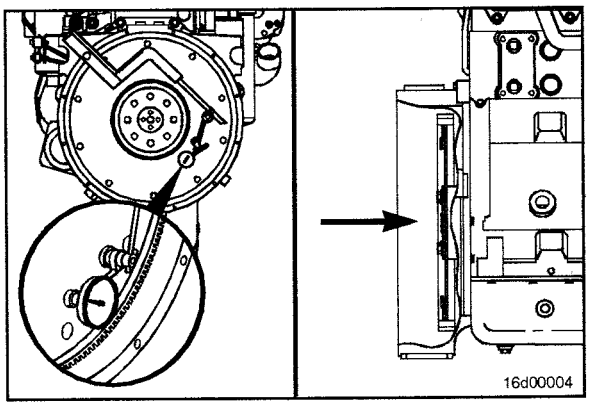
- Replace the flywheel if the runout does **not** meet specifications.



Face Runout

Install the contact tip of the indicator against the flywheel face as close to the outside circumference as possible to inspect the face (1) runout.

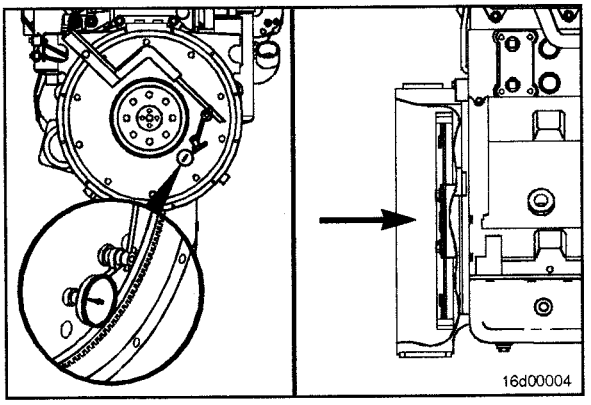
NOTE: Push the flywheel forward to remove the crankshaft end clearance. Adjust the dial on the indicator until the needle points to zero.



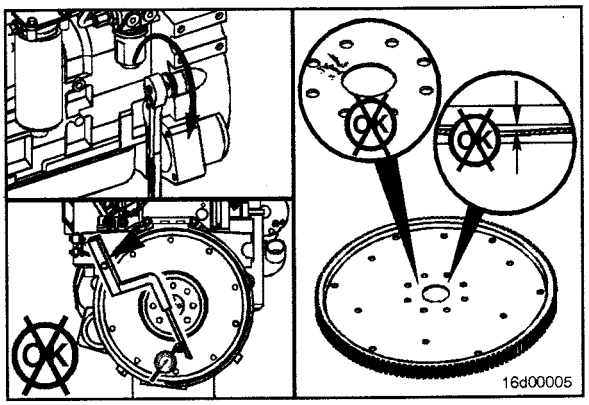
Use the barring tool, Part Number 3824591, to rotate the crankshaft one complete revolution. Measure the flywheel runout at four (4) equal points on the flywheel.

NOTE: The flywheel **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a point is measured.

NOTE: The total indicator reading (TIR) **must not** exceed 0.127 mm [0.0050 in].



If the flywheel runout is **not** within specifications, remove the flywheel. Check for nicks, burrs, or foreign material between the flywheel mounting surface and the crankshaft flange.



Finishing Steps

Install the clutch discs and the pressure plate.

NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

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

Flywheel Housing (016-006)

Preparatory Steps

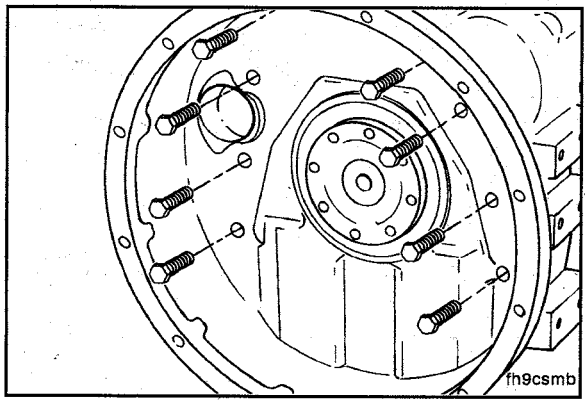
Remove the transmission, clutch, and all related components (if equipped). Refer to the manufacturer's instructions.

Remove the flywheel/ring gear assembly. Refer to Procedure 016-005.

Adequately support the engine to prevent damage.

Remove the starting motor. Refer to Procedure 013-002.

Remove the rear engine mounts. Refer to Procedure 016-003.

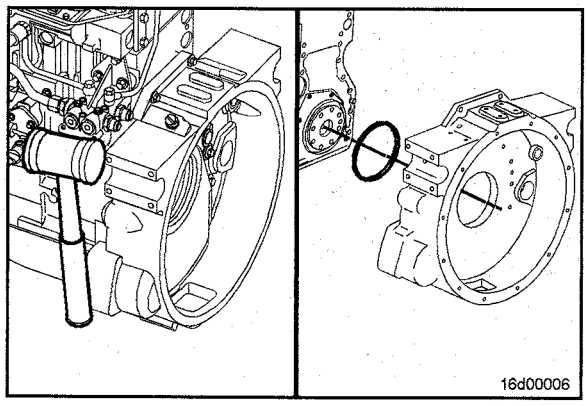


Remove

⚠ WARNING ⚠

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

While supporting the flywheel housing, remove the mounting capscrews.



Use a rubber hammer to loosen the flywheel housing.

Remove the flywheel housing and rectangular seal.

Clean and Inspect for Reuse

⚠WARNING⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠WARNING⚠

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

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

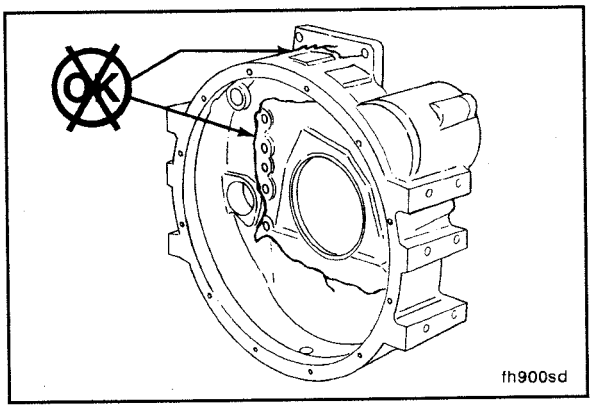
Use steam or solvent to clean the flywheel housing.

Dry with compressed air.

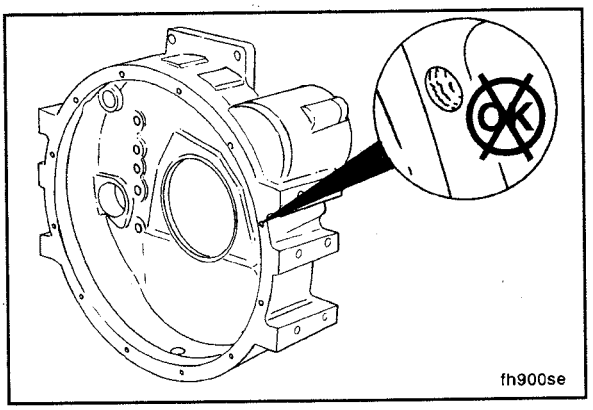
Inspect the flywheel housing for cracks, especially in the bolt pattern area.

Inspect all surfaces for nicks, burrs, or cracks.

Use a fine crocus cloth to remove small nicks and burrs.

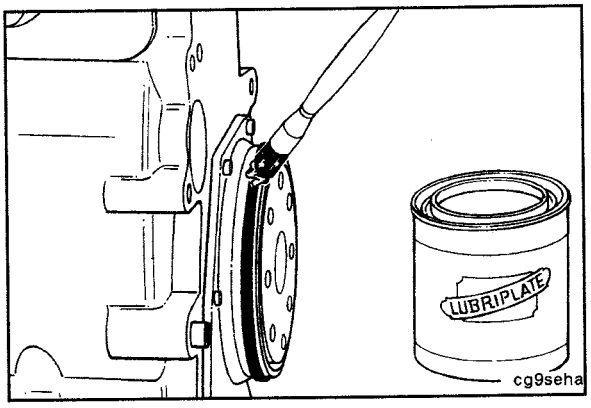


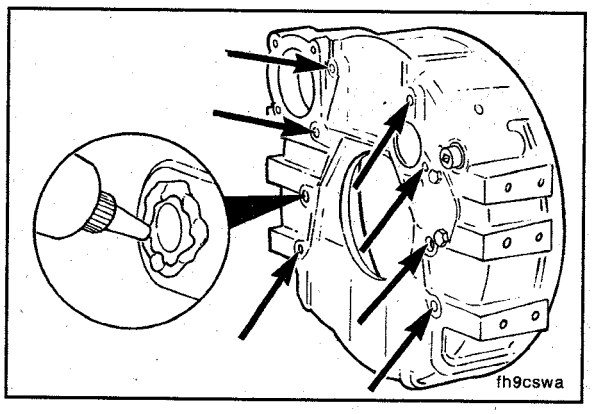
Inspect for damaged threads commonly caused by cross threaded capscrews or installing an incorrect capscrew. Heli-coils are available to repair damaged threads.



Install

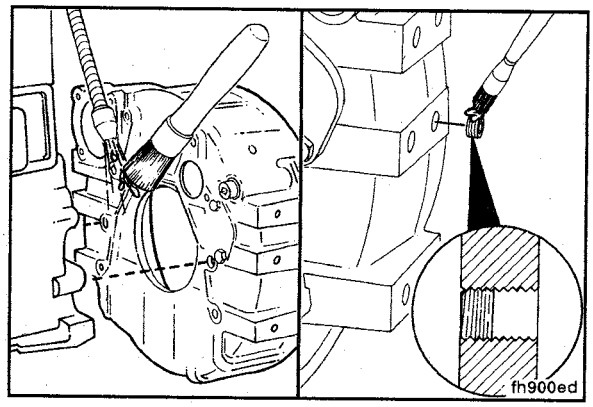
Install rectangular seal and lubricate with Lubriplate™ 105, or equivalent.





Wet Flywheel Applications

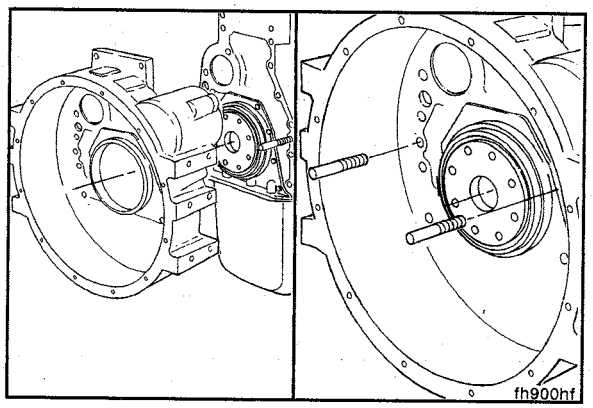
Apply a continuous bead of Three-Bond™, or equivalent, around all capscrew holes on the mounting surface of the flywheel housing.



Wet Flywheel Applications

NOTE: The capscrew holes on the mounting pads are drilled through. Coat set screws with Loctite™ 277, or equivalent, and install into holes.

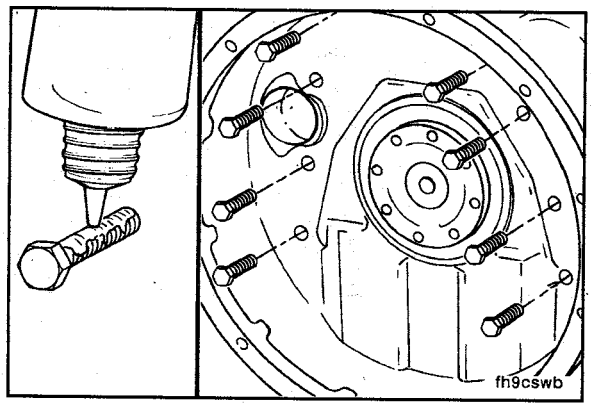
Set Screw Installation Depth (Flywheel Housing)		
mm		in
3.00	MAX	0.118



Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and nicks or burrs.

Install the flywheel housing over the two ring dowels.

NOTE: Be sure the sealing ring is **not** damaged during installation.



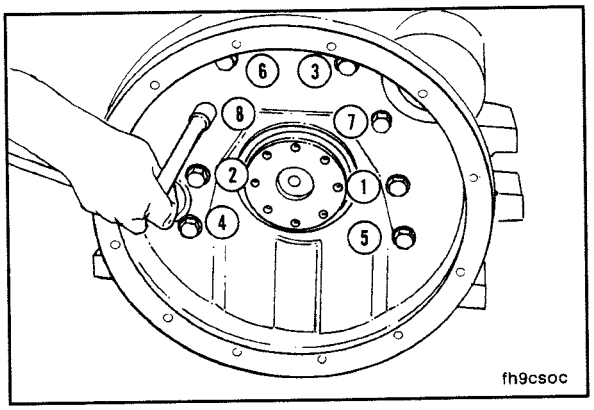
Wet Flywheel Applications

Coat the threads of the mounting capscrews with Loctite™ 277, or equivalent.

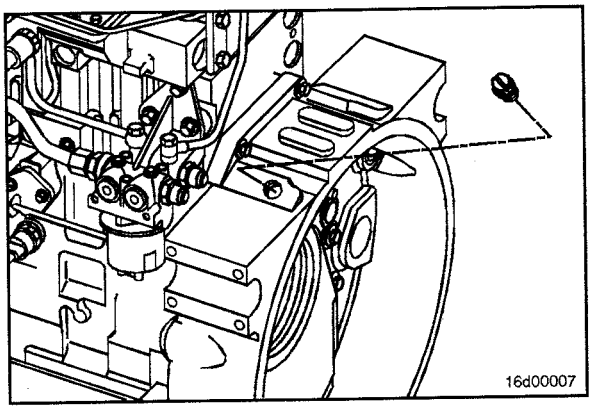
Install and tighten the capscrews.

Tighten the flywheel housing capscrews in the sequence shown.

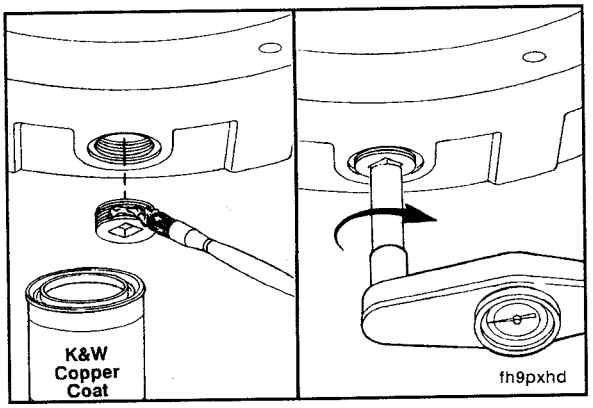
Torque Value: 77 N•m [57 ft-lb]



Install the plastic plug in the tachometer drive access hole.



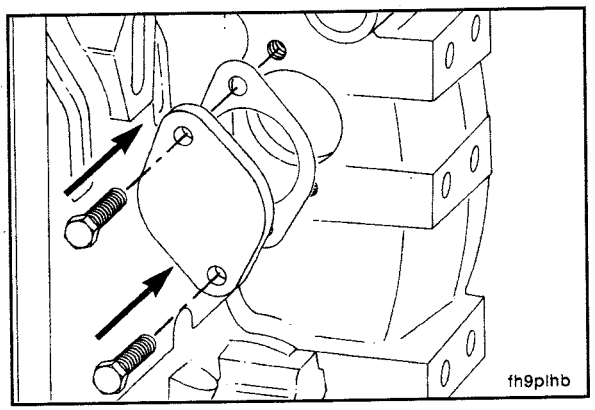
- Coat the flywheel housing drain plug with pipe sealant and install in the hole in the bottom of the flywheel housing.
- Tighten the plug.
- Refer to the pipe plug torque values in Section 17 for different plug sizes.

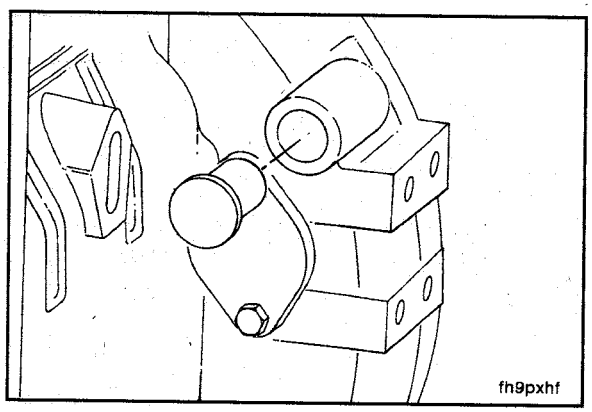


Install the access plate and new gasket.

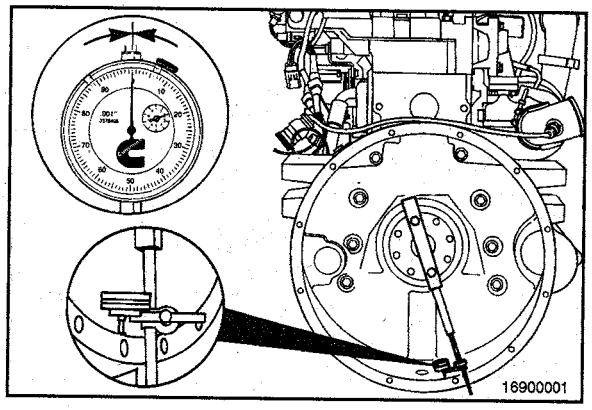
Install the capscrews and tighten.

Torque Value: 24 N•m [18 ft-lb]





Install the plug into the barring gear hole.

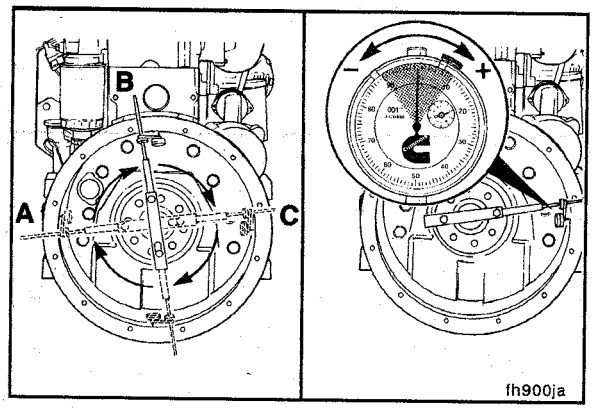


Measure

Bore Alignment

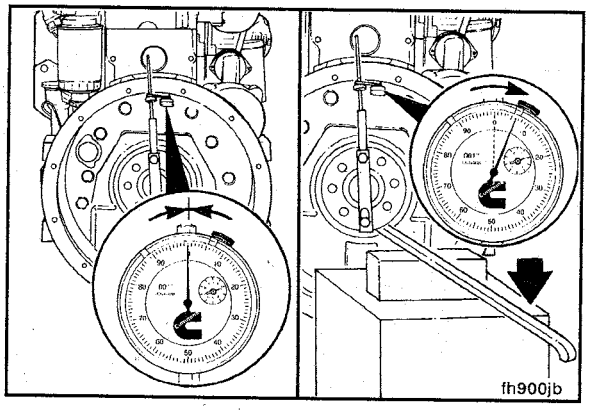
Attach a dial indicator gauge, Part Number 3376050, to the crankshaft. The dial indicator can be mounted by any method that holds the extension bar of the indicator rigid so it does **not** sag. If the bar sags or the indicator slips, the readings obtained will be inaccurate.

Position the indicator in the 6-o'clock position and the gauge at zero.



Slowly rotate the crankshaft. Record the readings obtained at the 9-o'clock, 12-o'clock, and 3-o'clock positions as (a), (b), and (c) in the concentricity work sheet. Recheck 0 at the 6-o'clock position.

The values for (a), (b), and (c) can be positive or negative. Refer to the accompanying figure to determine the correct sign when recording these values.



△CAUTION△

Do not force the crankshaft beyond the point where the bearing clearance has been removed. Do not pry against the flywheel housing. These actions could cause false bearing clearance readings.

Rotate the crankshaft until the dial indicator is at the 12-o'clock position and 0 the gauge.

Using a pry bar, raise the rear of the crankshaft to its upper limit. Record the value as (d) in the concentricity work sheet. This is the vertical bearing clearance adjustment and will **always** be positive.

Be careful **not** to damage the sealing surface when using a pry bar on the crankshaft.

Using the concentricity work sheet, determine the values for the total vertical, and total horizontal values.

The total horizontal is equal to the 9-o'clock reading, (a), minus the 3-o'clock reading, (c).

The total vertical is equal to the 12-o'clock reading, (b), plus the bearing clearance, (d).

Example:

6 o'clock = ref = 0

9 o'clock = [a] = 0.004

12 o'clock = [b] = 0.003

3 o'clock = [c] = -0.002

Using the work sheet and the numbers from the example, the total horizontal value equals 0.006 and the total vertical value equals 0.005.

Concentricity Worksheet

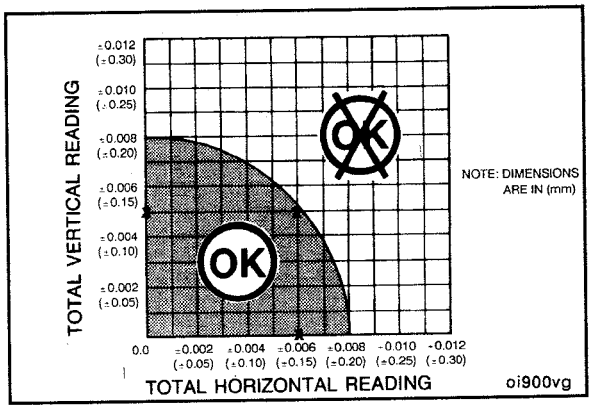
9 o'clock	a = 0.004
3 o'clock	c = -0.002
Total Horizontal	a - c = .006
12 o'clock	b = .003
Bearing Clearance	d = .002
Total Vertical	b + d = .005

oi900vf

Mark the total horizontal value on the horizontal side of the chart and the total vertical on the vertical side of the chart.

Using a straight edge, find the intersection point of the total horizontal and total vertical values. The intersection point **must** fall within the shaded area for the flywheel housing concentricity to be within specification.

Using the total horizontal and total vertical values from the previous example, the intersection point falls within the shaded area. Therefore, the flywheel housing concentricity is within specification.



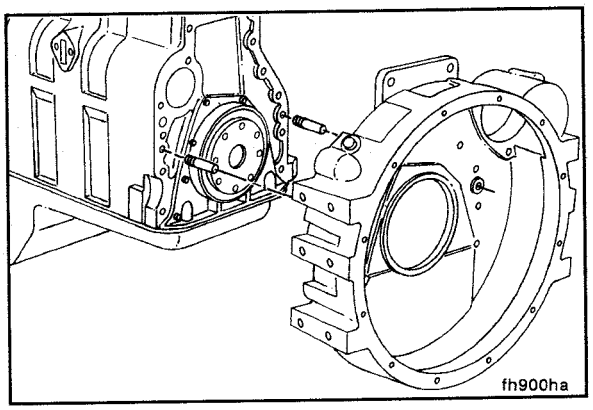
If the intersection point falls outside the shaded area, the ring dowels **must** be removed and the housing repositioned.

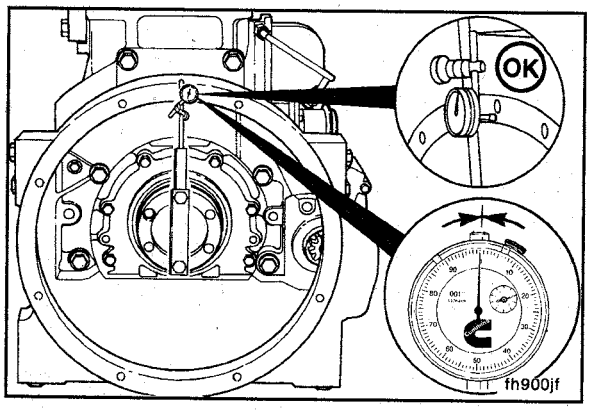
NOTE: The ring dowels are **not** required to maintain concentricity of the housing; the clamping force of the capscrews holds the housing in place.

After the ring dowels are discarded, install the flywheel housing on the engine.

To position the housing, tighten the capscrews enough to hold the flywheel housing in place, but loose enough to enable small movement when struck lightly with a mallet.

Recheck the concentricity. When concentricity is within specification, torque the capscrews to the specified value.



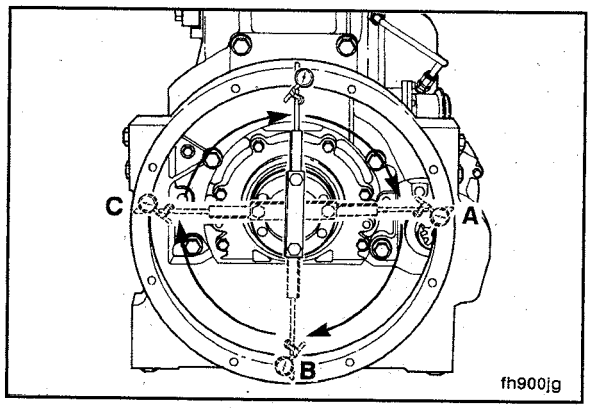


⚠CAUTION⚠

The dial indicator tip must not enter the capscrew holes or the gauge will be damaged.

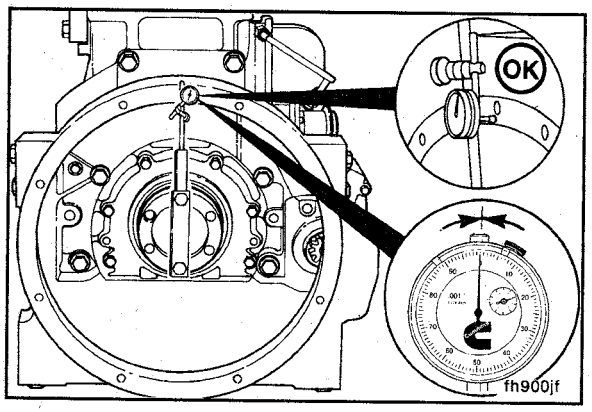
Install a dial indicator as illustrated.

NOTE: The extension bar for the indicator **must** be rigid for an accurate reading. It **must not** sag. Position the indicator at the 12-o'clock position. Adjust the dial until the needle points to zero.

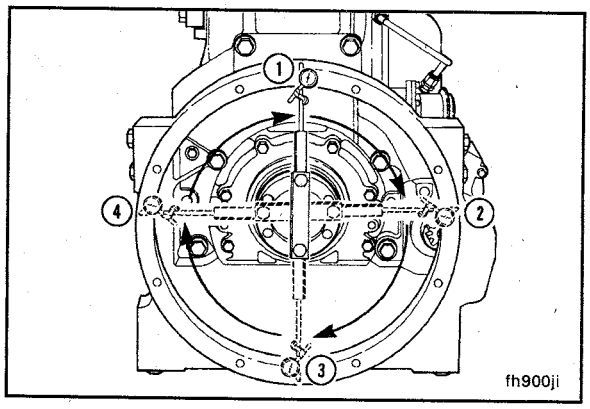


Slowly rotate the crankshaft. Record the readings at the 3-o'clock, 6-o'clock, and 9-o'clock positions.

NOTE: The crankshaft **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a position is measured.



Continue to rotate the crankshaft until the indicator is at the 12-o'clock position. Check the indicator to make sure the needle points to zero. If it does **not**, the readings will be incorrect.

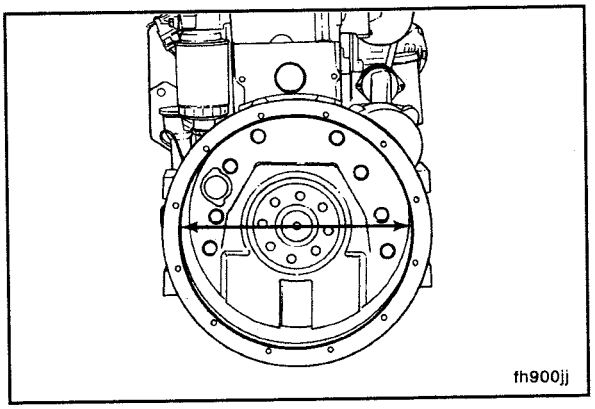


Determine the Total Indicator Reading (TIR).

Example:	mm	in
12-o'clock	0.00	0.000
3-o'clock	+ 0.08	+ 0.003
6-o'clock	- 0.05	- 0.002
9-o'clock	+ 0.08	+ 0.003
Equals TIR	0.13	0.005

The maximum allowable TIR is determined by the diameter of the housing bore. If out of specifications, replace the housing.

Flywheel Housing Bore Size/TIR				
SAE No.	Bore Diameter		TIR Max	
	mm	in	mm	in
2	447.68 to 447.80	17.625 to 17.30	0.20	0.008
3	409.58 to 409.70	16.125 to 16.130	0.20	0.008



Finishing Steps

Install both rear engine mounts. Refer to Procedure 016-003.

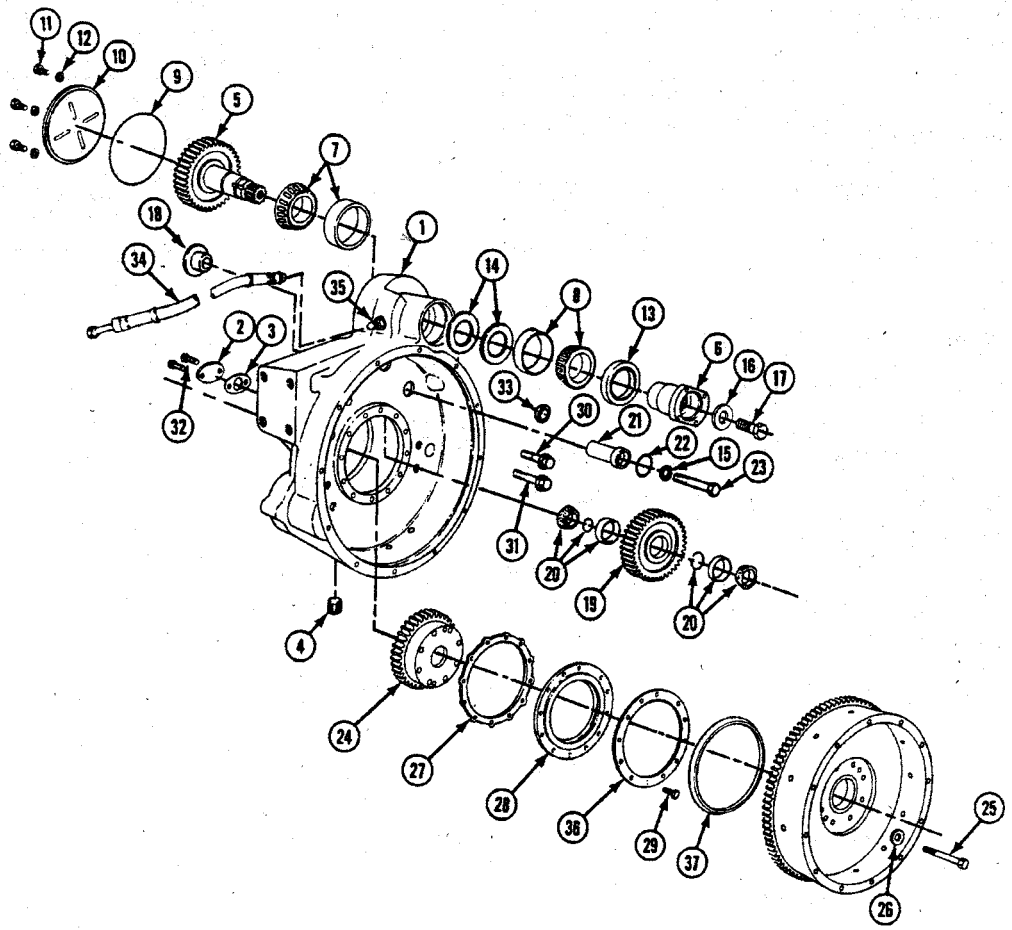
Install the starting motor. Refer to Procedure 013-020.

Install the flywheel/ring gear assembly. Refer to Procedure 016-005.

Install the clutch, transmission, and all related components (if equipped). Refer to the manufacturer's instructions.

Flywheel Housing, REPTO (016-007)

Exploded View



Rear Engine Power Takeoff

Flywheel Housing, REPTO (016-007)

Exploded View

1. Housing, flywheel - 1
2. Cover, access hole - 1
3. Gasket, cover plate - 1
4. Plug, threaded drain - 1
5. Shaft, accessory drive output - 1
6. Flange, power takeoff - 1
7. Bearing, roller (large) - 1
8. Bearing, roller (medium) - 1
9. Seal, rectangular ring (tetra) - 1
10. Plate, cover (ribbed) - 1
11. Capscrew - 4
12. Washer, plain - 4
13. Seal, oil (output shaft) - 1
14. Shims (see next page)
15. Washer, plain - 1
16. Washer, plain (PTO flange) - 1
17. Screw, hexagon head cap - 1
18. Retainer, shaft - 1
19. Gear, idler - 1
20. Assembly, bearing and race - 1
21. Shaft, idler - 1
22. Seal, o-ring - 2
23. Screw, hexagon head cap - 1
24. Gear, crankshaft - 1
25. Screw, hexagon head cap - 8
26. Washer, plain - 8
27. Gasket, carrier - 1
28. Kit, seal - 1
29. Screw, captive washer cap - 12
30. Screw, hexagon head cap - 5
31. Screw, hexagon head cap - 7
32. Screw, hexagon head cap - 2
33. Plug, expansion - 1
34. Hose, flexible oil supply - 1
35. Connection, mate oil supply - 1
36. Ring, clamping - 1
37. Seal, dust - 1.

NOTE: There are seven shims available. A given REPTO could have any combination of these shims.

Ref. No.	Description	mm	in
14	Shim	0.127	0.005
14	Shim	0.254	0.010
14	Shim	0.381	0.015
14	Shim	0.051	0.002
14	Shim	0.076	0.003
14	Shim	0.508	0.020
14	Shim	1.016	0.040

Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

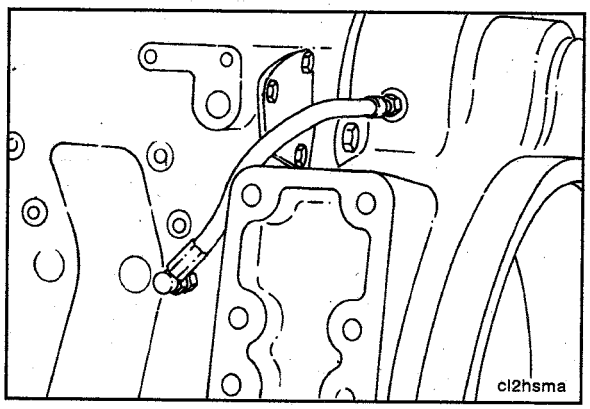
Remove the transmission, clutch, and all related components (if equipped). Refer to the vehicle manufacturer's instructions.

Remove the flywheel/ring gear assembly. Refer to Procedure 016-005.

Adequately support the engine to prevent damage.

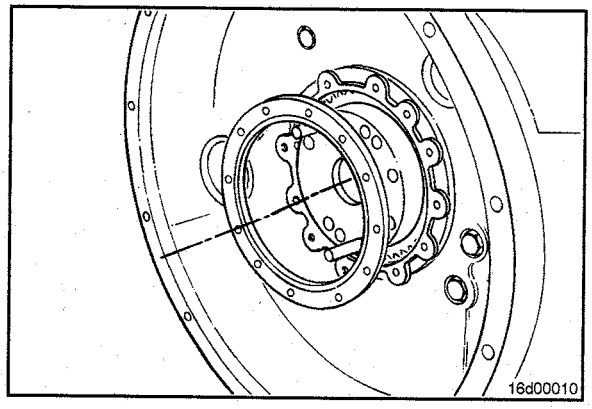
Disconnect the battery cables and remove the starting motor. Refer to Procedure 013-020.

Remove both rear engine mounts. Refer to Procedure 016-003.



Remove

Remove the REPTO oil supply line.

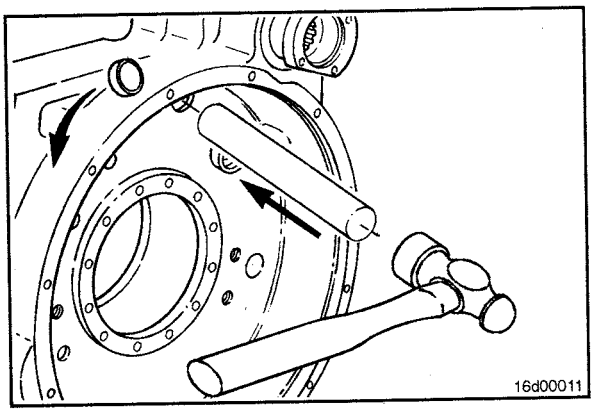


Remove the oil seal capscrews, oil seal, and gasket.

To gain access to the housing capscrews, use a drift to drive the cup plugs straight through into the housing.

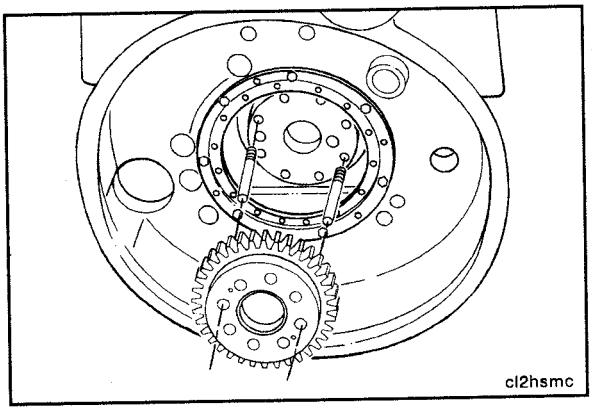
Retrieve the plugs from inside the housing.

Do **not** attempt to back the plugs out or rotate the plugs out of the housing. The cup plug bore will be damaged and oil leakage will occur.

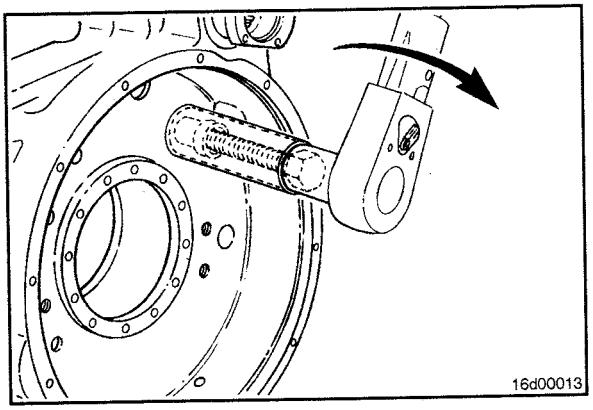


Install two crankshaft locator studs, Part Number 3822784, into the crankshaft flywheel mounting flange 180 degrees apart.

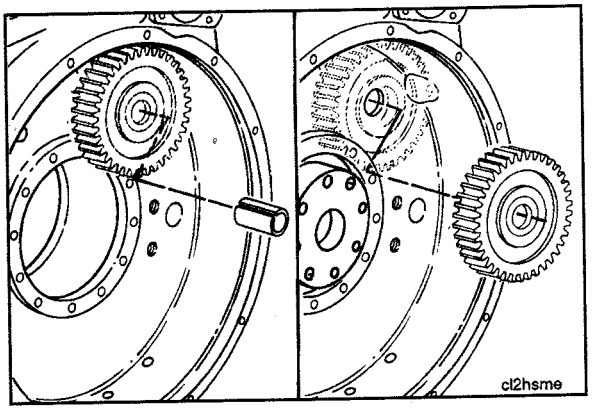
Remove the crankshaft drive gear.

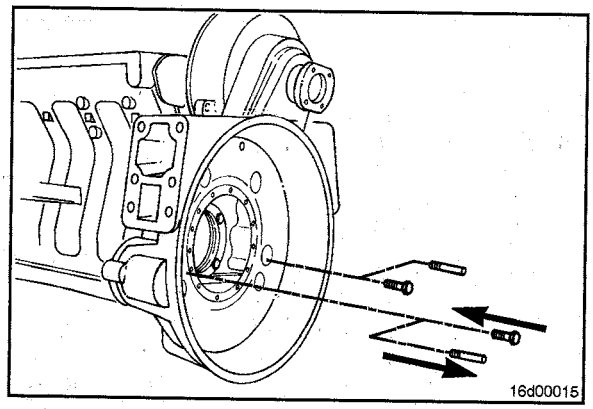


Use the idler shaft puller, Part Number 3823709, to remove the idler shaft.



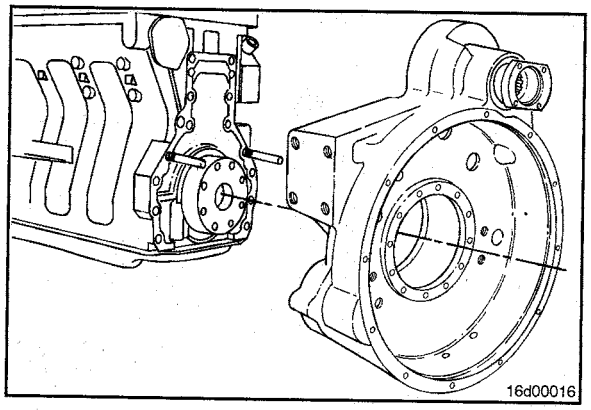
Remove the idler gear to gain access to the rest of the housing capscrews.





Remove two of the capscrews and install two guide pins, Part Number 3376638, to support the housing during removal.

Use an offset wrench, Part Number 3823892, to remove the capscrews that are **not** in view.

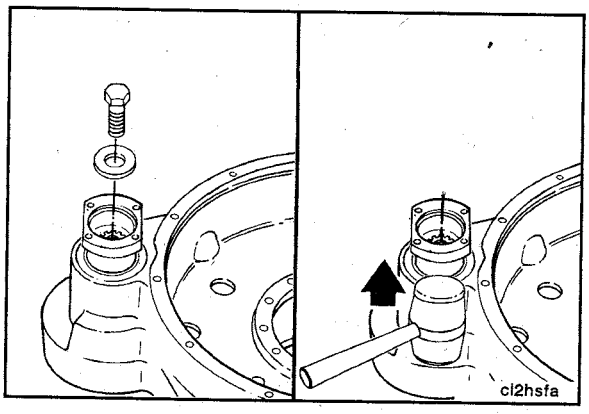


⚠WARNING⚠

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

Remove the remaining capscrews. Use a rubber hammer to loosen the housing.

Remove the housing.

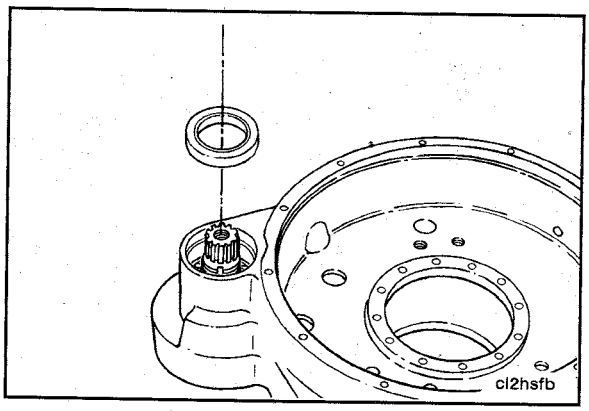


Disassemble

Use gear locking tool, Part Number 3823891, to prevent the output shaft from turning when removing the retainer capscrew.

Remove the capscrew and washer that secures the output flange to the output shaft.

Use a rawhide hammer to remove the output flange and flat washer from the output shaft.



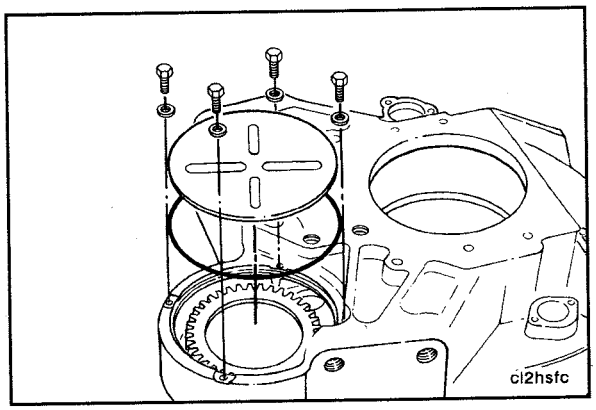
Use a dent puller to remove the seal. Do **not** damage the surface of the housing or seal bore.

When the housing is turned over, the bearing will fall out. Do **not** allow the bearing to be damaged.

Turn the housing over so the four cover plate capscrews are accessible. Be careful **not** to damage the output shaft.

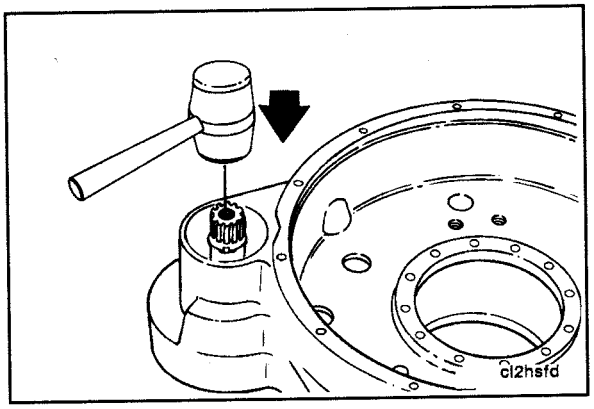
Remove the capscrews and ribbed cover plate from the output gear housing.

Remove and discard the square cut o-ring seal.

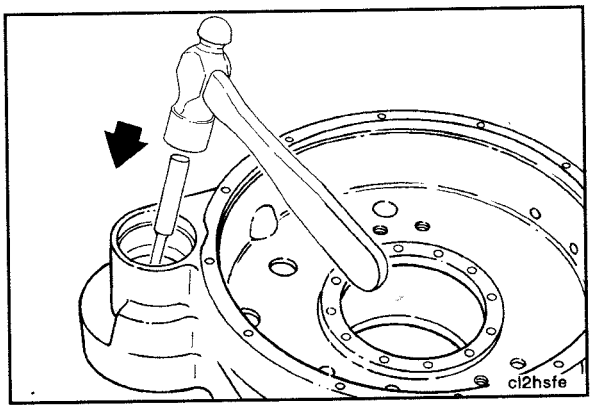


Save the original shims for rebuild purposes. They will be used to set the proper end clearance on the output shaft and bearing assembly.

Turn the housing over and use a rawhide hammer to hit the end of the output shaft to remove the output shaft subassembly from the REPTO housing.



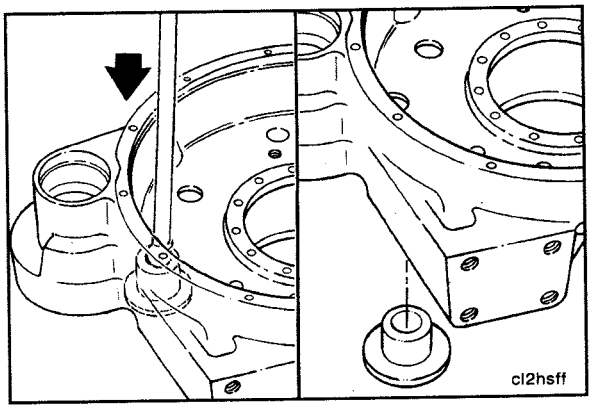
With the housing positioned so the cylinder block mating surface is down, use a hammer and brass punch to drive the bearing outer races out of the output shaft housing bore.

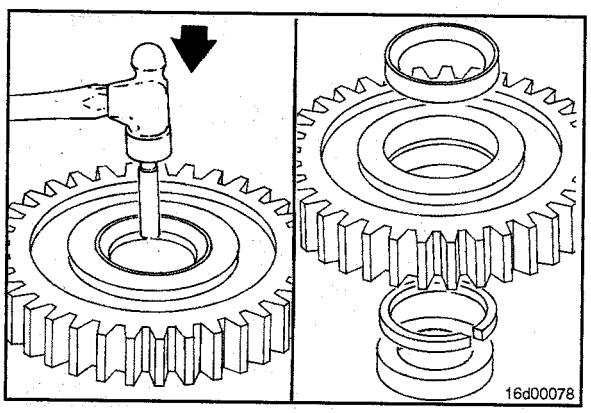


Support the housing in a press with the cylinder block mating surface down.

With a long mandrel, press out the idler shaft bushing.

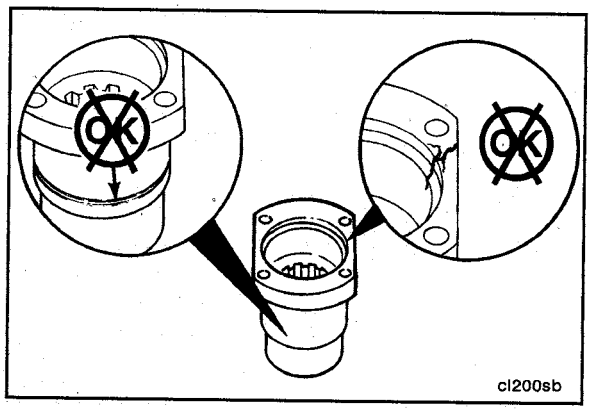
Remove and discard the o-ring.





Use a hammer and brass drift to remove the two bearing outer races from the bore of the idler gear. Discard the outer races.

Remove the large spacer ring from the center groove of the gear. Discard the spacer ring.



Clean and Inspect for Reuse

⚠ 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.

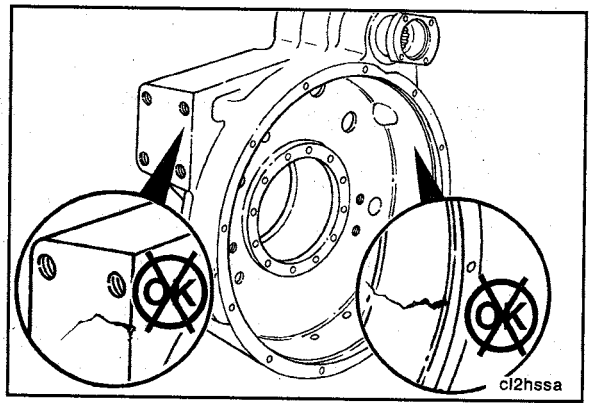
Use a steam cleaner to clean all areas of the idler gear.

Inspect the output shaft and bearings for wear.

Inspect the output gear for damage.

Inspect the output flange for damage or wear grooves from the oil seal.

Replace if necessary.

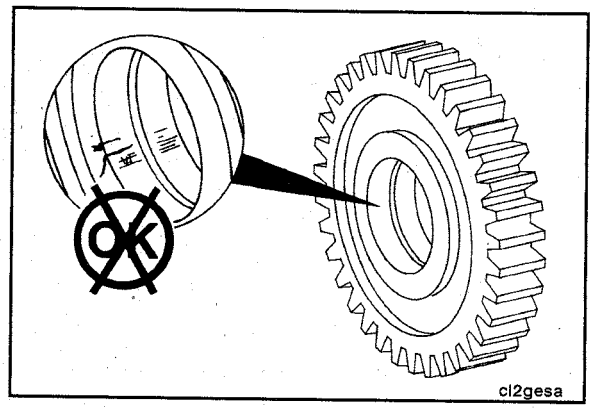


Inspect the REPTO housing for cracks at the rear engine mounting surfaces and the flywheel bore.

Replace the housing if cracked.

Inspect the idler shaft bushing for wear.

Replace the bushing if worn.



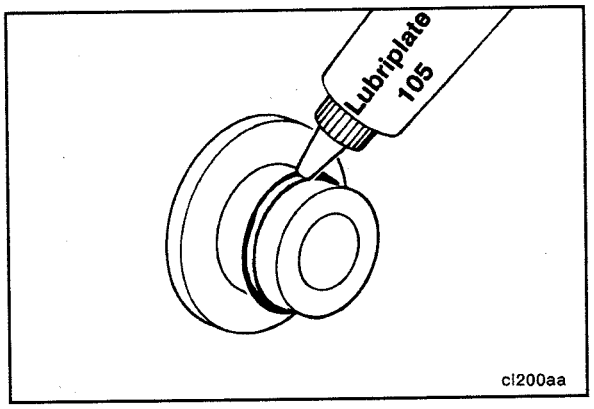
Inspect the bore, side faces, and teeth of the idler gear.

Replace the gear if there are cracks or discoloration from heat damage or other damage.

Assemble

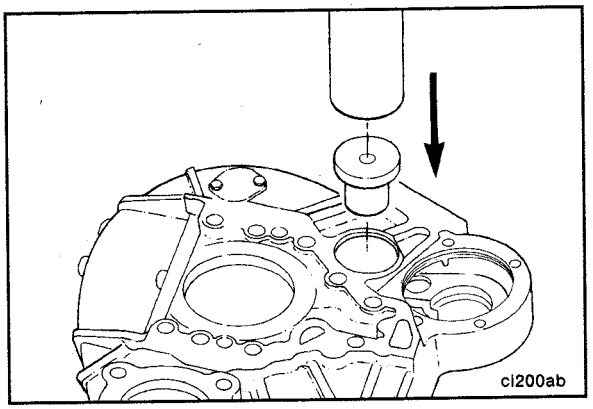
Install a new o-ring on the idler shaft bushing.

Use Lubriplate™ 105 to lubricate the o-ring.



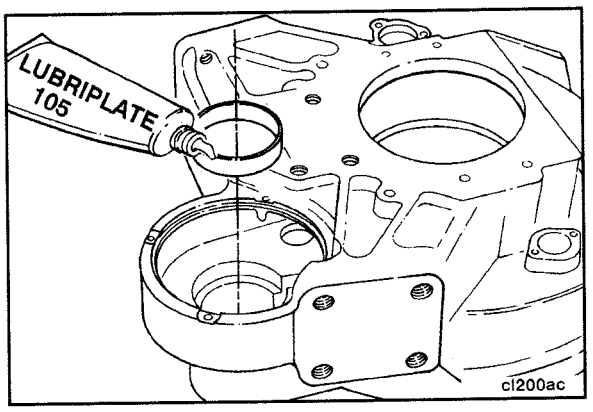
Support the housing evenly with the engine mating surface up.

Press the new bushing into the housing until it is below the surface of the cylinder block mating surface.



Use Lubriplate™ 105 to lubricate the larger bearing race.

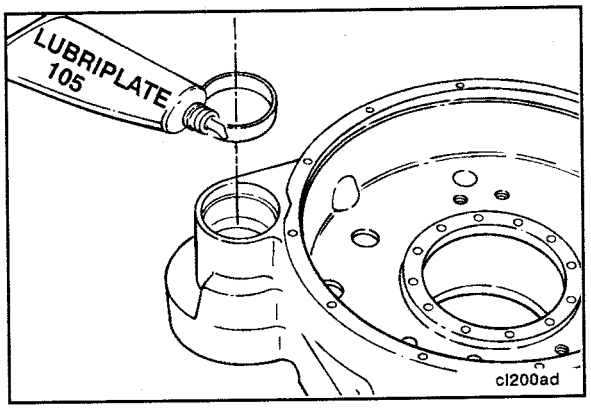
Use the larger end of the driver, Part Number 3823893, to press the bearing race to the shoulder in the housing.

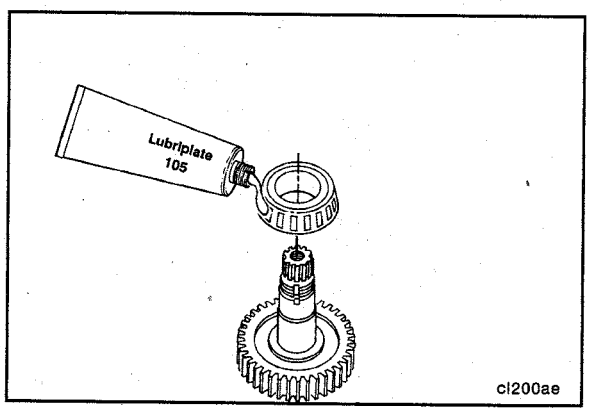


Turn the housing over and support it evenly in the press.

Use Lubriplate™ 105 to lubricate the smaller bearing race.

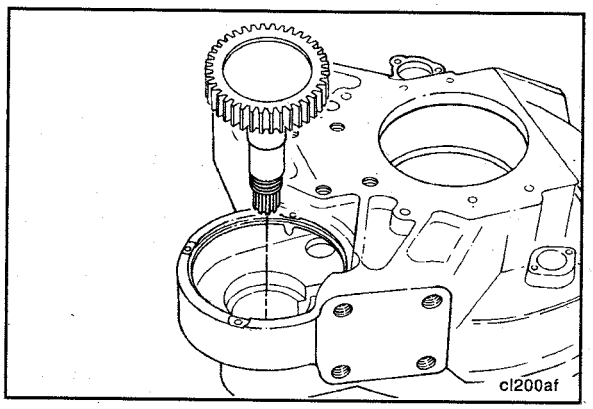
Use the smaller end of the driver, Part Number 38923893, to press the bearing race to the shoulder in the housing.





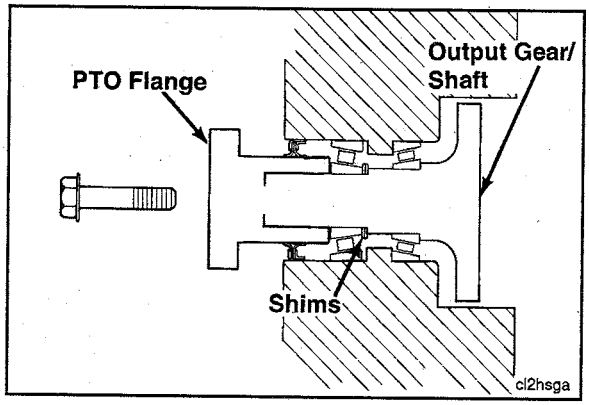
Use Lubriplate™ 105 to lubricate the output shaft and larger bearing.

Install the larger bearing onto the output shaft.



Position the housing on the table so the cylinder block mating surface is up.

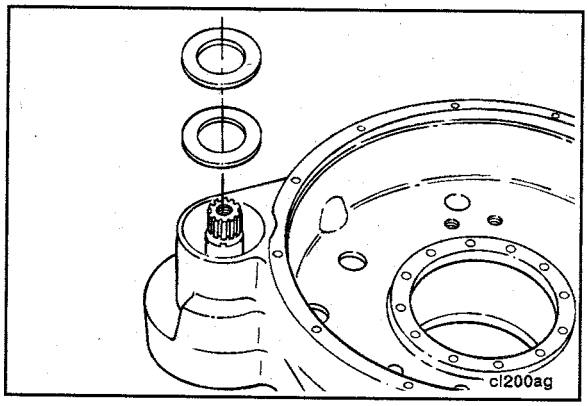
Install the output shaft assembly into the housing.



The correct end clearance (rolling resistance) is determined by the number and thickness of shims used between the two bearings.

When the shim thickness is increased, there is more shaft end clearance and less rolling resistance.

When the shim thickness is decreased, there is less shaft end clearance and more rolling resistance.



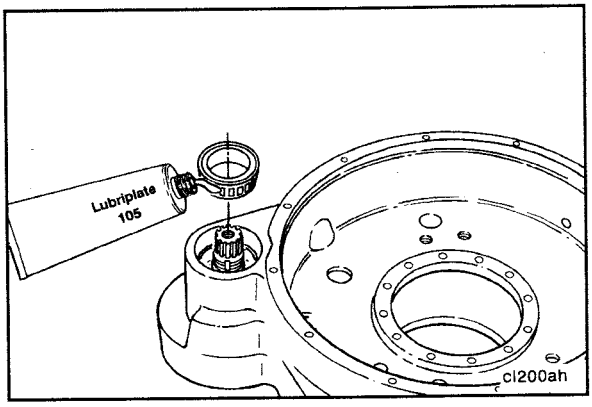
Turn the housing over with the engine mating surface sown, while holding the output shaft and gear in place.

If the original thickness of shims is **not** available for reuse, beginning thickness of 1.47 mm [0.058] can be used as a starting point.

Install the original thickness of shims.

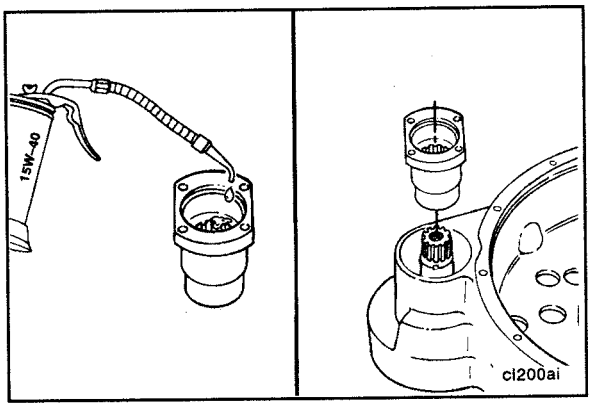
Use Lubriplate™ 105 to lubricate the smaller bearing.

Install the smaller bearing onto the shaft.



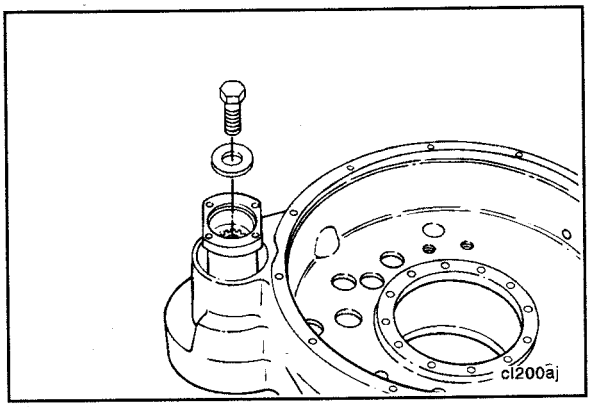
Temporarily install the output flange before installing the oil seal.

Use clean 15W-40 engine oil to lubricate the splines.



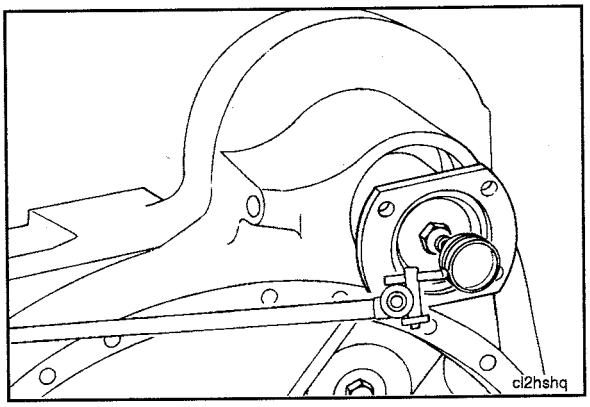
Install the flat washer and capscrew. Use the gear locking tool, Part Number 3823891, to hold the output shaft while tightening the capscrew.

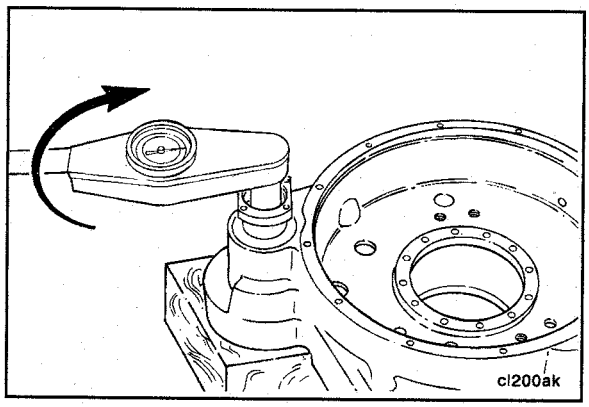
Torque Value: 205 N•m [150 ft-lb]



Measure the shaft end play.

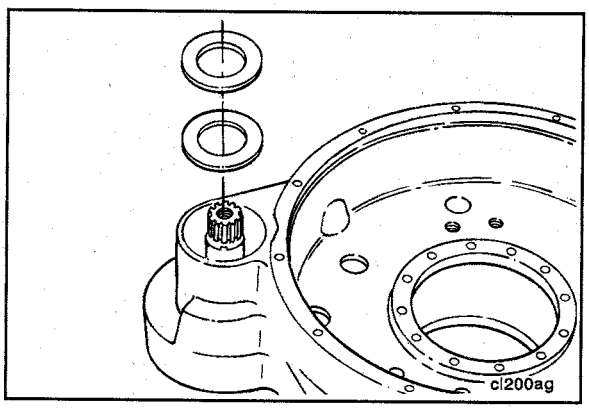
Shaft End Play		
mm		in
0.0	MIN	0.0
0.03	MAX	0.001





Check the output shaft rolling resistance with a torque wrench.

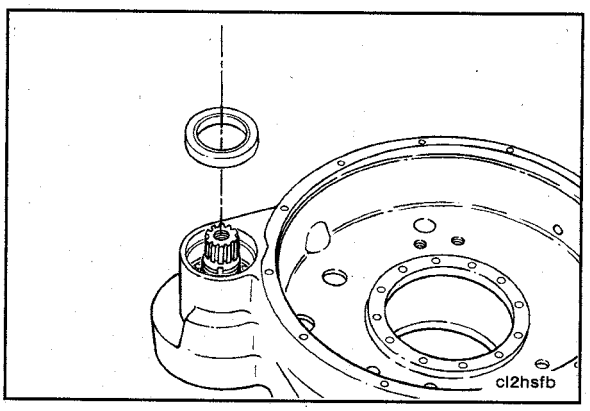
Rolling Resistance 0.6 to 1.1 N•m [5 to 10 in-lb]



If the rolling resistance is **not** within specification, remove the output flange and smaller bearing.

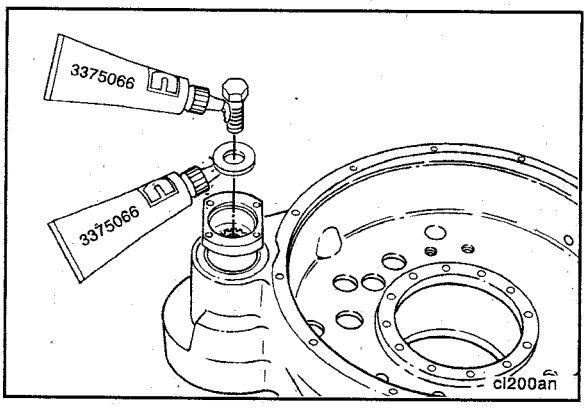
Add or subtract shims to obtain the correct rolling resistance.

Adding more shims will decrease the resistance and removing shims will increase resistance. Any combination of shims can be used.



Once the correct rolling resistance is obtained, remove the output flange and install a new oil seal.

Press the oil seal flush with the housing surface.



Apply pipe sealant, Part Number 3375066, to the output flange capscrew and under the washer.

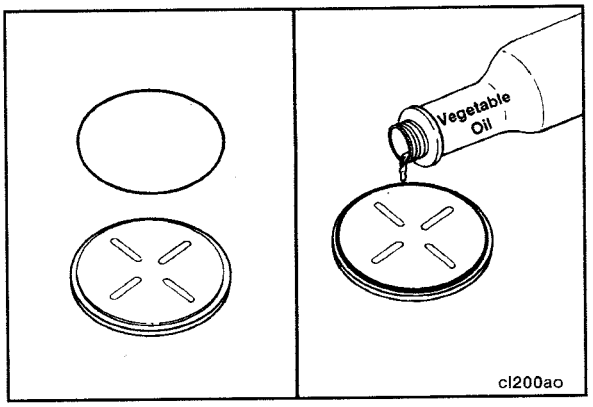
Install the output flange flat washer and capscrew.

Tighten the capscrew.

Torque Value: 205 N•m [150 ft-lb]

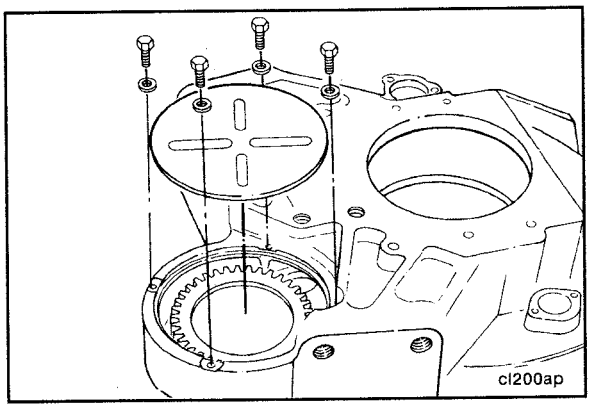
Install a new o-ring on the bearing housing cover.

Use clean vegetable oil to lubricate the o-ring.



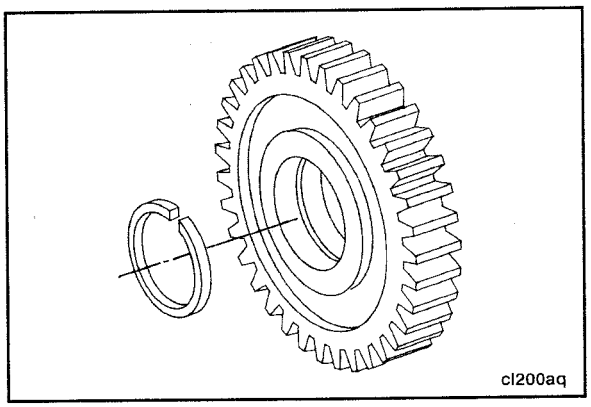
Install and tighten the cover and four capscrews.

Torque Value: 18 N•m [14 ft-lb]



Insert a new spacer ring into the bore of the idler gear.

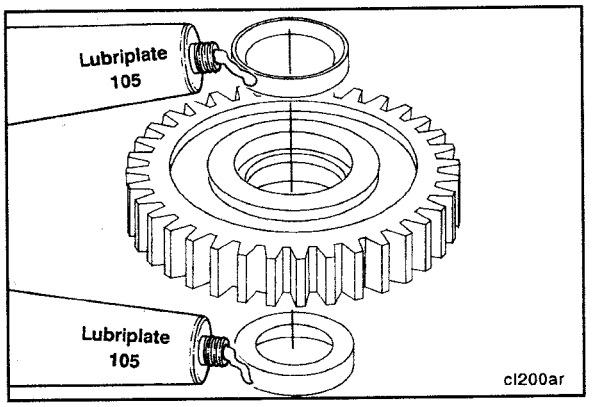
Push until it snaps into place in the center groove.

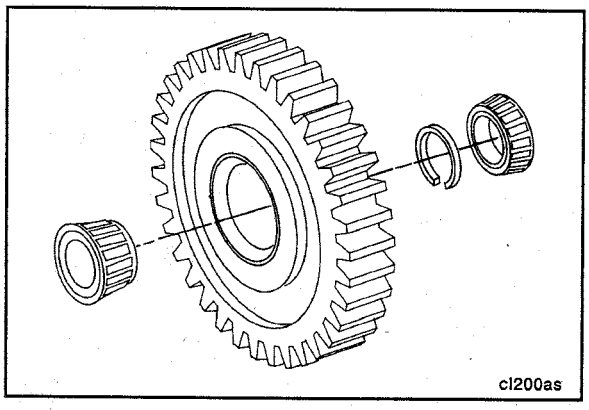


Use Lubriplate™ 105, or equivalent, to lubricate the bearing outer races.

Press the two new bearing outer races into the bore of the idler gear.

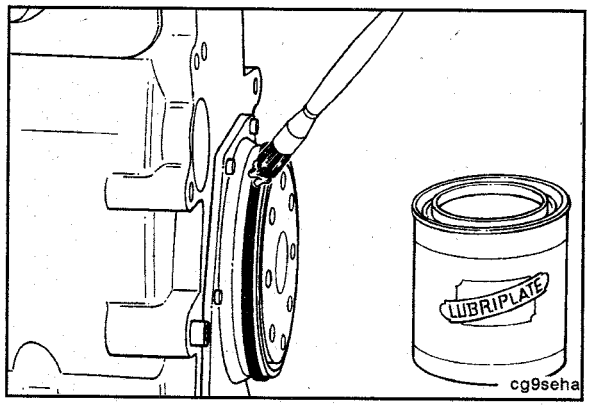
The larger side of the taper **must** face toward the outside of the gear.





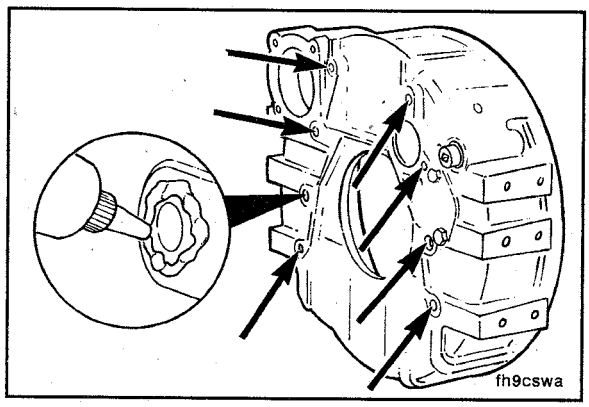
Do **not** interchange individual parts that make up the idler gear bearing assembly. Rebuild the idler gear with bearing that are packaged together.

Keep the two roller bearing assemblies and the spacer ring with the idler gear.

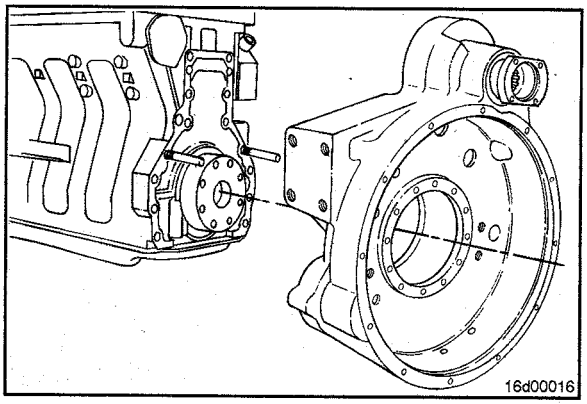


Install

Install the rectangular seal and lubricate with Lubriplate™ 105, or equivalent.



Apply a continuous bead of Three-Bond™, or equivalent, around all capscrew holds on the mounting surface of the flywheel housing.



⚠WARNING⚠

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

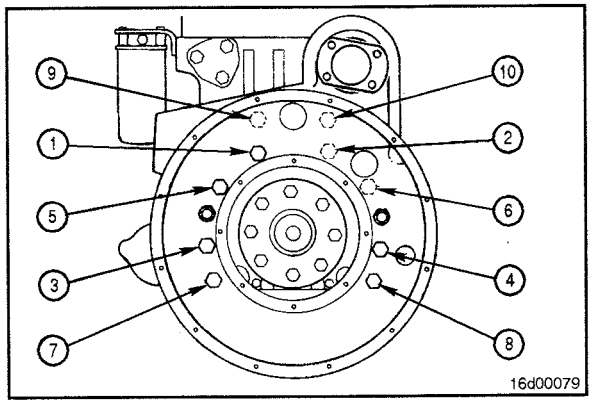
Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and nicks or burrs.

Install the flywheel housing over the two ring dowels.

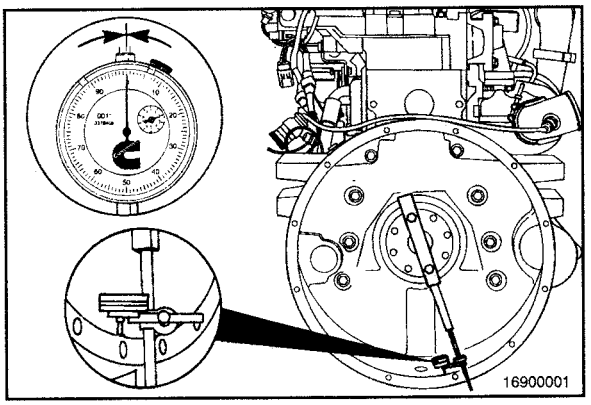
Be sure the sealing ring is **not** damaged during installation.

Install the capscrews and tighten in the sequence shown, using an offset wrench, Part Number 3823892, for capscrews hidden from view.

Torque Value: 77 N•m [57 ft-lb]



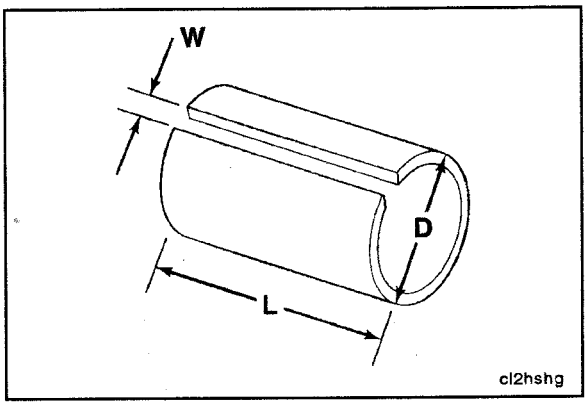
Before installing the idler gear, measure the flywheel housing bore and face alignment. Refer to Procedure 016-006.



Manufacture a sleeve from 26.035 mm [1.25 in] PVC (or equivalent) to the following dimensions:

Length: 25.4 mm [1.0 in]

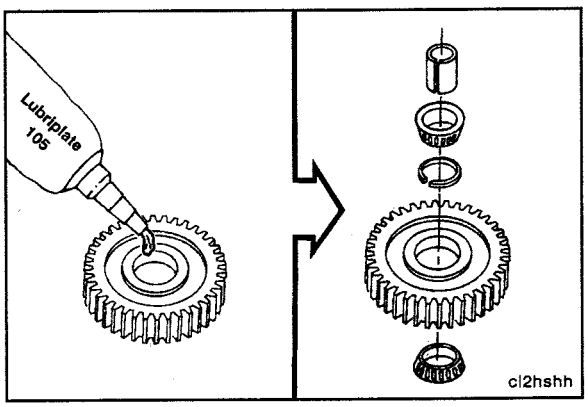
Slot: 1.27 mm [0.50 in]

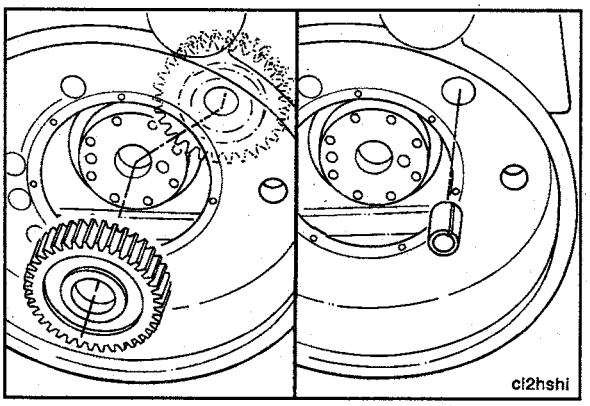


The outer bearing races of new replacement gears are already pressed into the gear.

Apply a thin film of Lubriplate™ 105, or equivalent, on the outer races and bearings.

Install the bearing and spacer into the idler gear. Use a plastic sleeve to hold the bearing assembly together when installing the idler gear assembly.

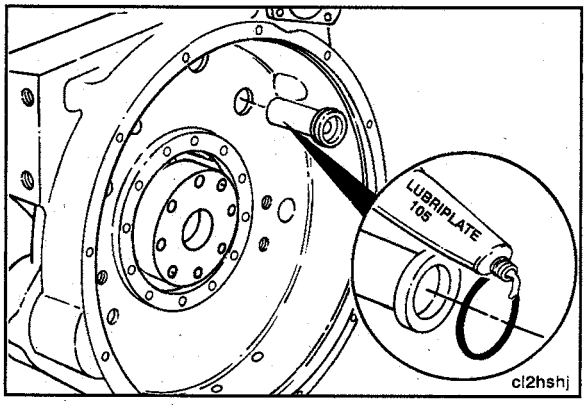




Apply a thin film of Lubriplate™ 105, or equivalent, into the idler shaft bore of the housing and on the idler shaft.

Install the idler gear assembly into the flywheel housing.

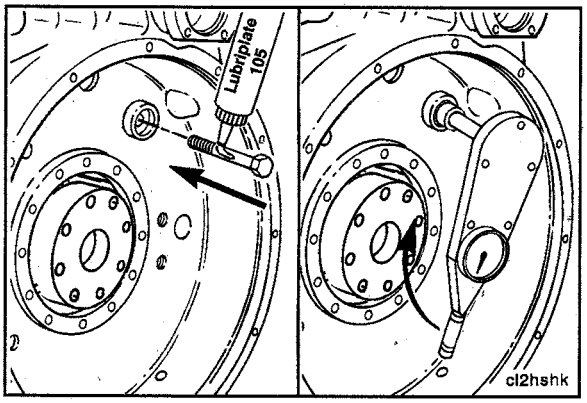
Hold the idler gear and bearing in place and remove the plastic sleeve.



Use clean Lubriplate™ 105 to lubricate the idle shaft o-ring and install the o-ring into the shaft.

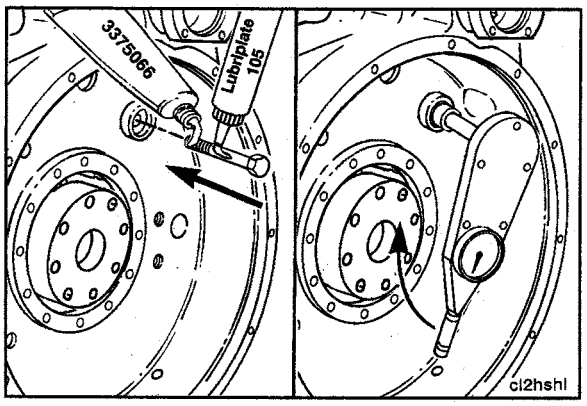
Hold the gear assembly in place and insert the idler shaft through the housing and idler gear bearings.

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.

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 is an indication of misalignment between the bore and the shaft. Remove the idler shaft and install it again.



When the idler shaft has been seated, remove the capscrew.

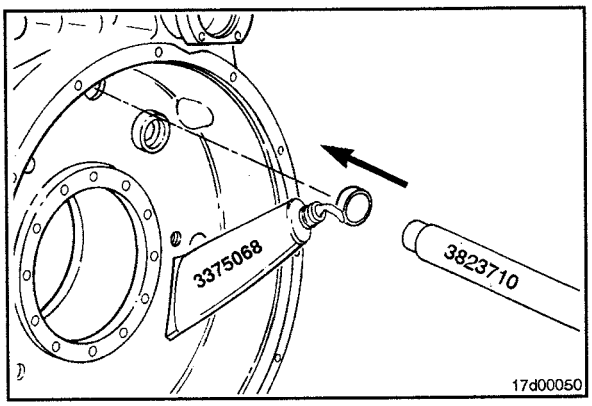
Apply pipe sealant, Part Number 3375066, to the threads of the idler shaft capscrew. Apply Lubricate™ 105 under the head of the capscrew and tighten to it's final torque value.

Torque Value: 105 N•m [75 ft-lb]

Apply a film of cup plug sealant, Part Number 3375068, to the outside diameter of the cup plugs.

Use a driver, Part Number 3823710, to install the cup plugs into the housing, as shown.

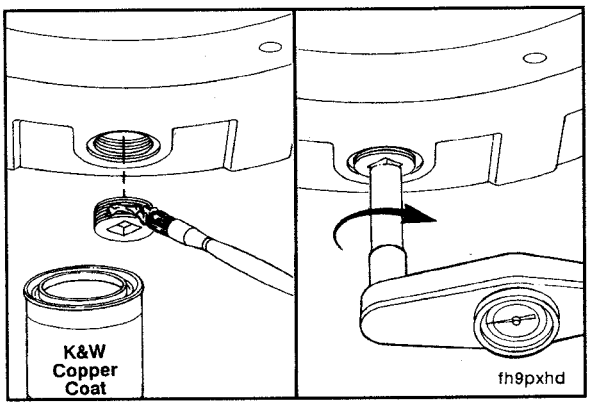
When installing cup plugs, make sure they are flush with the spot face on the flywheel housing and are **not** crooked.



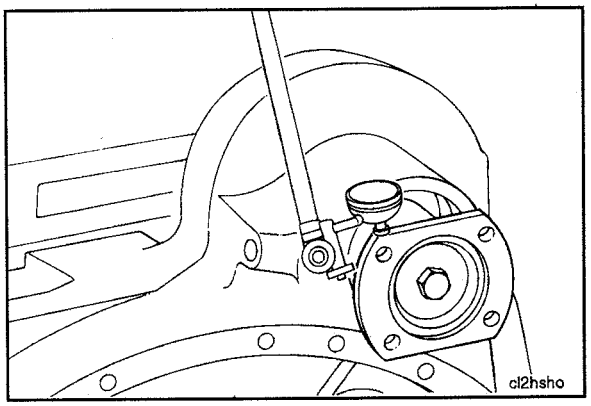
Coat the flywheel housing drain plug with pipe sealant and install in the hole in the bottom of the flywheel housing.

Tighten the plug.

Refer to the pipe plug torque values in Section 017 for different plug sizes.



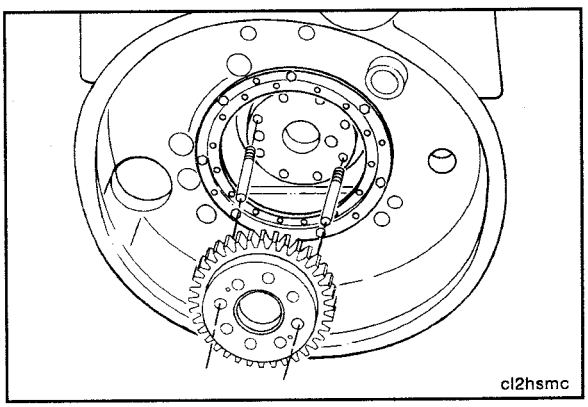
Turn the output flange so that the flat sides are on the top and bottom. This prevents any interference when the transmission is installed onto the housing.

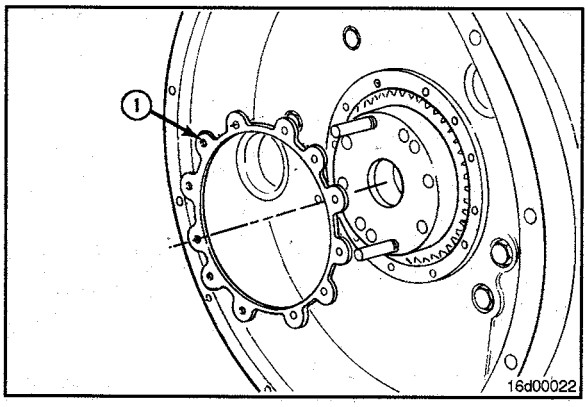


Install two crankshaft locator studs, Part Number 3822784, into the crankshaft flywheel mounting flange 180 degrees apart.

Make sure the crankshaft and crankshaft gear is clean.

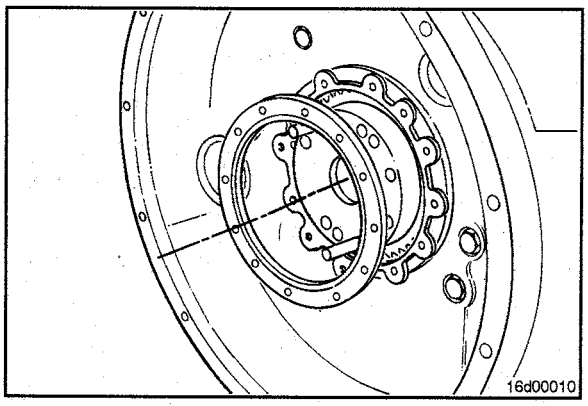
Install the crankshaft gear in the locator studs.



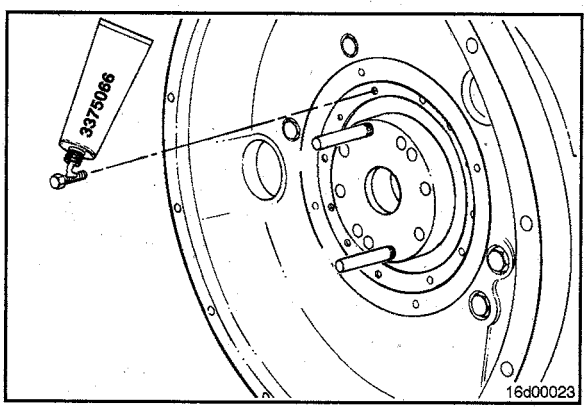


Do **not** use any kind of lubricant to install the seal. The oil seal **must** be installed with the crankshaft gear seal contact surface and the lip of the seal clean and dry to provide a proper oil sealing surface.

Install a new gasket (1) in the flywheel housing.



Install a new seal over the crankshaft gear seal contact surface.



Apply sealant, Part Number 3375066, to seal the retainer capscrews.

Install the capscrews and tighten in a star pattern.

Torque Value: Step1 7 N•m [60 in-lb]
Step2 19 N•m [170 in-lb]

Finishing Steps

Install the starting motor. Refer to Procedure 013-020.

Install the rear engine mounts. Refer to Procedure 016-003.

Install the flywheel/ring gear assembly. Refer to Procedure 016-005.

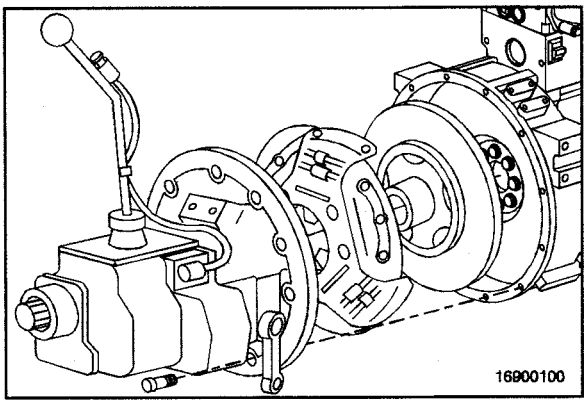
Install the transmission, clutch, and all related components (if equipped). Refer to the manufacturer's instructions.

Flywheel Ring Gear (016-008)

Initial Check

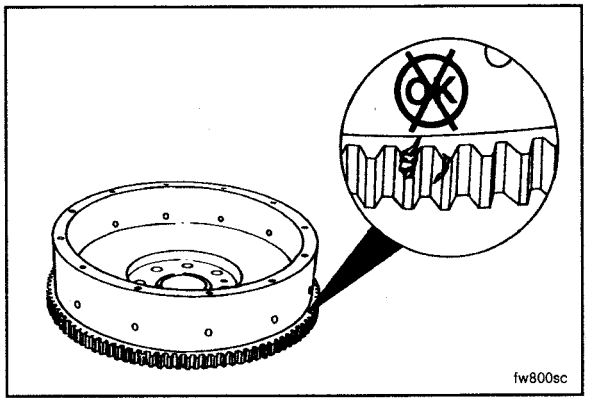
Remove the transmission. Refer to the equipment manufacturer's instructions.

Remove the flywheel/ring gear assembly. Refer to Procedure 016-005.



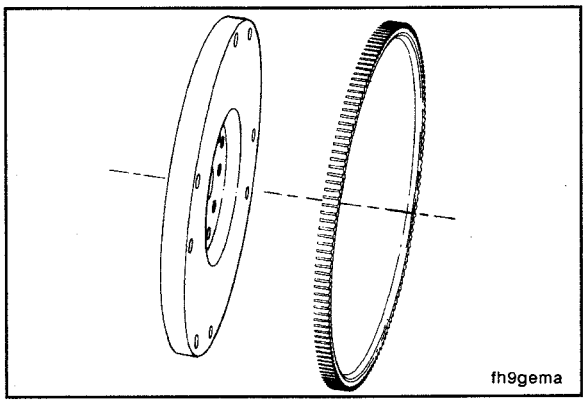
Inspect the ring gear teeth for cracks and chips.

NOTE: If the ring gear teeth are damaged, the ring gear **must** be replaced.



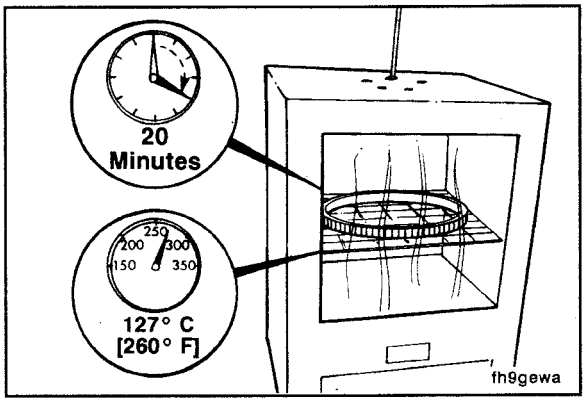
Remove

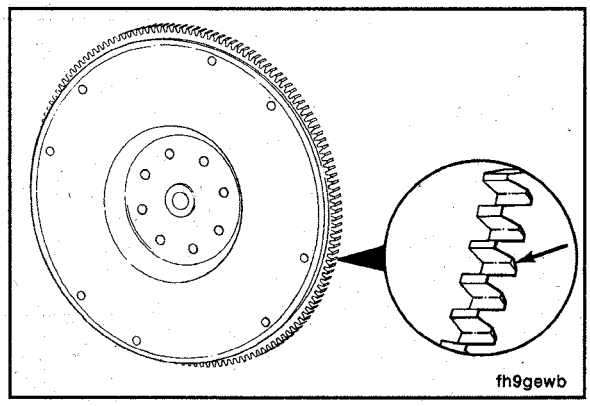
Use the drift pin to drive the ring gear from the flywheel.



Install

Heat the ring gear for 20 minutes in an oven pre-heated to 127°C [260°F].





Install the ring gear. The ring gear **must** be installed so the bevel on the teeth is toward the crankshaft side of the flywheel.

Finishing Steps

Install the flywheel/ring gear assembly. Refer to Procedure 016-005.

Install the transmission, clutch, and all related components (if equipped). Refer to the manufacturer's instructions.

Section 17 - Miscellaneous - Group 17

Section Contents

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Cup Plug (017-002)

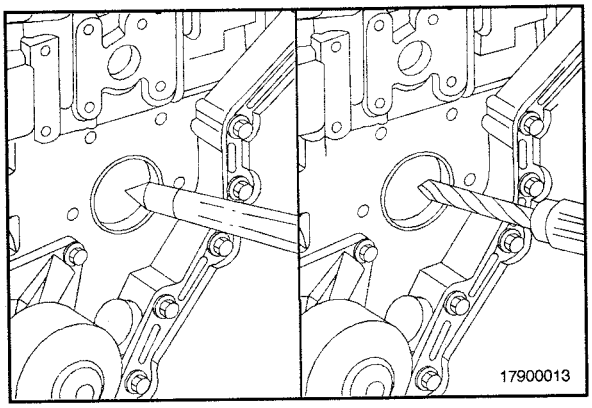
Remove

⚠CAUTION⚠

Do not allow metal shavings to fall in the engine when drilling a hole in the cup plug. Damage to engine components can occur.

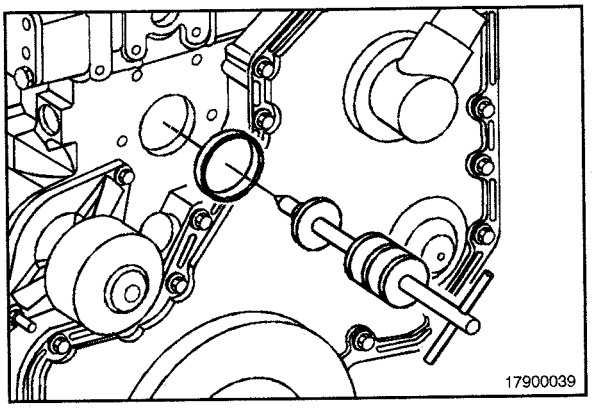
Use a center punch to mark the cup plug for drilling.

Drill an 1/8-inch hole into the cup plug.



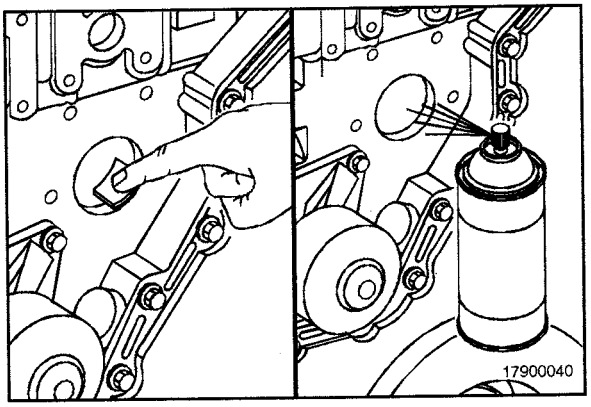
Use a dent puller to remove the plug.

Discard all used cup plugs. Do **not** use them again.

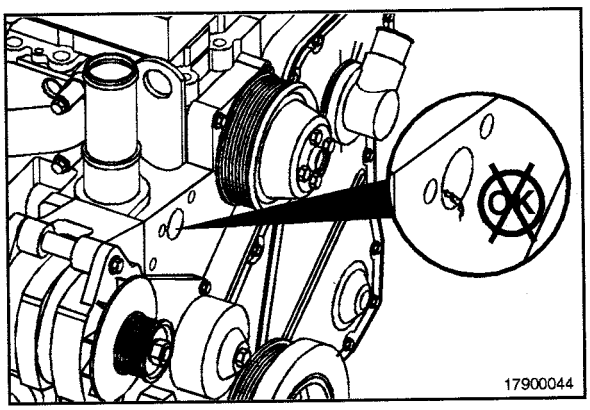


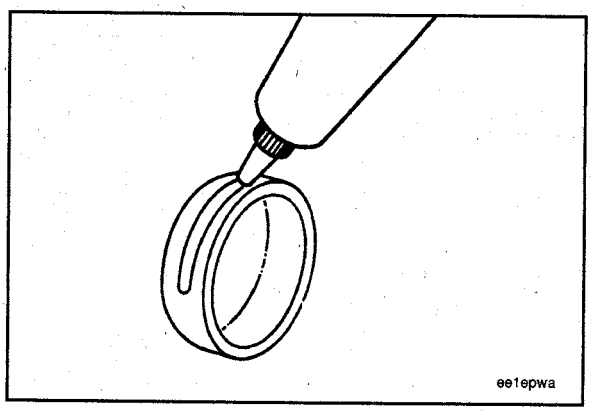
Clean and Inspect for Reuse

Thoroughly clean the cup plug hole using Scotch-Brite™, or equivalent. Use spray cleaner, Cummins Part Number 3375433, or equivalent, to perform a final clean of the bore.



Inspect the cup plug bores for damage.





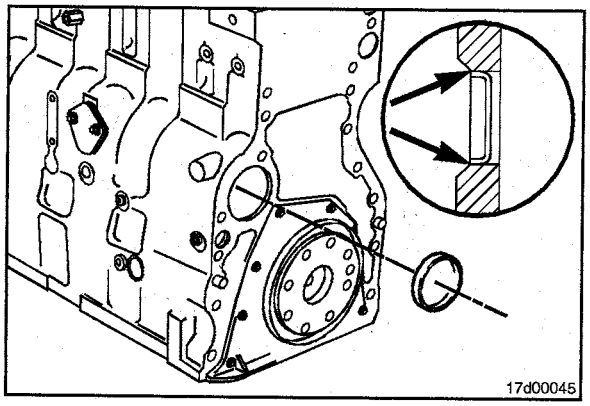
Install

⚠CAUTION⚠

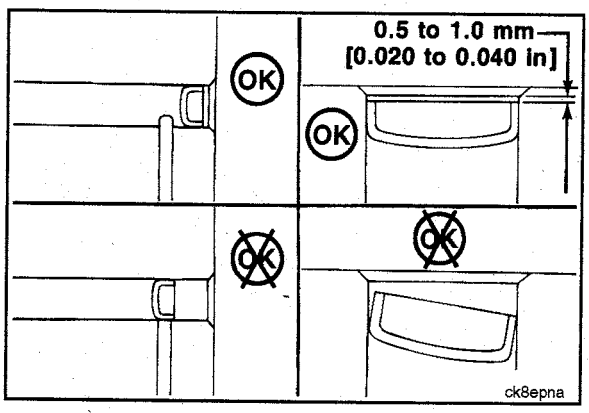
Excessive sealant can run back into the engine and cause damage to other components. Allow the sealant to dry for a minimum of 2 hours before operating the engine. The plug can come out of the bore if the sealant is not dry.

Apply a 2 mm [1/16 in] bead of cup plug sealant, Part Number 3375068, or equivalent to the outside circumference of the cup plug and the inside diameter of cup plug bore.

NOTE: Do **not** install a used cup plug. Discard all plugs after removal.



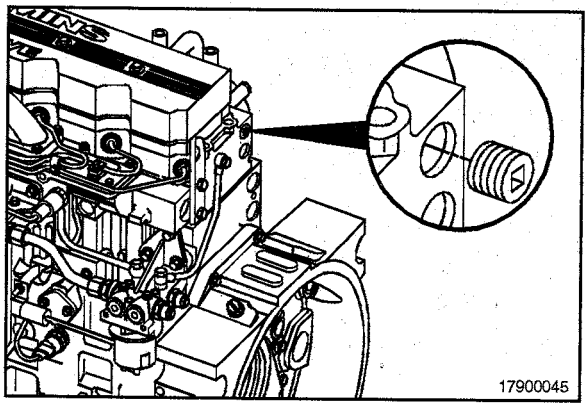
Install the cup plug with the appropriate cup plug driver. Refer to Service Tools Catalog, Bulletin Number 3377710.



⚠CAUTION⚠

Do not install the cup plug too deeply. If the cup plug is not installed straight and flat, it must be replaced with a new cup plug.

The cup plug **must** be installed with the edge of the cup plug 0.5 to 1.0 mm [0.020 to 0.040 in] deeper than the leading chamber of the bore.



Pipe Plug (017-007)

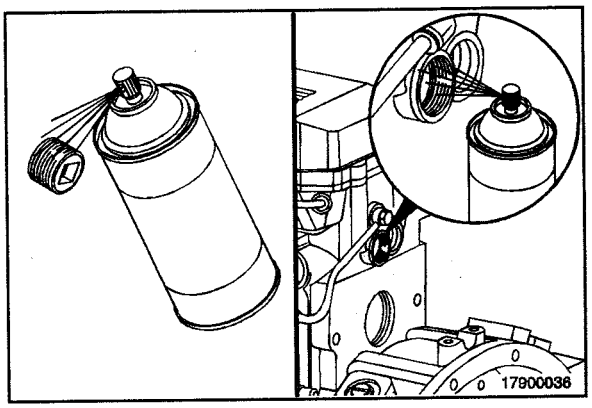
Remove

Remove the pipe plug.

Clean and Inspect for Reuse

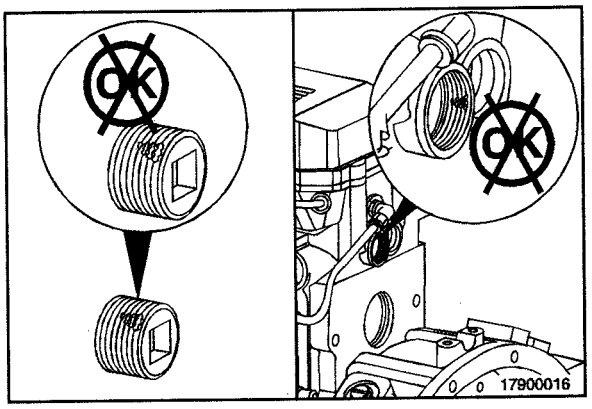
Center Sump Pan

Use spray cleaner, Part Number 3375433, or equivalent to clean the threads of the pipe plugs and threaded bores.



Inspect the threads of the pipe plugs for mutilation or damage.

Inspect the threaded bores for damage.

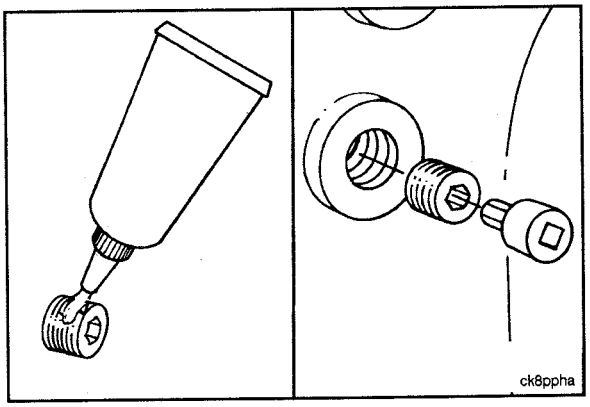


Install

Apply a film of pipe plug sealant, Part Number 3375066, or equivalent to the threads.

Install and tighten the pipe plugs.

Refer to the following chart for torque values.

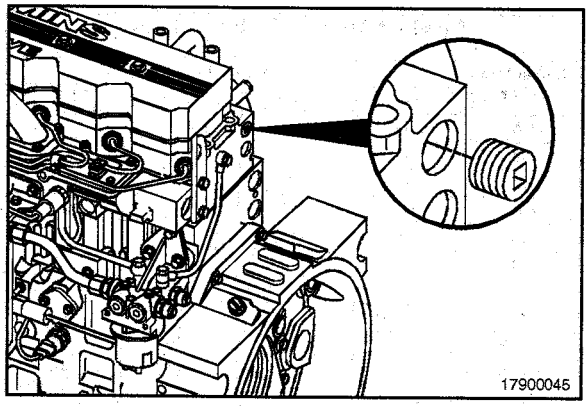


Tighten pipe plugs to the appropriate torque values.

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]

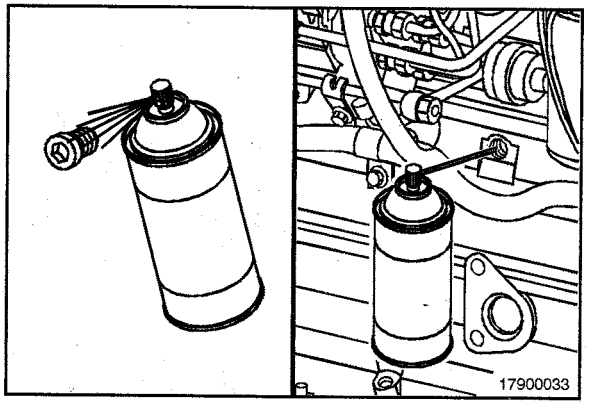
ck8ppoa



Straight Thread Plug (017-011)

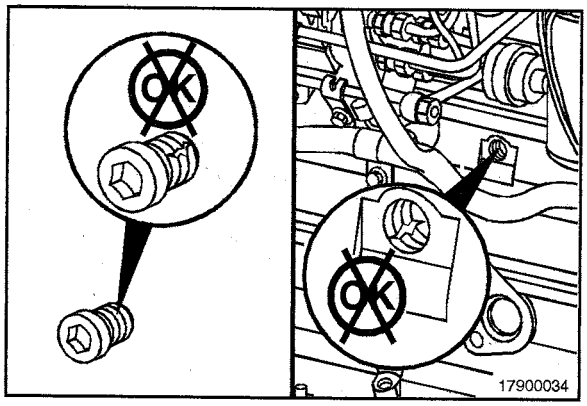
Remove

Select the appropriate size Allen wrench or socket and remove the plug.



Clean and Inspect for Reuse

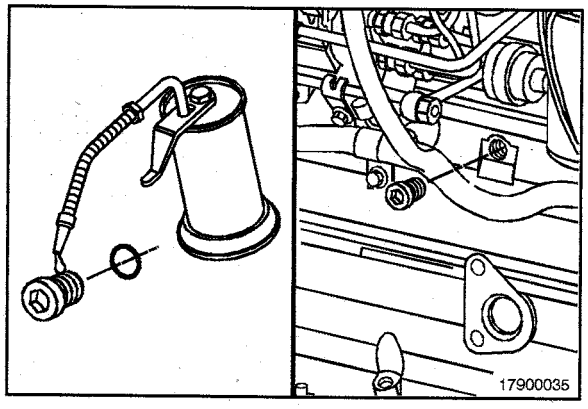
Use a spray cleaner, Part Number 3375433, or equivalent to clean the threads of the straight-thread plugs and threaded bores.



Inspect the threads of the pipe plugs for mutilation or damage.

Inspect the threaded bores for damage.

Repair the bores, if necessary. Replace the plugs, if damaged.



Install

Install a new o-ring on the straight threaded plugs. Lubricate with clean 15W-40 oil.

Install the plugs.

Tighten the straight-threaded plugs. Refer to the adjoining chart for the appropriate torque values.

Straight Thread O-Ring Plugs				
Thread Size Inches	Torque - lbf			
	Nem	In-lb	Nem	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

oi203vg

Notes

Section 20 - Vehicle Braking - Group 20

Section Contents

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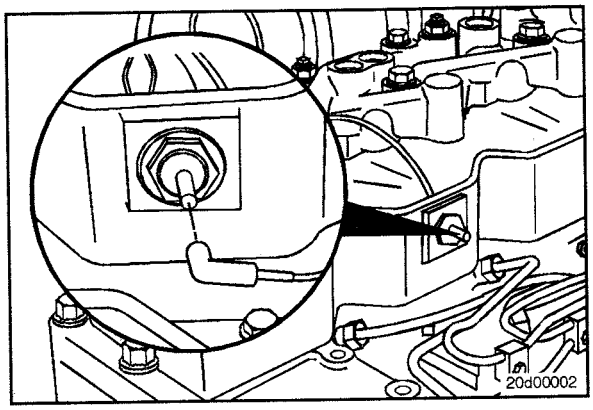
Engine Brake Assembly (020-004)

Preparatory Steps

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

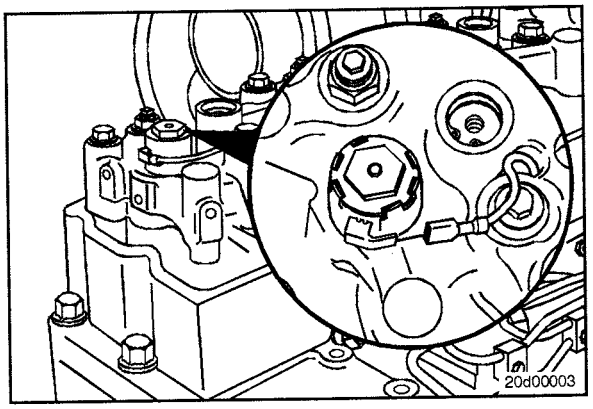
Remove

Disconnect the wiring harness from the electrical connectors in the rocker lever housing.

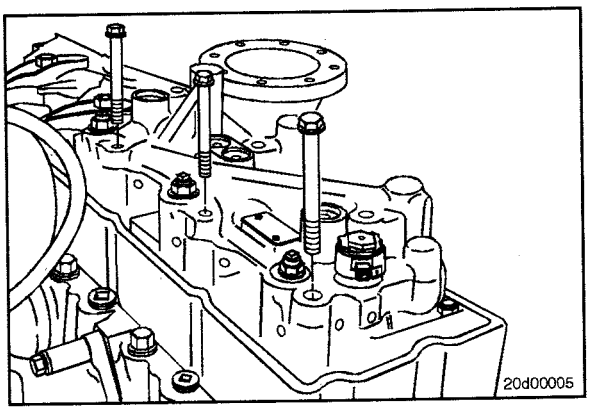


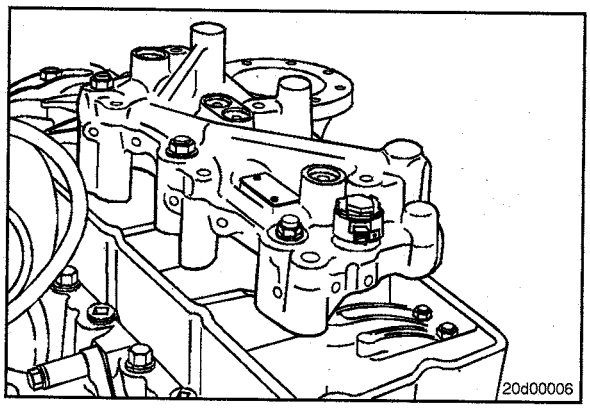
Unplug the wires from the brake solenoid.

NOTE: It is easier to remove the wire from the rocker lever housing after the brake is removed.



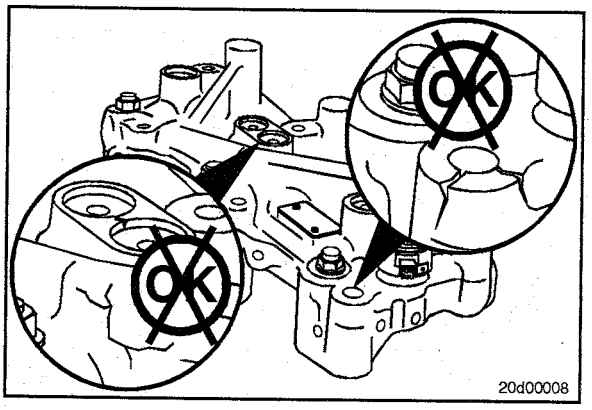
Remove the six mounting capscrews and flat washers from one or both of the engine brake assemblies as required.





Remove the brake assembly or assemblies as required.

Remove the rocker lever housing, if necessary. Refer to Procedure 003-013.



Clean and Inspect for Reuse

⚠WARNING⚠

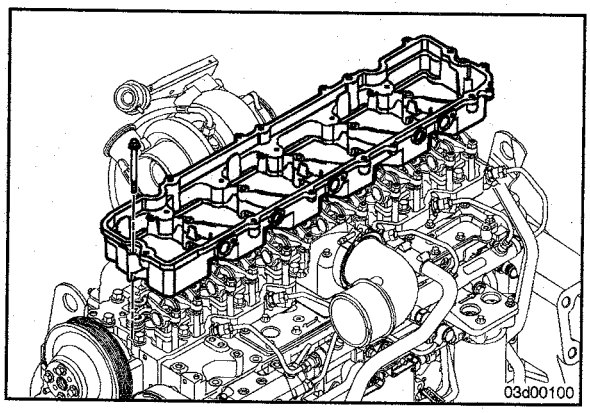
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean the engine brake assembly with solvent and a brush.

Inspect the engine brake assembly for cracks or any other damage.

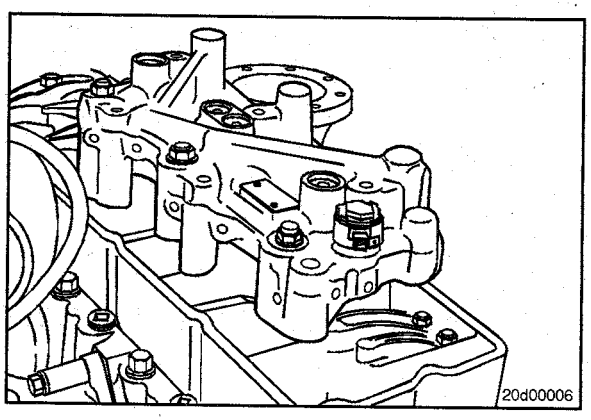


Install

If necessary, check and set the valve lash prior to installing the engine brake. Refer to Procedure 003-004.

To install the engine brake specific crossheads and rocker lever hold-downs, refer to Procedure 003-008.

If necessary install the rocker lever housing and mounting bolts. Refer to Procedure 003-013.



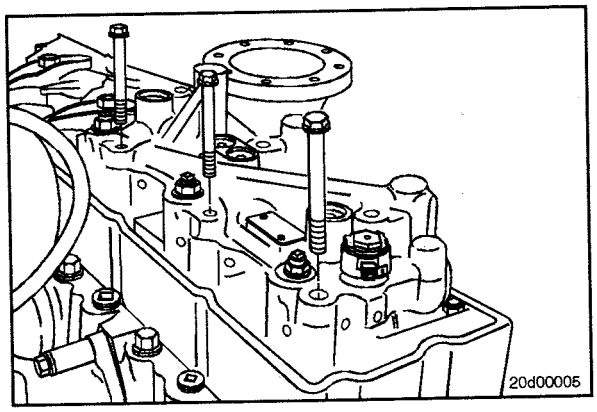
At the intake mounting stud (cylinder number 1 and/or cylinder number 4) lubricate the oil adapter and o-ring with lubricating oil.

Install the engine brake overhead assembly.

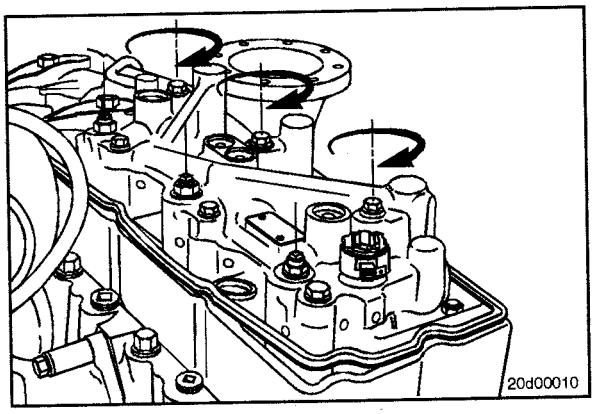
NOTE: Make sure the oil supply adapter at the intake manifold stud is fitted into the oil supply hole in the brake assembly.

Install the six 10-mm mounting capscrews at the brake mounting spacers (exhaust side of engine) and hand-tighten.

NOTE: Do **not** tighten the capscrews to their final torque specification at this time.



Turn the adjusting sleeves (preassembled in the engine brake) at the exhaust mounting locations to make contact with the engine brake mounting studs and tighten.



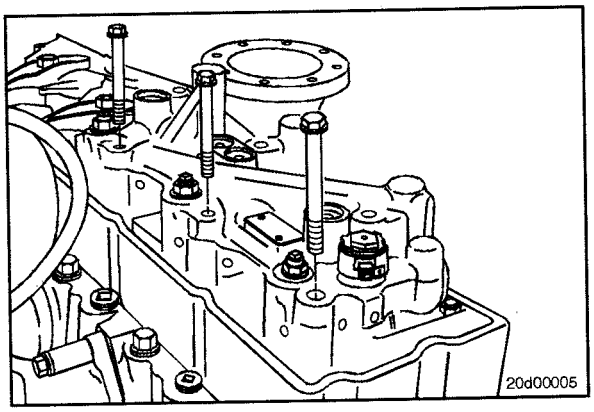
Loosen the three 10-mm outer mounting capscrews.

Install the three 10-mm mounting capscrews at the exhaust rocker mounting locations with flat washers between the screws and the engine brake spacer.

Tighten the six 10-mm mounting capscrews.

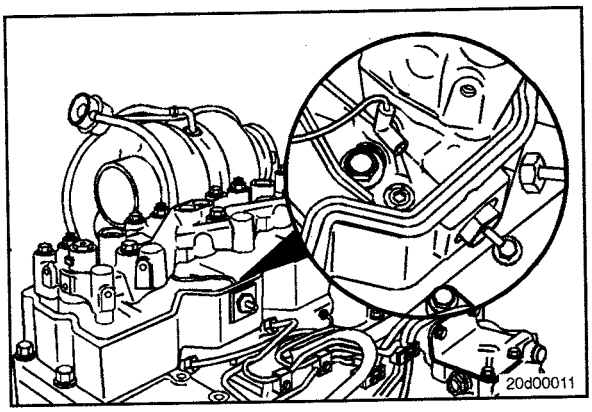
NOTE: No tightening sequence is required but the capscrews can be tightened in a crossing sequence.

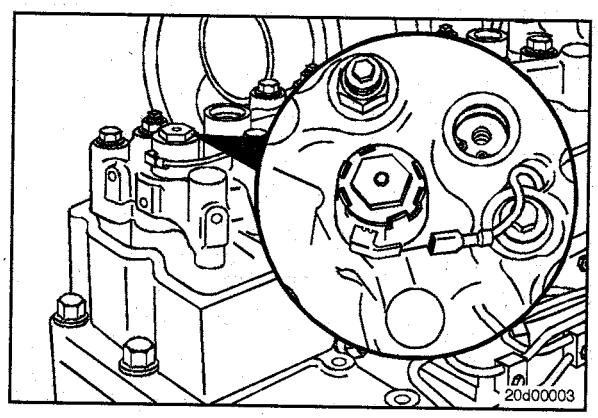
Torque Value: 32 N•m [23 ft-lb]



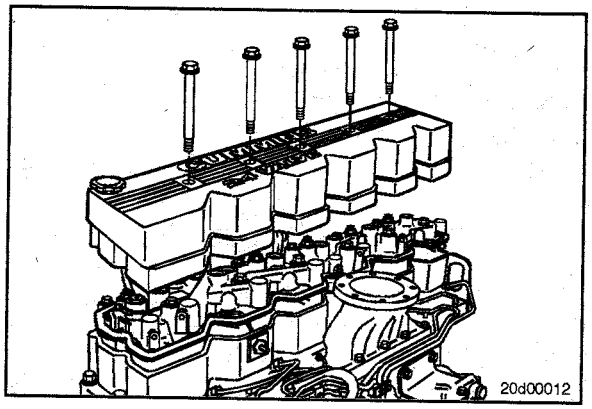
Install the wires to the terminals on the inside of the spacer.

NOTE: The longer wire **must** be connected to the front engine brake solenoid. It is possible to install the wires in the incorrect orientation which will result in an interference with rocker levers.



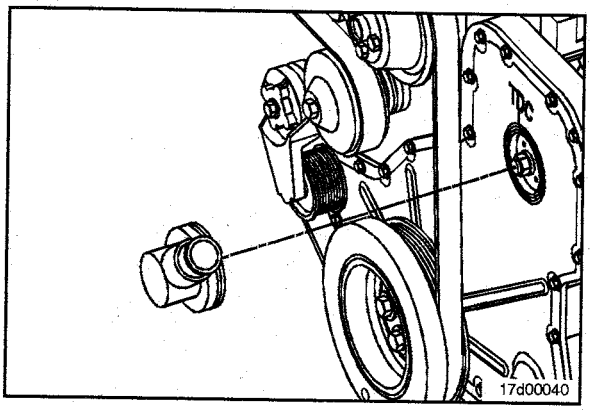


Connect the wires from the terminals on the inside of the spacer to the solenoid.

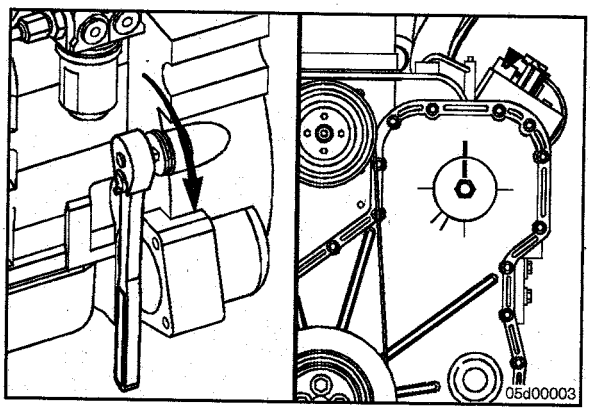


Adjust

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



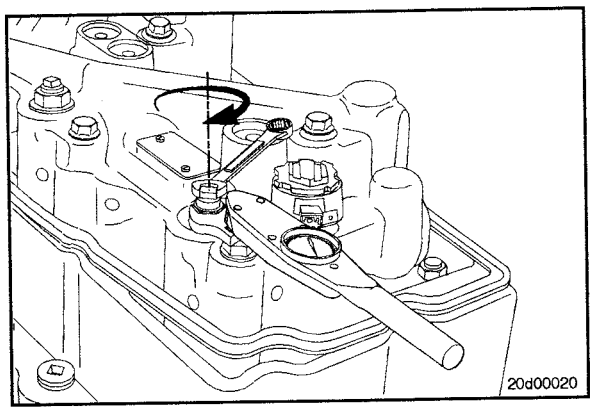
Remove the plastic fuel pump drive cover located on the front of the engine.



Using the barring tool, Part Number 3824591, rotate the crankshaft to align the mark on the fuel pump gear with the top dead center mark on the gear cover.

When the engine is in the top dead center position, brake lash can be set on cylinders 1, 3, and 5.

Using two wrenches, hold the adjusting nut and loosen the lock nuts on the brake at cylinders 1, 3, and 5.

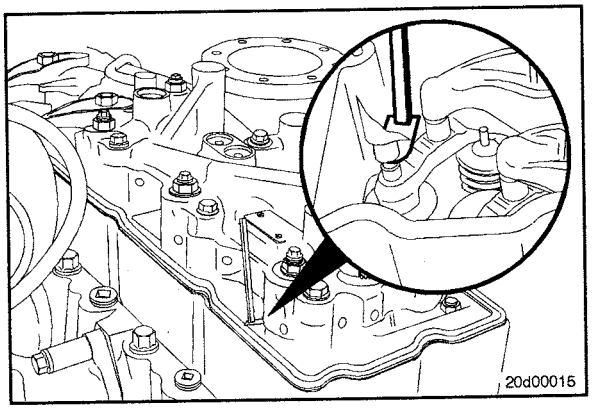


Brake Lash - Feeler Gauge Method

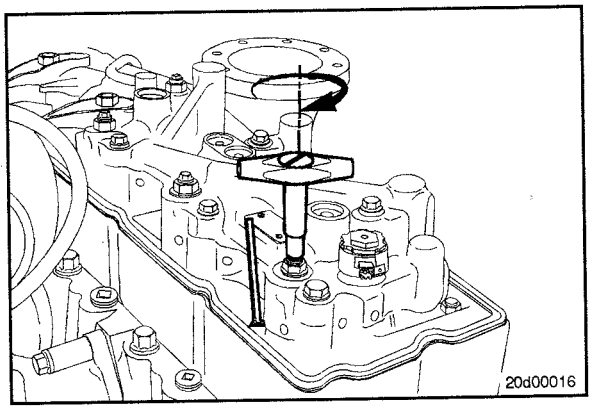
Insert the appropriate brake lash feeler gauge between the brake slave piston and exhaust crosshead pin on cylinder number 1.

Brake Lash - Feeler Gauge	
Tool Part No.	**Lash Specification**
3163681	2.286 mm [0.090 in]

NOTE: If the correct size feeler gauge is **not** available, there is an alternate dial indicator method for setting the brake lash following in this procedure.



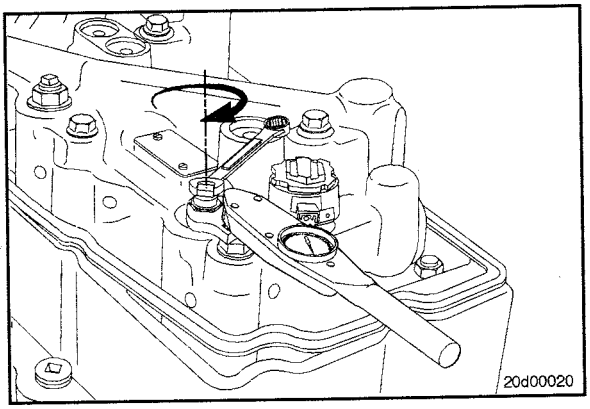
Using the 6 in-lb torque wrench, Part Number 3376592, tighten the adjusting nut until the torque wrench "clicks," or until drag is felt on the feeler gauge.

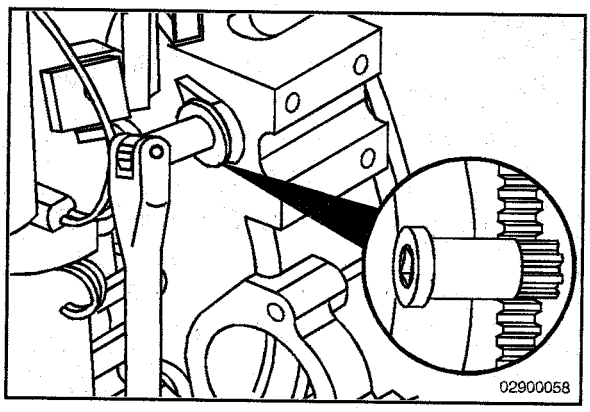


Remove the feeler gauge. Using two wrenches, hold the adjusting nut and tighten the locknut.

Torque Value: 35 N•m [25 ft-lb]

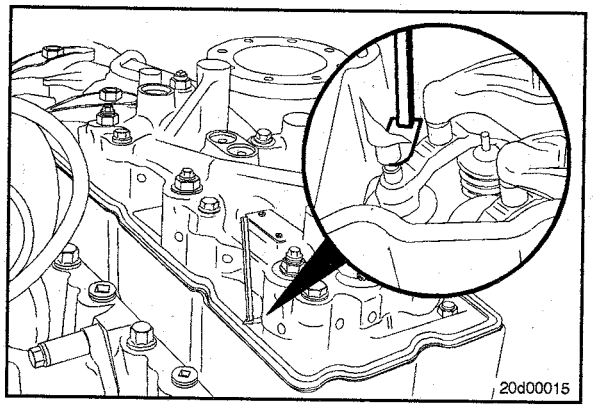
Repeat for cylinders 3 and 5.





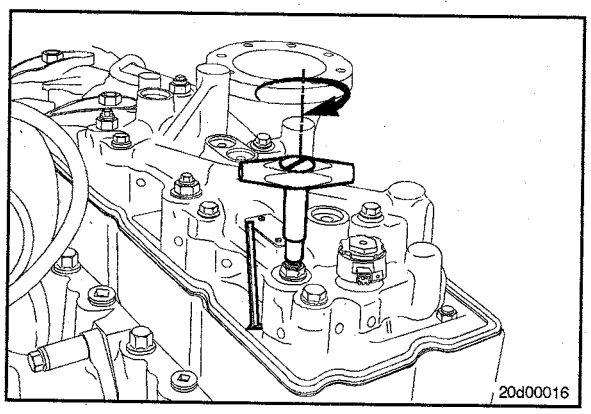
Using the engine barring tool, Part Number 3824591, rotate the crankshaft 360 degrees to align the mark on the fuel pump gear with the mark on the gear cover that is 180 degrees away from top dead center.

When the engine is in position, brake lash can be set on cylinders 2, 4, and 6.

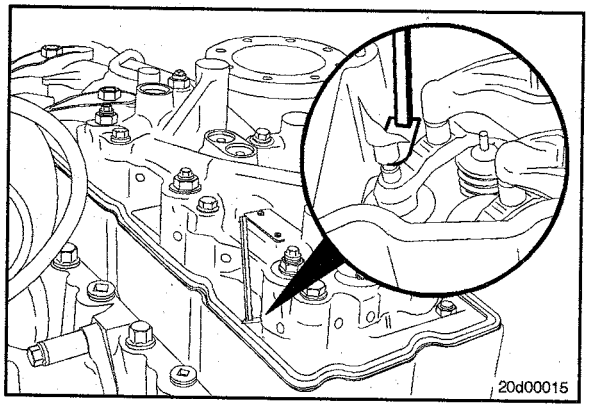


Insert the appropriate brake lash feeler gauge between the brake the brake sleeve piston and the exhaust crosshead pin on cylinder number 2.

Brake Lash - Feeler Gauge	
Tool Part No.	**Lash Specification**
3163681	2.286 mm [0.090 in]



Using the 6 in-lb torque wrench, Part Number 3376592, tighten the adjusting nut until the torque wrench "clicks," or until drag is felt on the feeler gauge.



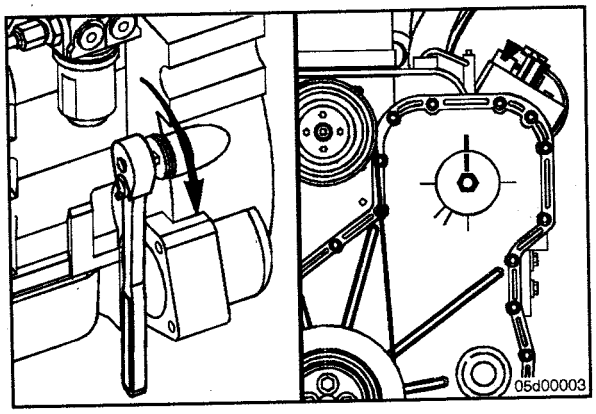
Remove the feeler gauge. Using two wrenches, hold the adjusting nut and tighten the locknut.

Torque Value: 35 N•m [25 ft-lb]

Repeat for cylinders 4 and 6.

The following method can be used instead of the feeler gauge method if a feeler gauge of the proper size is **not** available.

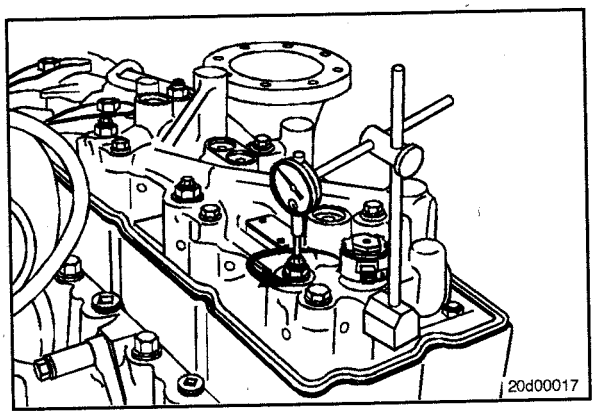
Using the barring tool, Part Number 3824591, rotate the crankshaft to align the mark on the fuel pump gear with the top dead center mark on the gear cover.



Brake Lash - Dial Indicator

Tighten the backlash adjusting nut on cylinder 1 until resistance is felt. Place the dial indicator tip on the adjusting nut and zero the dial indicator. Turn the lash adjusting nut in a **counterclockwise** direction until the appropriate lash is reached.

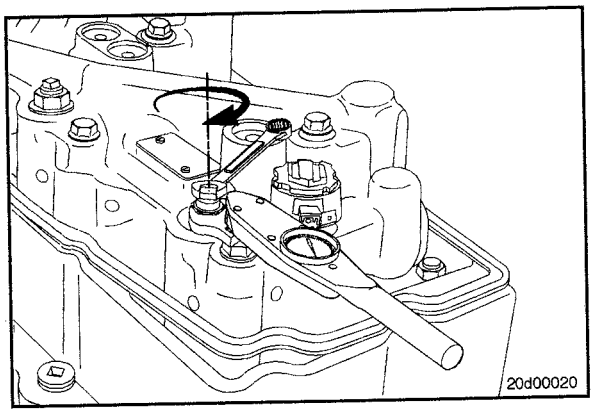
Brake Lash Specification 2.286 mm [0.090 in]



Using two wrenches, hold the adjusting nut and tighten the locknut.

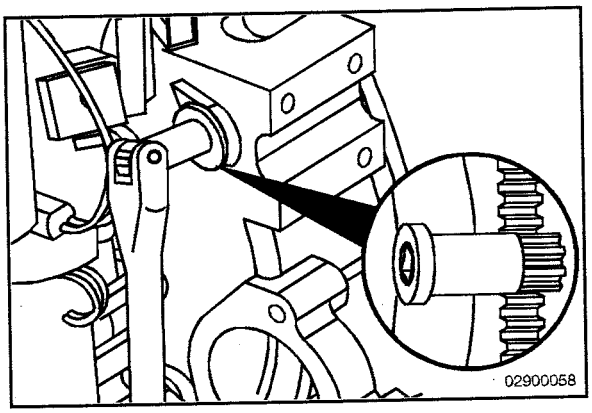
Torque Value: 35 N•m [25 ft-lb]

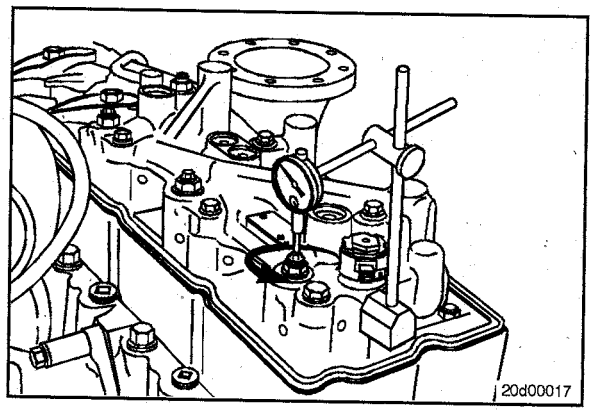
Repeat for cylinders 3 and 5.



Using the engine barring tool, Part Number 3824591, rotate the crankshaft 360 degrees to align the mark on the fuel pump gear with the mark on the gear cover that is 180 degrees away from top dead center.

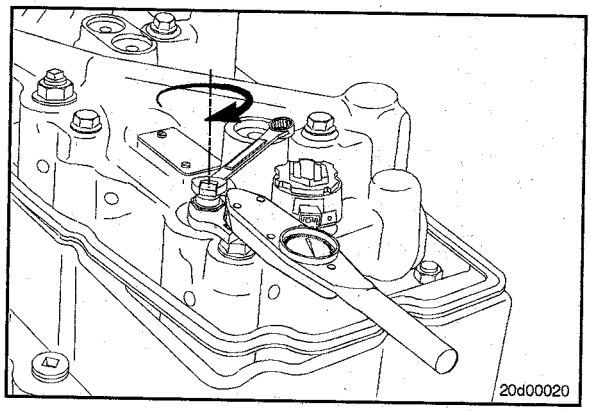
When the engine is in position, brake lash can be set on cylinders 2, 4, and 6.





Tighten the backlash adjusting nut on cylinder number 2 until resistance is felt. Place the dial indicator tip on the adjusting nut and zero the dial indicator. Turn the lash adjusting nut in a **counterclockwise** direction until the appropriate lash is reached.

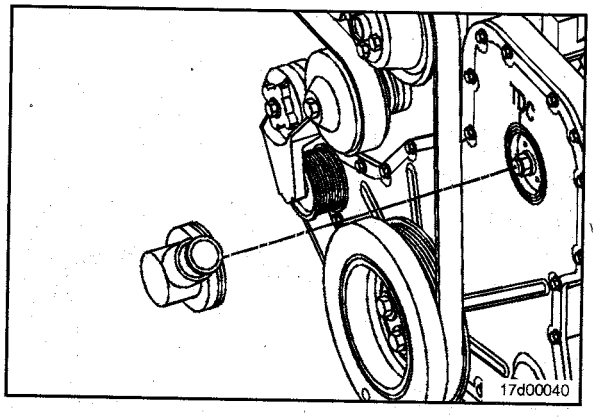
Brake Lash Specification 2.286 mm [0.090 in]



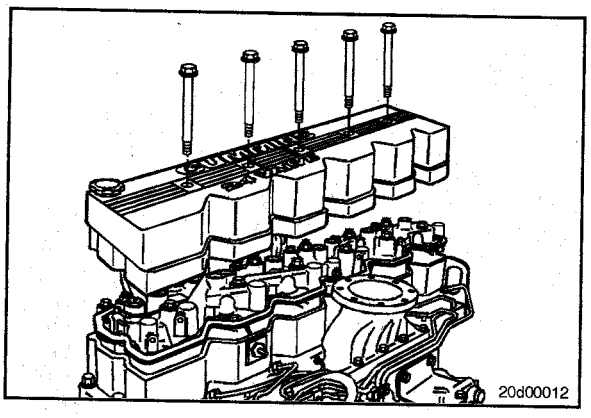
Using two wrenches, hold the adjusting nut and tighten the locknut.

Torque Value: 35 N•m [25 ft-lb]

Repeat for cylinders 4 and 6.



Install the plastic fuel pump drive cover located on the front of the engine.



Install the rocker lever cover.

Refer to Procedure 003-011.

Engine Brake Housing Spacer (020-007)

Preparatory Steps

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

Remove the engine brake assemblies. Refer to Procedure 020-004.

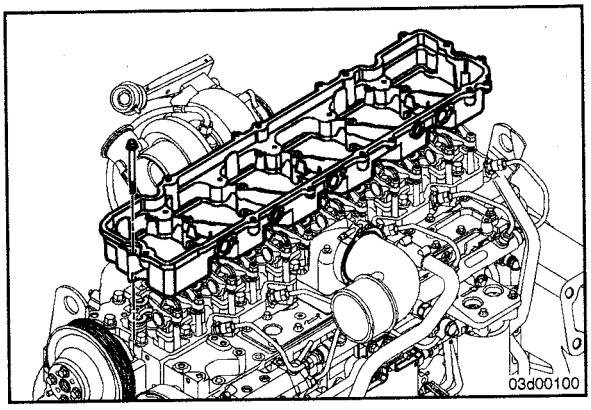
Remove

⚠CAUTION⚠

Do not damage the mounting surface of the spacer when removing it from the cylinder head, or oil leaks can result when the spacer is installed.

Remove the engine brake spacer 5 mounting capscrews.

Carefully remove the engine brake spacer from the cylinder head.



Clean and Inspect for Reuse

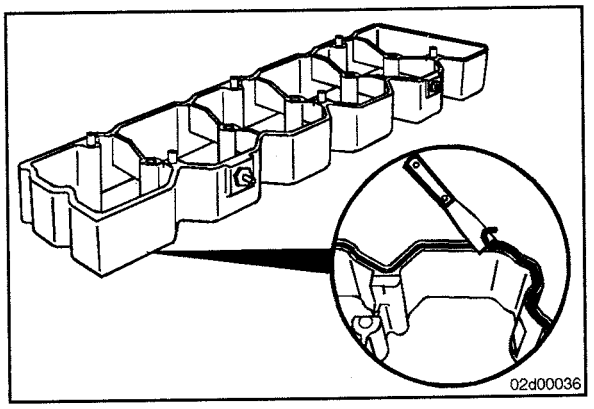
⚠CAUTION⚠

Be sure to remove all RTV from the groove in the mounting surface spacer, or oil leaks can result after installation.

Carefully clean the RTV from the mounting surface of the spacer.

Clean all RTV from the top of cylinder head where the spacer is mounted.

Inspect the engine brake spacer for cracks or any other damage, especially on the cylinder head mounting surface.



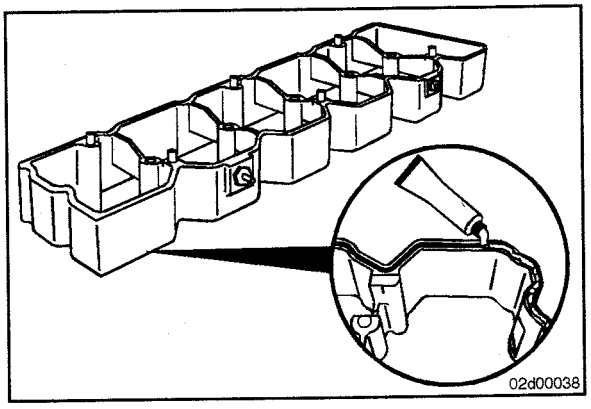
Install

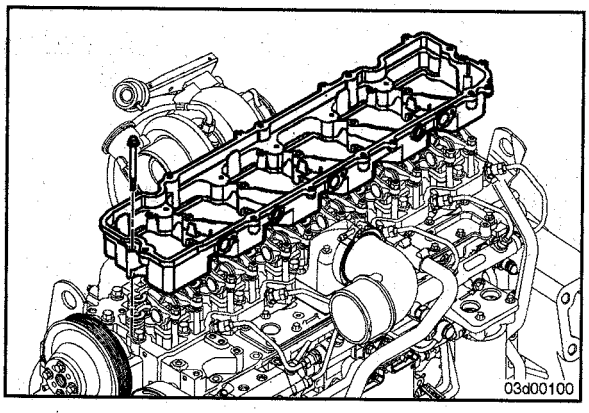
⚠CAUTION⚠

To minimize the possibility of oil leaks, allow the RTV to cure for at minimum 1 hour prior operating the engine.

NOTE: Once the RTV has been applied, make sure to install the spacer within 15 minutes.

Apply a continuous bead of RTV in the groove around the brake spacer.





Install the engine brake spacer and the 5 mounting capscrews.

Torque Value: 32 N•m [23 ft-lb]

Finishing Steps

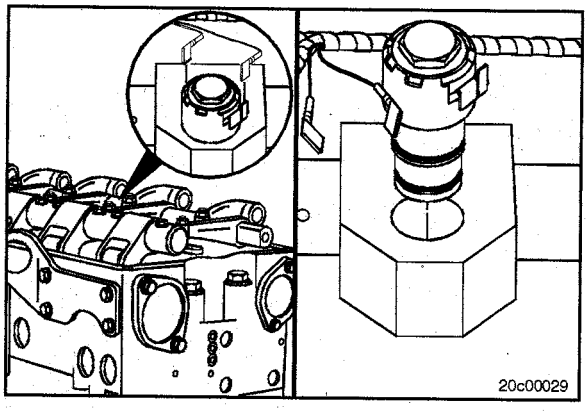
Install the engine brake assemblies. Refer to Procedure 020-004.

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

Engine Brake Solenoid Valve (020-012)

Preparatory Steps

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



Remove

Disconnect the engine brake wiring harness from the solenoid.

Remove the solenoid and discard the o-rings.

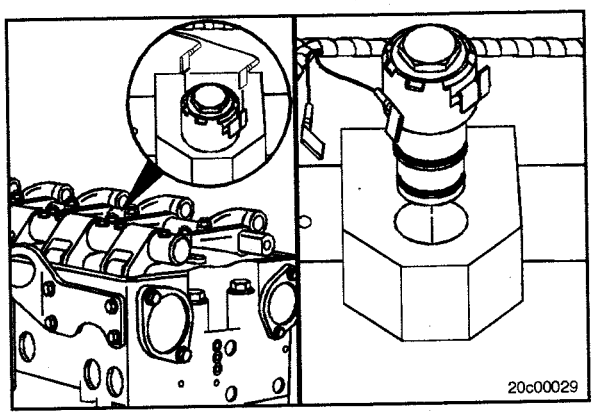
Install

Install new o-rings and the solenoid.

Tighten the solenoid.

Torque Value: 20 N•m [15 ft-lb]

Connect the engine brake wiring harness to the solenoid.



Finishing Steps

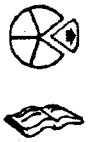
Install the rocker lever cover. Refer to Procedure 003-011.

Engine Brake Wiring Harness (020-015)

Preparatory Steps

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

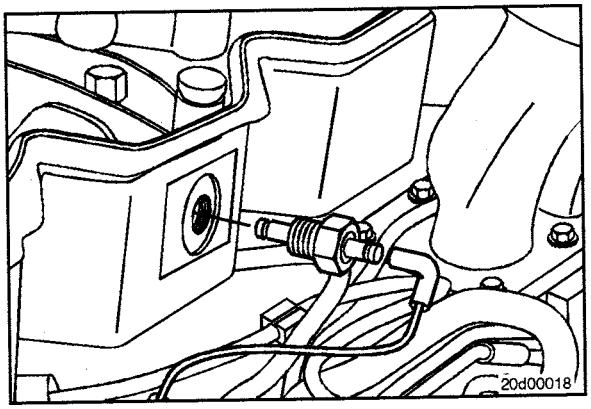
Remove

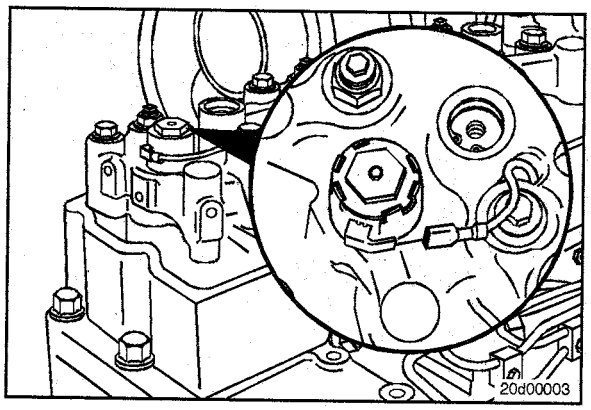


Remove the engine plug connector at the engine brake spacer.

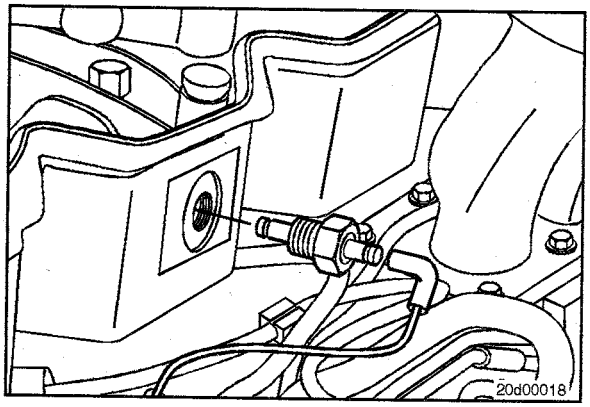
Remove the engine receptacle connector retaining nut and o-ring.

Remove the engine receptacle from the engine brake spacer.





Disconnect the solenoid wires.

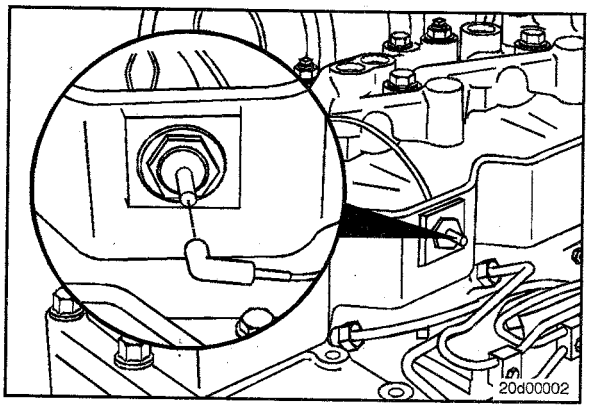


Install

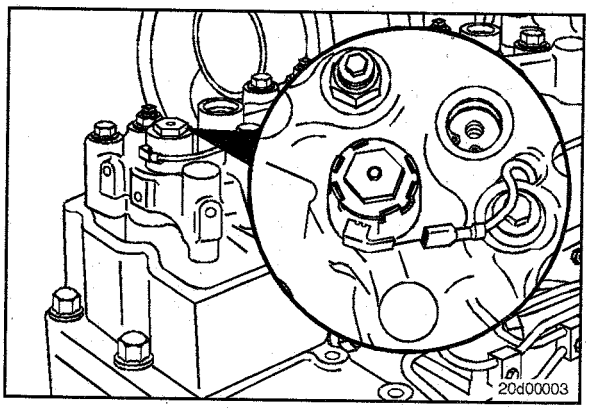
Install the engine receptacle into the engine brake spacer.

Install the engine receptacle connector retaining o-ring and tighten the nut.

Torque Value: 11 N•m [97 in-lb]



Install the engine plug connector at the rocker lever housing.



Connect the solenoid wires.

Finishing Steps

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

Notes

Section L - Service Literature

Section Contents

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Additional Service Literature

General Information

The following publications can be purchased.

Bulletin Number	Title of Publication
4021416	Troubleshooting and Repair Manual, CM850 Electronic Control System
3666271	Troubleshooting and Repair Manual, ISC, QSC8.3, ISL Electronic Control System
4021421	Wiring Diagram, ISC and ISL CM850 Electronic Control Module
3666267	ISC Wiring and Fault Code Diagram
3666395	Wiring Diagram, QSC
3666416	Wiring Diagram, ISL
3666478	Wiring Diagram, QSL9
4021427	Owners Manual, ISC and ISL Engines
4021428	Operation and Maintenance Manual, ISC and ISL Engines
3379001	Fuel for Cummins Engines
3810340	Cummins Engine Oil Recommendations
3666132	Coolant Requirements and Maintenance
3379000	Air for Your Engines
3387622	Cold Weather Operation

Service Literature Ordering Location
Contact Information

Region	Ordering Location
United States and Canada	Cummins Distributors or Credit Cards at 1-800-646-5609 or Order online at www.powerstore.cummins.com
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 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

Cummins Customized Parts Catalog

General Information

Cummins is pleased to announce the availability of a parts catalog compiled specifically for you. Unlike the generic versions of parts catalogs that support general high volume parts content; Cummins Customized catalogs contains only the new factory parts that were used to build your engine.

The catalog cover, as well as the content, is customized with you in mind. You can use it in your shop, at your worksite, or as a coffee table book in your RV or boat. The cover contains your name, company name, address, and telephone number. Your name and engine model identification even appears on the catalog spine. Everybody will know that Cummins created a catalog specifically for you.

This new catalog was designed to provide you with the exact information you need to order parts for your engine. This will be valuable for customers that do not have easy access to the Cummins Electronic Parts Catalog or the Cummins Parts Microfilm System.

Additional Features of the Customized Catalog include:

- Engine Configuration Data
- Table of Contents
- Separate Option and Parts Indexes
- Service Kits (when applicable)
- ReCon Part Numbers (when applicable)

Ordering the Customized Parts Catalog

Ordering by Telephone

North American customers can contact their Cummins Distributor or call Gannett Direct Marketing Services at 1-800-646-5609 and order by credit card. Outside North America order on-line or make an International call to Gannett at (+ +)502-454-6660.

Ordering On-Line

The Customized Parts Catalog can be ordered On-Line from the Cummins Powerstore by credit card. Contact the Powerstore at WWW.POWERSTORE.CUMMINS.COM

Contact GDMS or the CUMMINS POWERSTORE for the current price; Freight may be an additional expense.

Information we need to take your Customized Parts Catalog Order. This information drives the cover content of the CPC.

- Customer Name
- Street Address
- Company Name (optional)
- Telephone no.
- Credit Card No.
- Cummins Engine Serial Number (located on the engine data plate)
- Please identify the required media: Printed Catalog, CD-ROM, or PDF File

Unfortunately not all Cummins Engines can be supported by this parts catalog. Engines older than 1984 or newer than 3 months may not have the necessary parts information to compile a catalog. We will contact you if this occurs and explain why we are unable to fill your order.

Customized Parts Catalogs are produced specifically for a single customer. This means they are not returnable for a refund. If we make an error and your catalog is not useable, we will correct that error by sending you a new catalog.

Notes

Section M - Component Manufacturers

Section Contents

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Component Manufacturers' Addresses (203-001)

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: (0)1895-838383

Prestolite Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: (0)1772-421663

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

T.B.A. Belting Ltd.
P.O. Box 77
Wigan
Lancashire
WN2 4XQ
England
Telephone: (0)1942-259221

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 Converters

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

Prestolite Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 01772-421663

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
Sunbury on Thames
Middlesex
TW16 7HF
England
Telephone: (0)9327-85500

Fan Clutches

Kysor Cooling Systems N.A.
6040 West 62nd Street
Indianapolis, IN 46278
Telephone: (317) 328-3330

Holset Engineering Co. Ltd.
ST Andrews Road
Huddersfield, West Yorkshire
England HD1 6RA
Telephone: (0)1484-22244

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: (0)121-3283041

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: 01327-341313

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: (0)1207-560-505

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

Grasslin U.K. Ltd.
Vale Rise
Tonbridge
Kent
TN9 1TB
England
Telephone: (0)1732-359888

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 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

Honeywell Control Systems Ltd.
Honeywell House
Arlington Business Place
Bracknell
Berks RG12 1EB
Telephone: (0)1344-656000

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

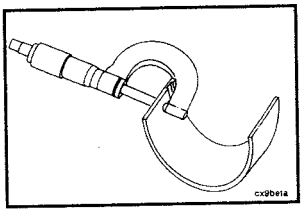
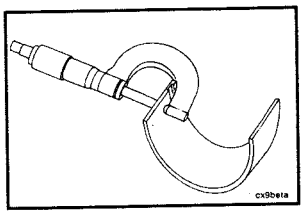
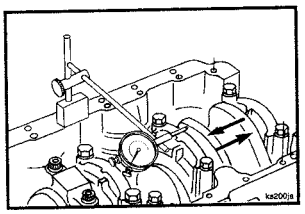
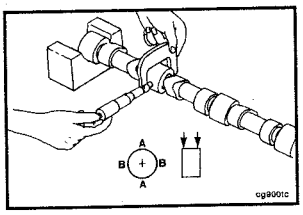
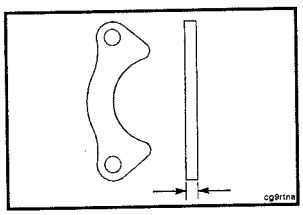
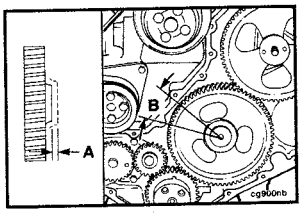
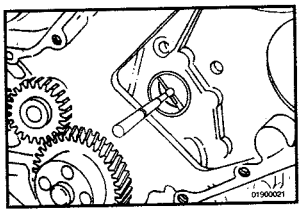
Modine Mfg. Co.
1500 DeKoven Avenue
Racine, WI 53401
Telephone: (414) 636-1640

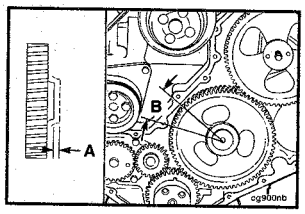
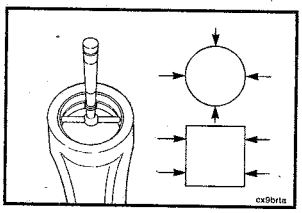
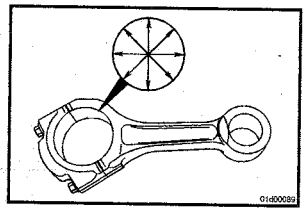
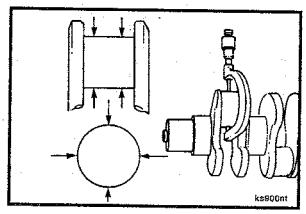
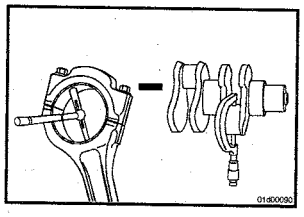
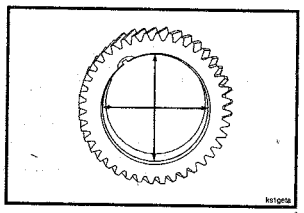
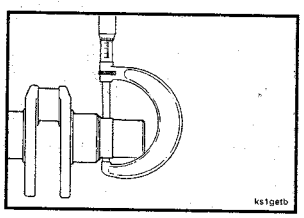
Notes

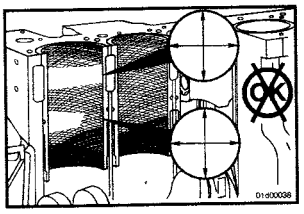
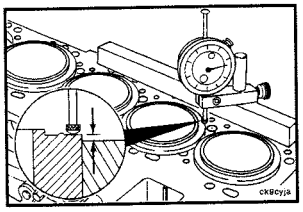
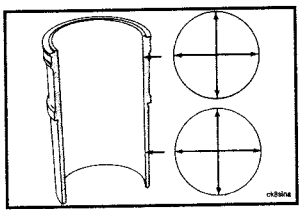
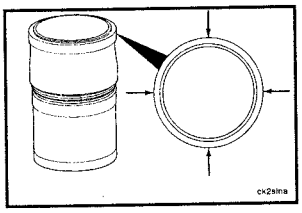
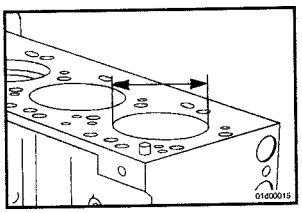
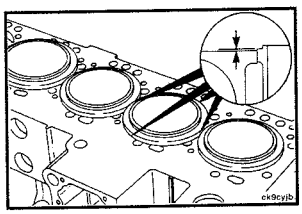
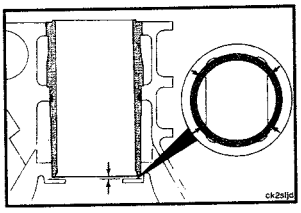
Section V - Specifications

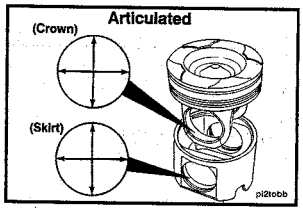
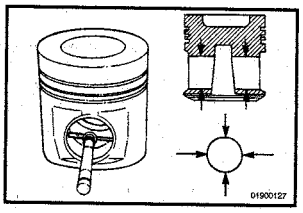
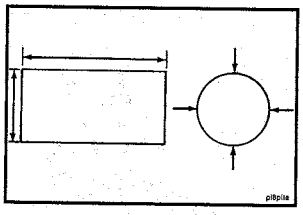
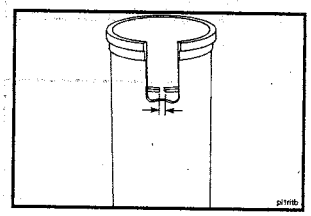
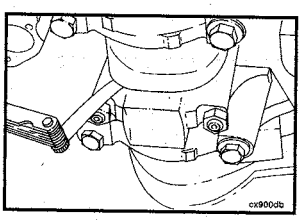
Section Contents

Cylinder Block - Group 01 - Specifications

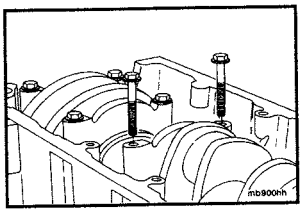
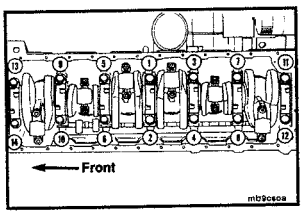
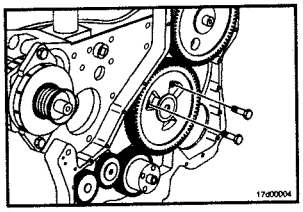
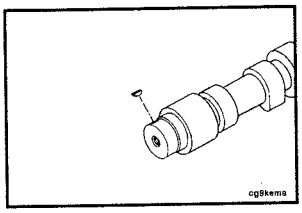
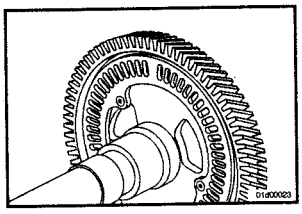
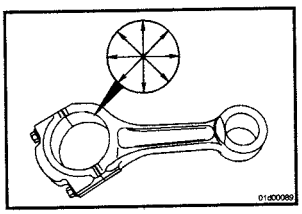
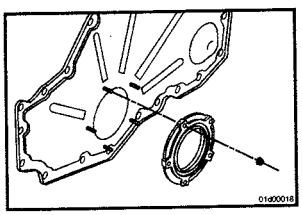
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Bearings, Connecting Rod (001-005)					
Connecting Rod Bearing Dimensions					
Standard		2.459 2.471	MIN MAX	0.0968 0.0973	
Bearings, Main (001-006)					
Main Bearing Dimensions					
Standard		3.446 3.454	MIN MAX	0.1357 0.1360	
Crankshaft End Play Limits		0.085 mm 0.385 mm	MIN MAX	0.003 in 0.015 in	
Camshaft (001-008)					
Camshaft Bearing Journal Diameter		59.962 mm 60.013 mm	MIN MAX	2.3607 in 2.3627 in	
Camshaft Thrust Plate		9.40 mm 9.60 mm	MIN MAX	0.370 in 0.378 in	
Camshaft End Play (A)		0.12 mm 0.50 mm	MIN MAX	0.005 in 0.020 in	
Camshaft Gear Backlash Limits (B)		0.08 mm 0.33 mm	MIN MAX	0.003 in 0.013 in	
Camshaft Bushings (001-010)					
Camshaft Bore Diameter (Maximum)					
Without bushing		64.013	MAX	2.5202	
With bushing		60.120	MAX	2.3669	

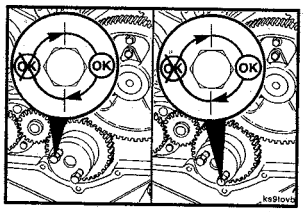
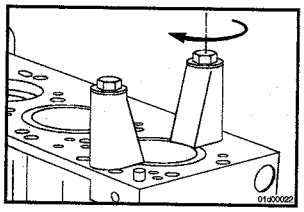
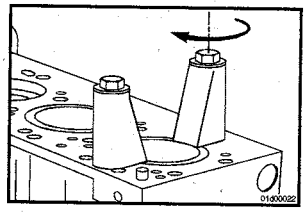
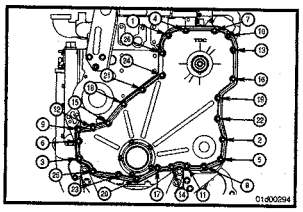
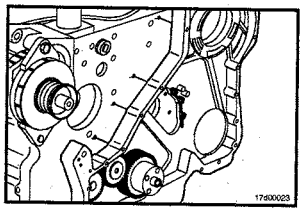
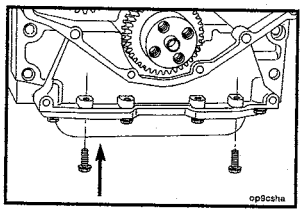
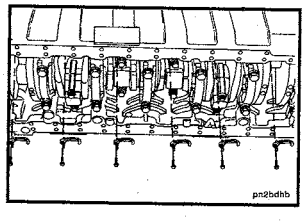
	Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
	**Camshaft Gear (Camshaft Installed) (001-012)**				
	Camshaft End Play (A)		0.12 mm	MIN	0.005 in
			0.50 mm	MAX	0.020 in
	Camshaft Gear Backlash Limits (B)		0.08 mm	MIN	0.003 in
			0.33 mm	MAX	0.013 in
	**Connecting Rod (001-014)**				
	Connecting Rod Piston Pin Bushing Diameter		45.023 mm	MIN	1.7726 in
			45.035 mm	MAX	1.7730 in
	Connecting Rod Crank Bore Diameter (Bearings Removed)		80.987 mm	MIN	3.1885 in
			81.013 mm	MAX	3.1895 in
	Out-of-Roundness		0.050 mm	MAX	0.002 in
	Taper		0.013 mm	MAX	0.0005 in
	Bearing Clearance		0.038 mm	MIN	0.0015 in
			0.116 mm	MAX	0.0045 in
	**Crankshaft Gear, Front (Crankshaft Removed) (001-019)**				
	Crankshaft Gear Bore I.D.		75.898 mm	MIN	2.9881 in
			75.923 mm	MAX	2.9891 in
	Crankshaft Gear Journal O.D.		75.987 mm	MIN	2.9916 in
			76.006 mm	MAX	2.9924 in

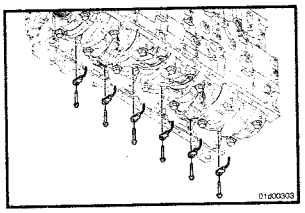
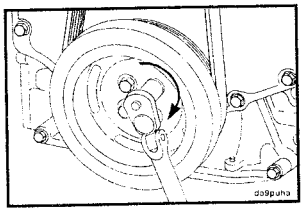
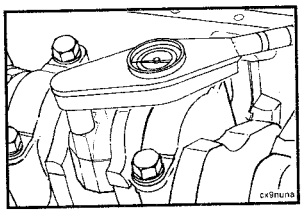
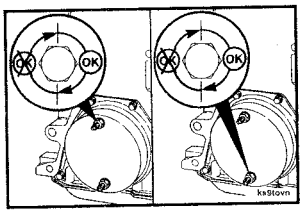
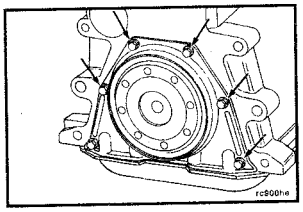
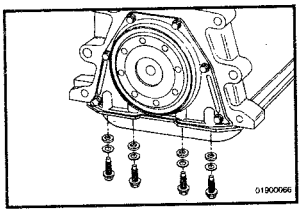
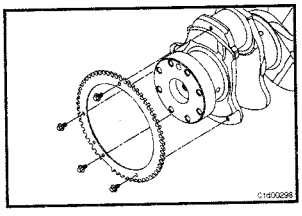
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Cylinder Liner (001-028)					
Cylinder Liner Dimensions					
Taper		0.04	MAX	0.0016	
Out Of Round		0.04	MAX	0.0016	
Bore Diameter		114.04	MAX	4.4898	
Cylinder Liner Protrusion		0.026 mm 0.122 mm	MIN MAX	0.0010 in 0.0048 in	
Cylinder Liner Inside Diameter		114.000 mm 114.040 mm	MIN MAX	4.4882 in 4.4898 in	
Cylinder Liner Out Diameter (Top Press Fit)		130.938 mm 130.958 mm	MIN MAX	5.1550 in 5.1558 in	
Cylinder Liner Bore in Block (Press Fit Bore)		130.900 mm 130.950 mm	MIN MAX	5.1535 in 5.1555 in	
Cylinder Liner Protrusion		0.026 mm 0.122 mm	MIN MAX	0.0010 in 0.0048 in	
Cylinder Liner to Block Clearance		0.229 mm	MIN	0.009 in	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
		**Piston (001-043)** **Articulated Piston Pin Bore Inside Diameter**		
		Crown	45.016	MIN	1.7723
			45.036	MAX	1.7731
		Skirt	45.012	MIN	1.7721
			45.026	MAX	1.7727
		Piston Pin Bore Diameter	45.006 mm	MIN	1.7719 in
			45.012 mm	MAX	1.7721 in
		Piston Pin Diameter	44.997 mm	MIN	1.7715 in
			45.003 mm	MAX	1.7718 in
		**Piston Rings (001-047)** **Ring Gap, Engines with CM550 Control Module**		
		Top Ring	0.35	MIN	0.014
			0.50	MAX	0.020
		Intermediate Ring	0.85	MIN	0.033
			1.15	MAX	0.045
		Oil Control Ring	0.30	MIN	0.012
			0.73	MAX	0.028
		Ring Gap, QSC Marine Engines with CM850 Control Module			
		Top Ring	0.35	MIN	0.014
			0.65	MAX	0.025
		Intermediate Ring	0.40	MIN	0.016
			0.70	MAX	0.027
		Oil Control Ring	0.30	MIN	0.012
			0.73	MAX	0.028
		Ring Gap, All Other Engines with CM850 Control Module			
		Top Ring	0.30	MIN	0.012
			0.45	MAX	0.018
		Intermediate Ring	0.85	MIN	0.033
			1.15	MAX	0.045
		Oil Control Ring	0.30	MIN	0.012
			0.73	MAX	0.028
		**Piston and Connecting Rod Assembly (001-054)** Connecting Rod and Crankshaft Side Clearance	0.10 mm	MIN	0.004 in
			0.30 mm	MAX	0.012 in

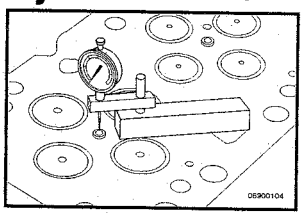
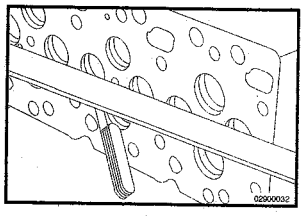
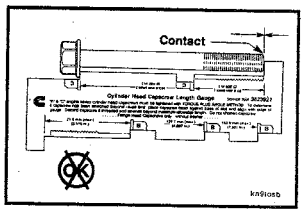
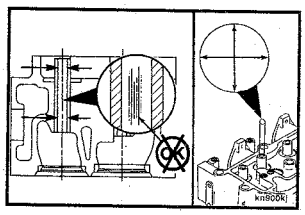
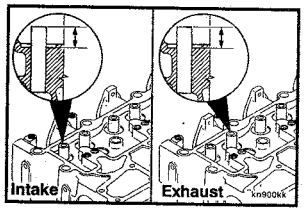
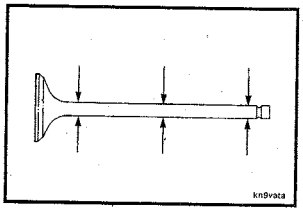
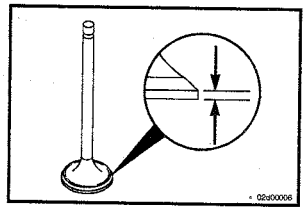
Cylinder Block - Group 01 - Torque Values

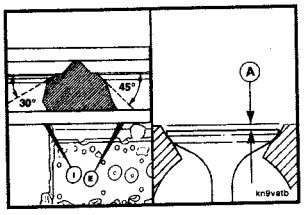
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Bearings, Main (001-006)				
Main Bearing Cap Initial Torque		50 N•m	[37 ft-lb]	
Main Bearing Capscrews 128 Mm [5 In] Capscrew	1	50 N•m	[37 ft-lb]	
	2	95 N•m	[70 ft-lb]	
	3	Rotate 60 degrees		
Main Bearing Capscrews 135 Mm [5.3 In] Capscrew	1	170 N•m	[125 ft-lb]	
	2	Loosen all capscrews		
	3	50 N•m	[37 ft-lb]	
	4	Rotate 120 degrees		
Camshaft (001-008)				
Camshaft Thrust Plate Capscrews		24 N•m	[18 ft-lb]	
Camshaft Gear (Camshaft Installed) (001-012)				
Camshaft Thrust Plate Capscrews		24 N•m	[18 ft-lb]	
Camshaft Gear (Camshaft Removed) (001-013)				
Camshaft Gear Timing Plate Capscrews		7 N•m	[62 in-lb]	
Connecting Rod (001-014)				
Connecting Rod Capscrews	1	60 N•m	[44 ft-lb]	
	2	Loosen Capscrews		
	3	70 N•m	[52 ft-lb]	
	4	Advance 60-degrees		
Crankshaft Seal, Front (001-023)				
Front Seal Carrier Mounting Nuts		10 N•m	[88 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
 **Crankshaft Wear Sleeve, Front (001-025)**		20 N•m	[15 ft-lb]
 **Cylinder Liner (001-028)**		68 N•m	[50 ft-lb]
		68 N•m	[50 ft-lb]
 **Gear Cover, Front (001-031)** Front Cover Mounting Capscrews		24 N•m	[18 ft-lb]
 **Gear Housing, Front (001-033)** Gear Housing Mounting Capscrews		40 N•m	[30 ft-lb]
 Oil Pan Mounting Capscrews		28 N•m	[21 ft-lb]
 **Piston Cooling Nozzle (001-046)** Banjo Mounted Piston Cooling Nozzle		25 N•m	[18 ft-lb]

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Flange Head Capscrew Mounted Piston Cooling Nozzles		33 N•m	[24 ft-lb]	
Vibration Damper, Viscous (001-052)		200 N•m	[148 ft-lb]	
Piston and Connecting Rod Assembly (001-054)				
Connecting Rod Capscrews	1	60 N•m	[44 ft-lb]	
	2	Loosen Capscrews		
	3	70 N•m	[52 ft-lb]	
	4	Advance 60-degrees		
Crankshaft Wear Sleeve, Rear (001-067)		20 N•m	[15 ft-lb]	
Rear Cover Mounting Capscrews		10 N•m	[86 in-lb]	
Rear Oil Pan Mounting Capscrews		28 N•m	[21 ft-lb]	
Crankshaft Speed Indicator Ring (001-071)				
Crankshaft Speed Indicator Ring Capscrews		8 N•m	[71 in-lb]	

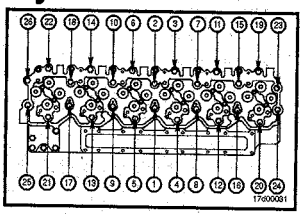
Cylinder Head - Group 02 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
 **Cylinder Head (002-004)**				
Injector Protrusion - Engines With Mechanical Injectors (CM554 Control Module)		2.60 mm	MIN	0.102 in
		3.40 mm	MAX	0.134 in
Injector Protrusion - Engines With Electronic Injectors (CM850 Control Module)		2.25 mm	MIN	0.088 in
		2.80 mm	MAX	0.110 in
 **Cylinder Head Flatness**				
End to End		0.203	MAX	0.008
Side to Side		0.075	MAX	0.003
 Cylinder Head Capscrew Free Length		162.6 mm	MAX	6.4 in
 Valve Guide Inner Diameter (I.D.)		8.019 mm	MIN	0.3157 in
		8.071 mm	MAX	0.3178 in
 Valve Guide Height (Installed)		13.15 mm	MIN	0.518 in
		13.65 mm	MAX	0.537 in
 Valve Stem Diameter		7.96 mm	MIN	0.313 in
		7.98 mm	MAX	0.314 in
 **Valve Rim Thickness Limit**				
Exhaust		1.83	MIN	0.072
Intake		2.20	MIN	0.087

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Valve Recess in Cylinder Head		0.84 mm 1.32 mm	MIN MAX	0.033 in 0.052 in	

Cylinder Head - Group 02 - Torque Values

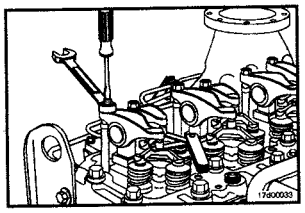
Cylinder Head (002-004)



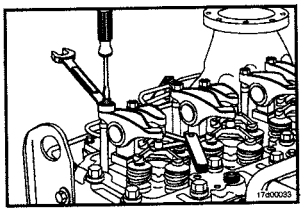
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
		80 N•m	[59 ft-lb]

Rocker Levers - Group 03 - Specifications

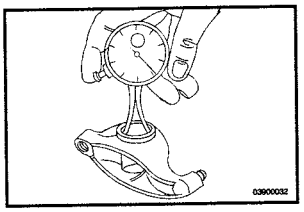
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Overhead Set (003-004)				
Lash Check Limits				
Intake		0.152	MIN	0.006
		0.559	MAX	0.022
Exhaust		0.381	MIN	0.015
		0.813	MAX	0.032



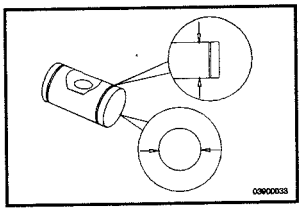
Lash Reset Specifications				
Intake		0.305	NOM	0.012
Exhaust		0.559	NOM	0.022



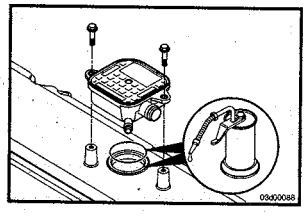
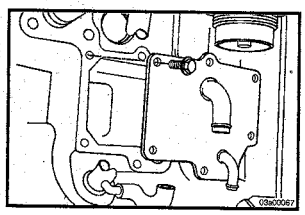
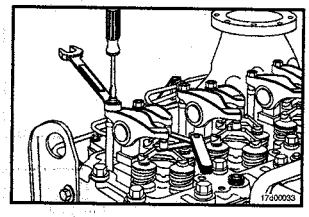
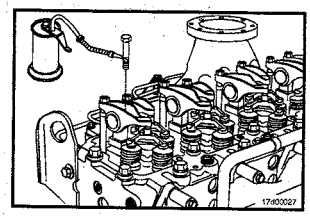
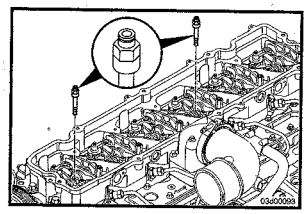
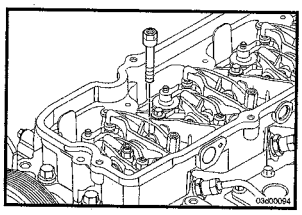
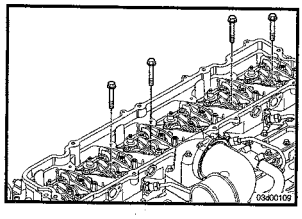
Rocker Lever (003-008)				
Rocker Lever Bore		22.027 mm	MIN	0.867 in

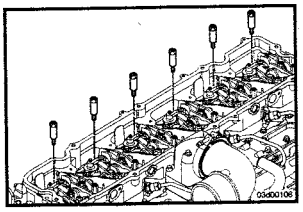
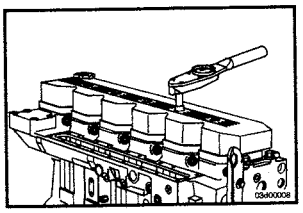
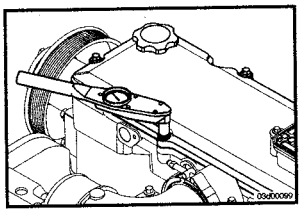
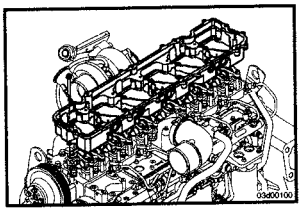
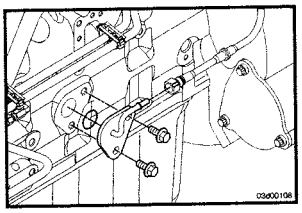


Rocker Lever Shaft		21.965 mm	MIN	0.865 in



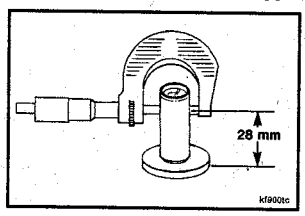
Rocker Levers - Group 03 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
 **Crankcase Breather (External) (003-001)** Crankcase Breather (External)		7 N•m	[62 in-lb]
 **Crankcase Breather (Internal) (003-002)** Crankcase Breather (Internal)		10 N•m	[89 in-lb]
 **Overhead Set (003-004)** Valve Adjusting Screw Locknut		24 N•m	[18 ft-lb]
 **Rocker Lever (003-008)** Pedestal Capscrews		65 N•m	[48 ft-lb]
 Engine Brake Oil Supply Studs		65 N•m	[48 ft-lb]
 Exhaust Rocker Lever Mounting Studs		65 N•m	[48 ft-lb]
 Intake Pedestal Capscrews		65 N•m	[48 ft-lb]

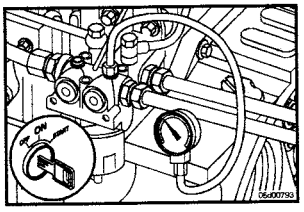
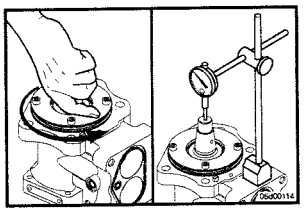
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		24 N•m	[18 ft-lb]	
Rocker Lever Cover (003-011) Center Bolted Rocker Lever Cover Mounting Capscrews		12 N•m	[106 in-lb]	
Perimeter Rocker Lever Cover Mounting Capscrews		12 N•m	[106 in-lb]	
Rocker Lever Housing (003-013) Perimeter Bolted Rocker Lever Housing Mounting Capscrews		24 N•m	[212 in-lb]	
Crankcase Breather Tube (003-018)		45 N•m	[33 ft-lb]	

Cam Followers/Tappets - Group 04 - Specifications

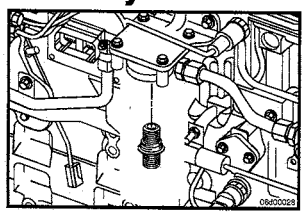
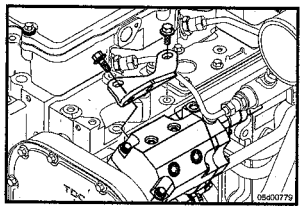
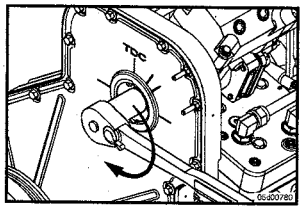
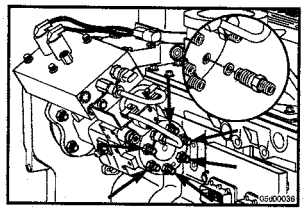
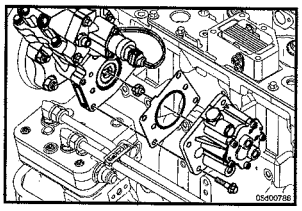
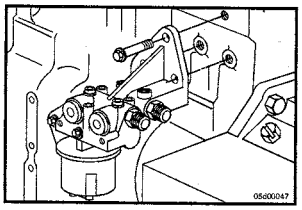
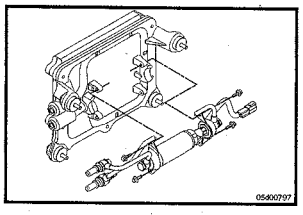
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Tappet (004-015)				
Valve Tappet Stem Diameter		15.936 mm	MIN	0.627 in
		15.977 mm	MAX	0.629 in

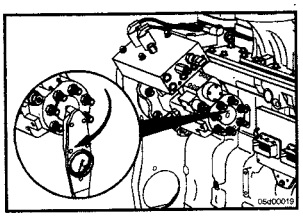
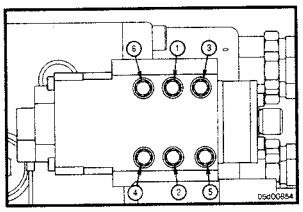
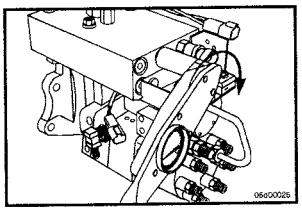
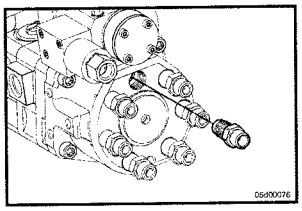
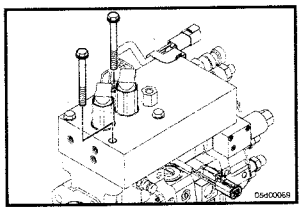
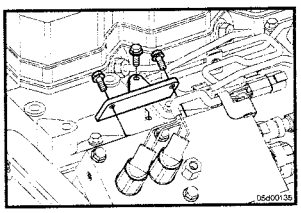
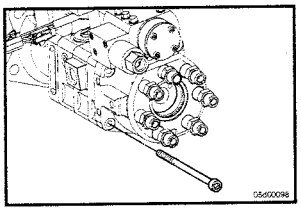


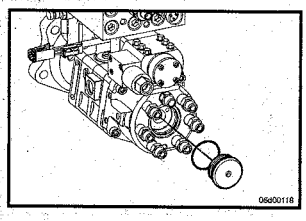
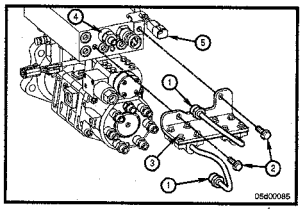
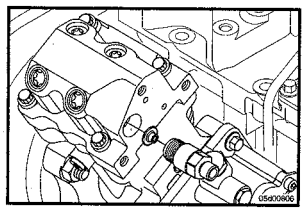
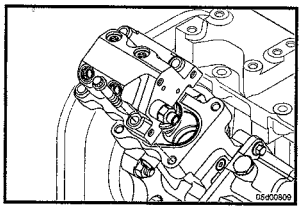
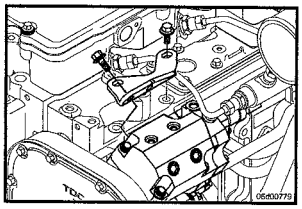
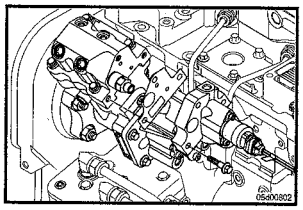
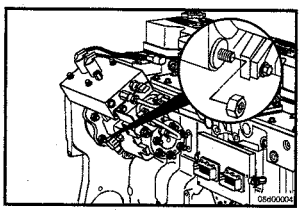
Fuel System - Group 05 - Specifications

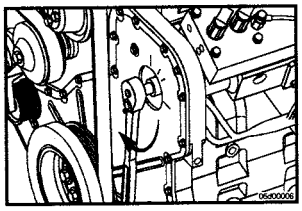
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Fuel Lift Pump (005-045)					
Fuel Lift Pump Inlet Restriction		102 mm Hg	MAX	4 in Hg	
Fuel Pump Cam Housing Module (005-088)					
Camshaft End-Play		0.05 mm	MAX	0.002 in	

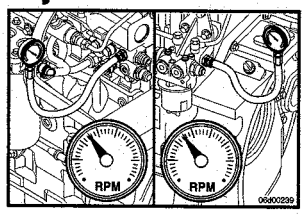
Fuel System - Group 05 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
 **Engine Fuel Heater, Electric (005-008)**			
Fuel Filter Spud		30 N•m	[20 ft-lb]
 **Fuel Pump (005-016)**			
Fuel Pump Mounting Nuts		44 N•m 65 N•m	[32 ft-lb] [48 ft-lb]
 Fuel Injection Pump Gear Nut		180 N•m	[132 ft-lb]
 **Fuel Pump Delivery Valve (005-020)**			
Fuel Delivery Valve Outlet Fitting Assemblies		81 N•m	[60 ft-lb]
 **Fuel Pump Gear Pump (005-025)**			
Fuel Pump Gear Pump Mounting Bolts		34 N•m	[25 ft-lb]
 **Fuel Lift Pump (005-045)**			
Block Mounted Lift Pump		12 N•m	[106 in-lb]
 Ecm Cooling Plate Mounted Lift Pump		10 N•m	[89 in-lb]

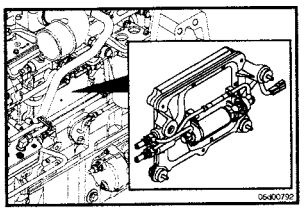
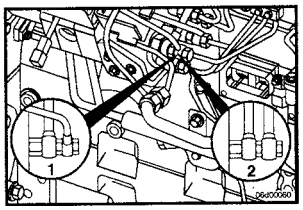
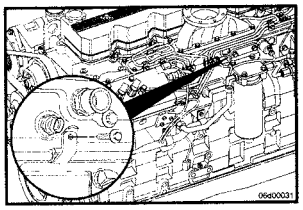
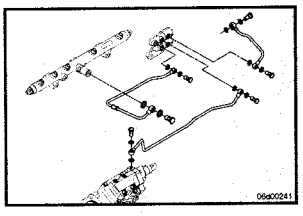
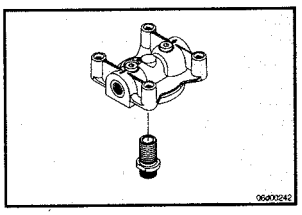
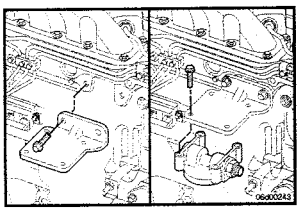
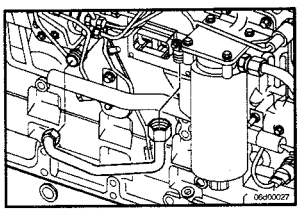
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Rotor, CAPS Fuel Injection Pump (005-072)		14 N•m	[10 ft-lb]	
Injection Control Valve (005-078)				
Injection Control Valve Bolts	1	1.8 N•m	[16 in-lb]	
	2	3.6 N•m	[32 in-lb]	
	3	5.6 N•m	[50 in-lb]	
	4	Torque to 5.6 N•m [50 in-lb] three more times following the torque sequence		
Snubber, Rate Shape (005-081)				
Rate Shap Snubber Assembly	1	14 N•m	[124 in-lb]	
	2	Rotate 80 degrees		
Fuel Pump Distributor Inlet Fitting (005-084)				
Fuel Pump Inlet Distributor Fitting	1	5.7 N•m	[50 in-lb]	
	2	Rotate 120 degrees clockwise		
Fuel Pump Accumulator Module (005-085)		68 N•m	[50 ft-lb]	
		44 N•m	[32 ft-lb]	
Fuel Pump Distributor and Injection Control Valve Module (005-086)		48 N•m	[35 ft-lb]	

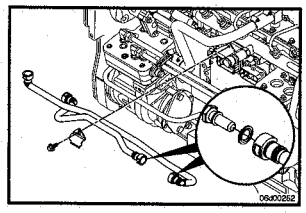
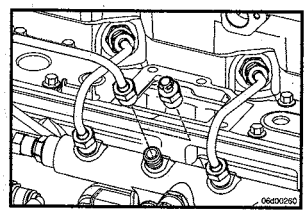
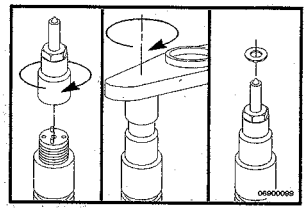
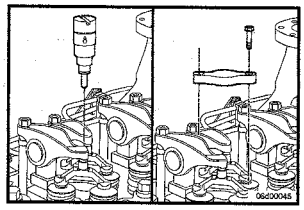
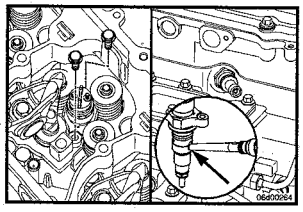
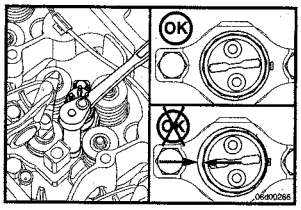
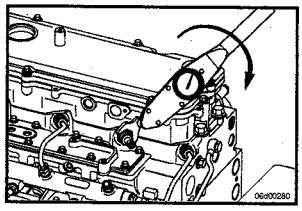
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
		14 N•m	[120 in-lb]
 **Fuel Pump Rate Shape Tube (005-090)**			
Rate Shape Tube Bracket Capscrew		46 N•m	[34 ft-lb]
Rate Shape Tube Bracket Thermistor Adapter		41 N•m 34 N•m	[30 ft-lb] [25 ft-lb]
 **Fuel Pump Head Outlet Fitting (005-226)**			
Fuel Pump Head Outlet Fitting	1 2	5.6 N•m Rotate 120 degrees	[50 in-lb]
 **Fuel Pump Head (005-227)**			
Fuel Pump Head Mounting Bolts		68 N•m	[50 ft-lb]
			
Support Bracket To Cylinder Head		43 N•m	[32 ft-lb]
Support Bracket To Pump Head		43 N•m	[32 ft-lb]
 **Fuel Pump Actuator Housing (005-228)**			
Fuel Pump Actuator Housing		34 N•m	[25 ft-lb]
 **Fuel Injection Pump (005-229)**			
Fuel Pump Mounting Nuts		44 N•m	[32 ft-lb]
Fuel Pump Support Brackets (8.8 Or 9.8 Capscrews)		44 N•m 65 N•m	[32 ft-lb] [48 ft-lb]
Fuel Pump Support Brackets (10.9 Capscrews)			

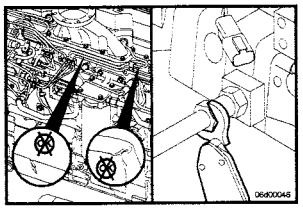
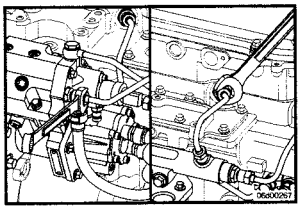
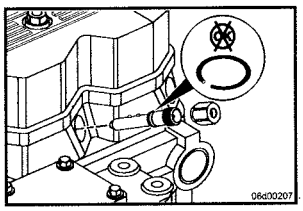
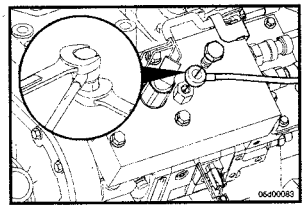
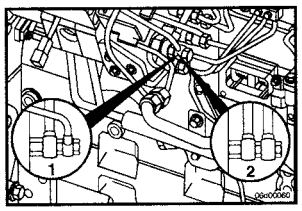
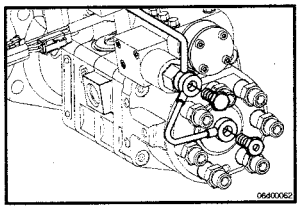
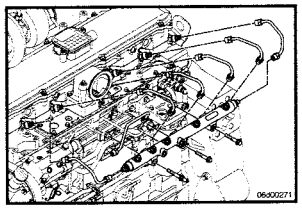
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Injection Pump		108 N•m	[132 ft-lb]	

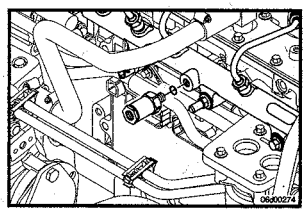
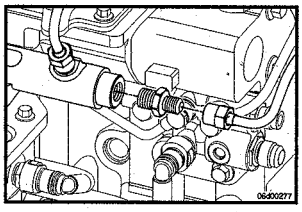
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Injectors and Fuel Lines - Group 06 - Specifications				
 **Fuel Drain Line Restriction (006-012)**				
Fuel Drain Line Pressure		254.0 mm Hg	MAX	10.0 in Hg

Injectors and Fuel Lines - Group 06 - Torque Values

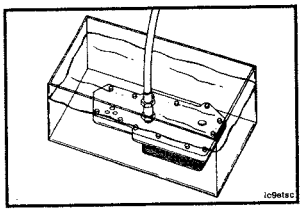
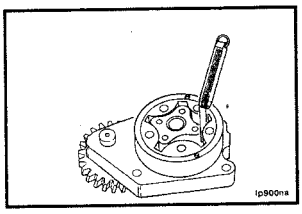
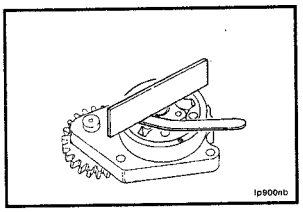
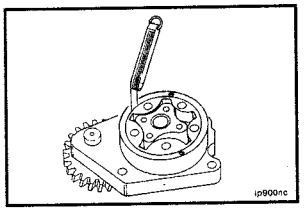
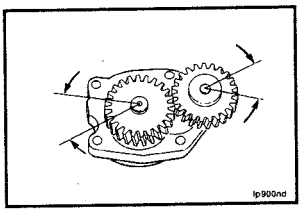
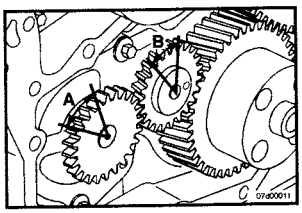
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
ECM Cooling Plate, Fuel Cooled (006-006)				
Ecm Cooling Plate Mounting Capscrews		24 N•m	[18 ft-lb]	
Fuel Drain Lines (006-013)				
Style One (1)		24 N•m	[18 ft-lb]	
Style Two (2)		24 N•m	[18 ft-lb]	
M12 Banjo Bolts		24 N•m	[18 ft-lb]	
P-Clip Capscrew		24 N•m	[18 ft-lb]	
M12 Banjo Bolts		24 N•m	[18 ft-lb]	
M16 Banjo Bolts		43 N•m	[32 ft-lb]	
P-Clip Capscrew		24 N•m	[18 ft-lb]	
Fuel Filter Head Bracket (006-018)		27 N•m	[20 in-lb]	
		43 N•m	[32 ft-lb]	
Fuel Supply Lines (006-024)				
Number 10 Flare Fitting		37 N•m	[27 ft-lb]	
M12 Quick Disconnect Union		24 N•m	[18 ft-lb]	

	Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
	Torque Value Fuel Line Brace Fuel Line Brace Clasp		24 N•m 24 N•m 24 N•m	[18 ft-lb] [18 ft-lb] [18 ft-lb]
	**Injector (006-026)** Isolation Tool, Part Number 3164325		43 N•m	[32 ft-lb]
	Mechanical Injector Retaining Nut		47 N•m	[35 ft-lb]
	Injector Hold-Down Clamp		10 N•m	[89 in-lb]
			15 N•m	[133 in-lb]
	Injector Hold-Down Capscrews		10 N•m	[89 in-lb]
	High-Pressure Fuel Connector Retaining Nut		41 N•m	[31 ft-lb]

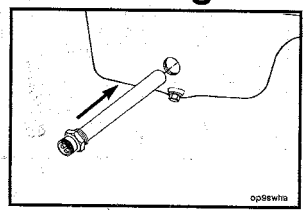
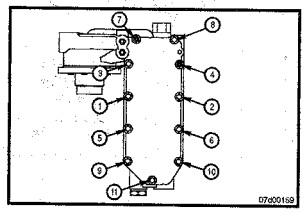
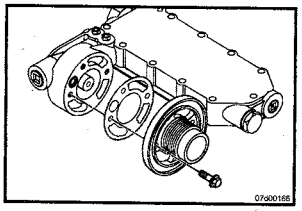
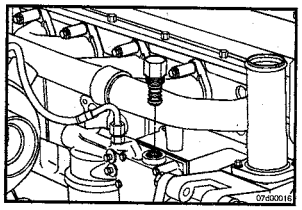
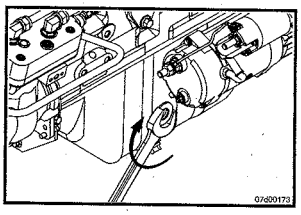
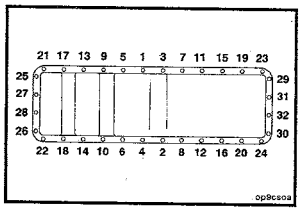
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Injector Supply Lines (High Pressure) (006-051)				
Injector Lines At Fuel Pump		24 N•m 38 N•m	[18 ft-lb] [28 ft-lb]	
Injector Lines At Fuel Pump		38 N•m 38 N•m 38 N•m	[28 ft-lb] [28 ft-lb] [28 ft-lb]	
Fuel Connector (Head Mounted) (006-052)				
Fuel Connector Retaining Nut		41 N•m	[31 ft-lb]	
Fuel Pump Air Bleed Line (006-056)				
Banjo Capscrew At Air Bleed Fitting		8 N•m	[70 in-lb]	
Banjo Capscrew Drain Fitting		8 N•m 24 N•m 24 N•m	[70 in-lb] [18 ft-lb] [18 ft-lb]	
Banjo Capscrew Distributor Plug		8 N•m	[70 in-lb]	
Fuel Rail (006-060)				
Fuel Rail Assembly Capscrews		43 N•m	[32 ft-lb]	

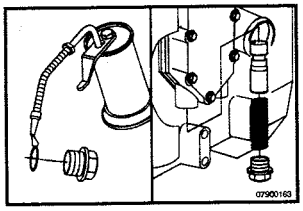
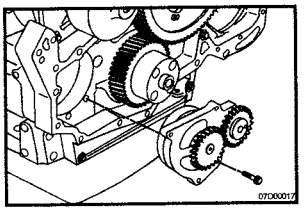
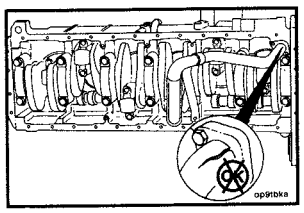
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
 **Fuel Pressure Relief Valve (006-061)**			
Fuel Pressure Relief Valve		100 N•m 37 N•m	[74 ft-lb] [27 ft-lb]
 **Fuel Rail High Pressure Fitting (006-067)**			
Fuel Pressure Relief Valve		100 N•m	[74 ft-lb]

Lubricating Oil System - Group 07 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Lubricating Oil Cooler (007-003)					
Air Pressure Test		449 kPa 518 kPa	MIN MAX	65 psi 75 psi	
Lubricating Oil Pump (007-031)					
Tip Clearance		0.025 mm 0.1778 mm	MIN MAX	0.001 in 0.007 in	
Gerotor Drive/Gerotor Planetary to Port Plate Clearance		0.025 mm 0.127 mm	MIN MAX	0.001 in 0.005 in	
Gerotor Planetary to Body Bore Clearance		0.1778 mm 0.381 mm	MIN MAX	0.007 in 0.015 in	
Lubricating Oil Pump Gears Backlash Limits (Used Pump)		0.076 mm 0.330 mm	MIN MAX	0.003 in 0.013 in	
Lubricating Oil Pump Gears Backlash Limits (Installed)					
A		0.076 0.330	MIN MAX	0.003 0.013	
B		0.076 0.330	MIN MAX	0.003 0.013	

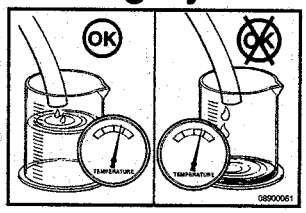
Lubricating Oil System - Group 07 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
 **Engine Oil Heater (007-001)**			
Engine Oil Heater Element		120 N•m	[89 ft-lb]
 **Lubricating Oil Cooler (007-003)**			
Lubricating Oil Cooler Capscrews		24 N•m	[18 ft-lb]
Lubricating Oil Filter Bypass Valve (007-014)			
Lubricating Oil Filter Head Plug		45 N•m	[33 ft-lb]
 **Lubricating Oil Filter Head (007-015)**			
Lubricating Oil Filter Head Mounting Capscrews		24 N•m	[18 ft-lb]
 **Lubricating Oil High Pressure Relief Valve (007-021)**			
Lubricating Oil High Pressure Relief Valve		50 N•m	[37 ft-lb]
 **Lubricating Oil Pan (007-025)**			
Composite Oil Pan Bulkhead Fitting		24 N•m	[20 ft-lb]
			
Lubricating Oil Pan Mounting Capscrews		28 N•m	[21 ft-lb]

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Lubricating Oil Pressure Regulator (Main Rifle) (007-029)				
Lubricating Oil Pressure Regulator (Main Rifle)		80 N•m	[59 ft-lb]	
Lubricating Oil Pump (007-031)				
Lubricating Oil Pump Mounting Capscrews		24 N•m	[18 ft-lb]	
Lubricating Oil Suction Tube (Block-Mounted) (007-035)				
Lubricating Oil Suction Tube To Block		10 N•m	[89 in-lb]	
		10 N•m	[89 in-lb]	
		10 N•m	[89 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

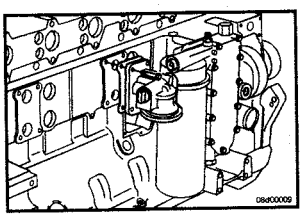
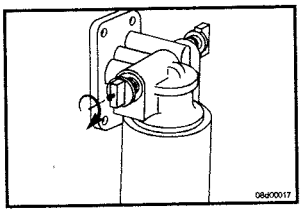
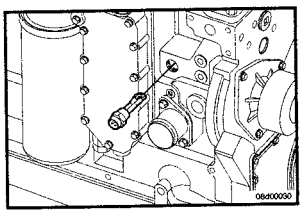
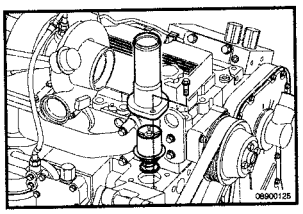
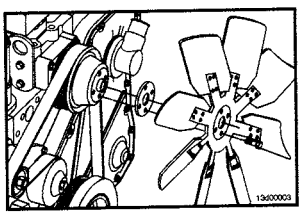
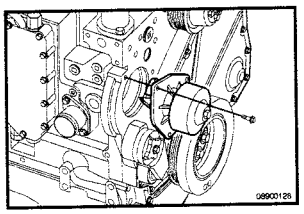
Cooling System - Group 08 - Specifications

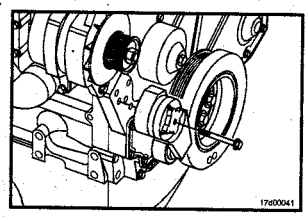
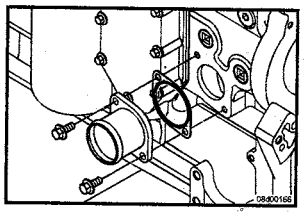


Coolant Thermostat (008-013)

Thermostat Initial Opening Temperature	81 °C	MIN	178 °F
	83 °C	MAX	182 °F

Cooling System - Group 08 - Torque Values

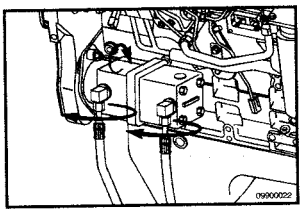
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Coolant Filter Head (008-007)				
Coolant Filter Head Mounting Capscrews		24 N•m	[18 ft-lb]	
Coolant Filter Valve (008-009)				
Coolant Filter Valve Shutoff Screw		1.5 N•m	[12 in-lb]	
Coolant Heater (008-011)				
Coolant Heater		75 N•m	[55 ft-lb]	
Coolant Thermostat (008-013)				
Water Outlet Connection Mounting Capscrews		24 N•m	[18 ft-lb]	
Fan, Cooling (008-040)				
Cooling Fan Mounting Capscrews		43 N•m	[32 ft-lb]	
Water Pump (008-062)				
Water Pump Mounting Capscrews		24 N•m	[18 ft-lb]	

	Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
	**Belt Tensioner, Automatic (Water Pump) (008-080)**			
	Belt Tensioner Capscrews		43 N•m	[32 ft-lb]
	**Water Inlet Connection (008-082)**			
	Water Inlet Mounting Capscrews		24 N•m	[18 ft-lb]

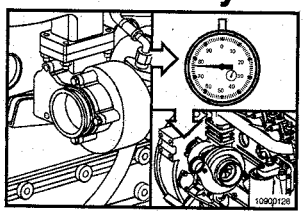
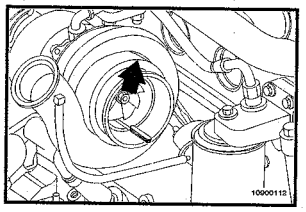
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.

Drive Units - Group 09 - Torque Values

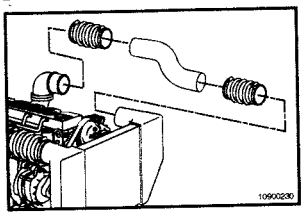
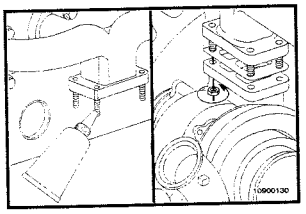
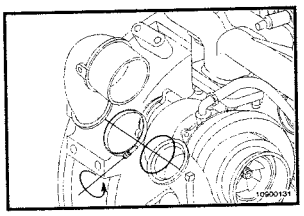
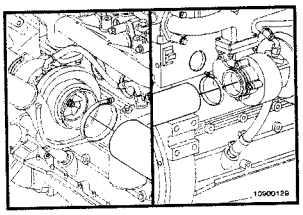
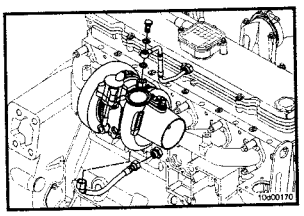
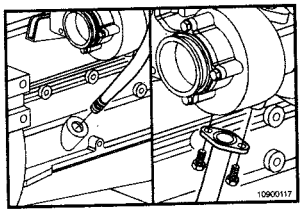
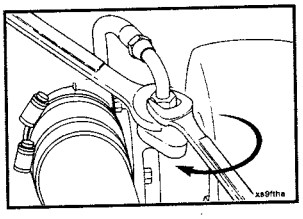
Hydraulic Pump Drive (009-016)		
Hydraulic Pump Mounting Bolts	43 N•m	[32 ft-lb]

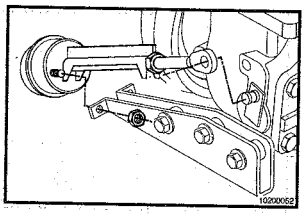
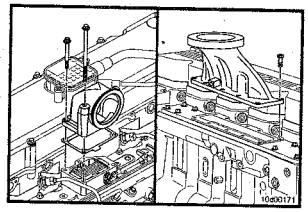
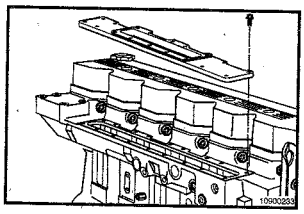
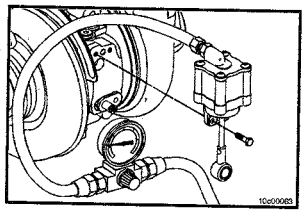
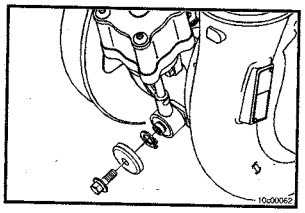
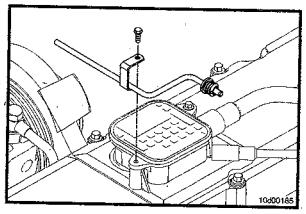
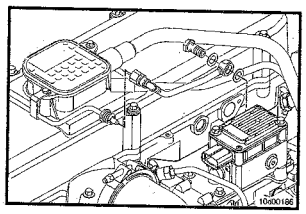


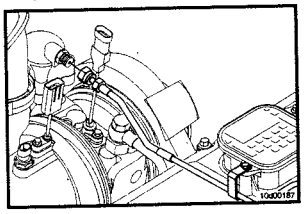
Air Intake System - Group 10 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Turbocharger (010-033)				
 Axial Clearance (HX40WG - Wastegate)		0.025 mm 0.127 mm	MIN MAX	0.001 in 0.005 in
Axial Clearance (HY40V Variable Geometry)		0.025 mm 0.127 mm	MIN MAX	0.001 in 0.005 in
 Wastegate Radial Bearing Clearance		0.330 mm 0.508 mm	MIN MAX	0.013 in 0.020 in

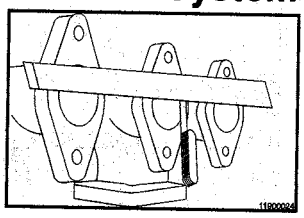
Air Intake System - Group 10 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Air Crossover (010-019)		5 N•m	[44 in-lb]	
Turbocharger (010-033)				
Turbocharger Mounting Nuts Variable Geometry Turbocharger		60 N•m	[44 ft-lb]	
Turbocharger Mounting Nuts Wastegate Turbocharger		45 N•m	[33 ft-lb]	
Turbocharger Compressor Outlet V-Band		8 N•m	[71 in-lb]	
Turbocharger Compressor Inlet		8 N•m	[71 in-lb]	
		8 N•m	[71 in-lb]	
Turbocharger Coolant Hoses (010-041)				
Turbocharger Coolant Lines		46 N•m	[34 ft-lb]	
Turbocharger Oil Drain Line (010-045)				
Turbocharger Oil Drain Line		27 N•m	[20 ft-lb]	
Turbocharger Oil Supply Line (010-046)				
Turbocharger Oil Supply Line Torque		24 N•m	[18 ft-lb]	

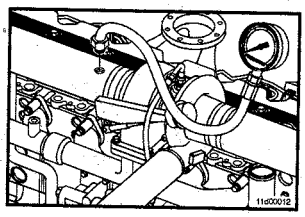
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
 **Turbocharger Wastegate Actuator (010-050)** Actuator Mounting Capscrews		8 N•m	[71 in-lb]
 **Air Intake Connection (010-080)** Air Intake Connection		24 N•m	[18 ft-lb]
 **Air Intake Manifold Cover (010-108)** Intake Manifold		24 N•m	[18 ft-lb]
 **Turbocharger, Variable Geometry Actuator (010-113)** Actuator Housing Capscrews		17 N•m	[150 in-lb]
 Actuator Rod Capscrew		23 N•m	[17 ft-lb]
 **Turbocharger Actuator Air Line (010-118)** Turbocharger Actuator Air Line Mounting		5 N•m	[44 in-lb]
 Flexible Elbow Mounting		18 N•m	[160 in-lb]

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Actuator Air Supply Line		24 N•m	[18 ft-lb]	

Exhaust System - Group 11 - Specifications

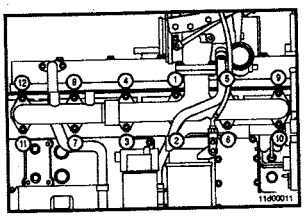
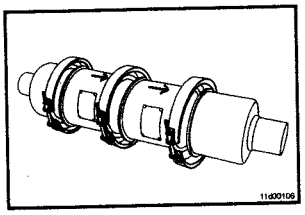
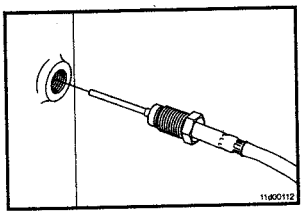


Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Exhaust Manifold, Dry (011-007)				
Exhaust Manifold Flatness		0.20 mm	MAX	0.008 in

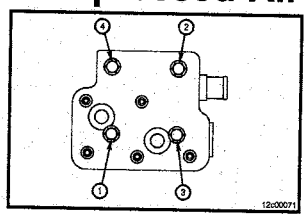
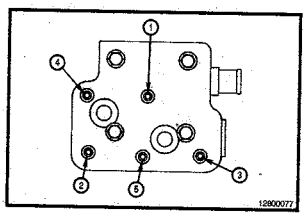
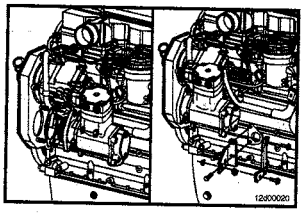
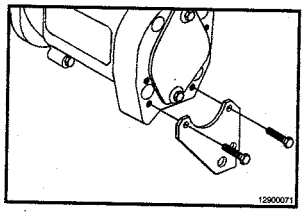
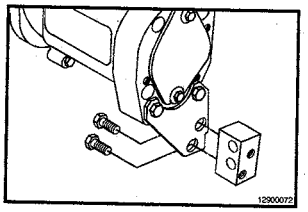
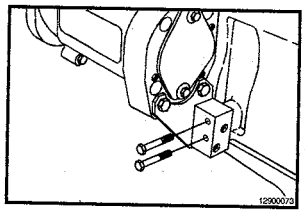


Exhaust Restriction (011-009)				
Exhaust Restriction - Muffler		76 mm Hg	MAX	3 in Hg
Exhaust Restriction - Diesel Oxidation Catalyst		114 mm Hg	MAX	4.5 in Hg
Exhaust Restriction - Exhaust Gas Filter		140 mm Hg	MAX	5.5 in Hg

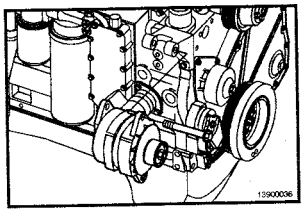
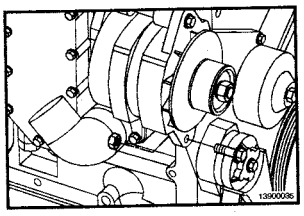
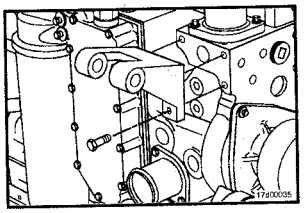
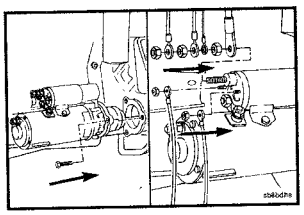
Exhaust System - Group 11 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Exhaust Manifold, Dry (011-007)				
Exhaust Manifold Mounting Capscrews		43 N•m	[32 ft-lb]	
Exhaust Catalyst (011-036)				
V-Band Clamp Torque		20 N•m	[180 in-lb]	
Exhaust Gas Temperature Sensor (011-037)				
Exhaust Gas Temperature Sensor		13.5 N•m	[120 in-lb]	

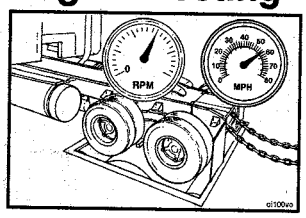
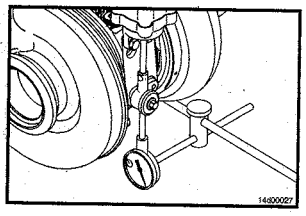
Compressed Air System - Group 12 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
 **Air Compressor Cylinder Head, Single Cylinder (012-007)**			
Air Compressor Cylinder Head Mounting Capscrews	1	25 N•m	[18 ft-lb]
	2	Rotate capscrews 1, 2, and 3 90 degrees	
	3	Rotate capscrew 4 60 degrees	
 Air Compressor Cylinder Head Small Mounting Capscrews	1	6 N•m	[53 in-lb]
	2	Rotate 90 degrees.	
 **Air Compressor (012-014)**			
Air Compressor Mounting Nuts		77 N•m	[57 ft-lb]
 Air Compressor Support Brace Capscrews		43 N•m	[32 ft-lb]
 Air Compressor Support Brace Capscrews		43 N•m	[32 ft-lb]
 Support Brace To Cylinder Block Capscrews		43 N•m	[32 ft-lb]

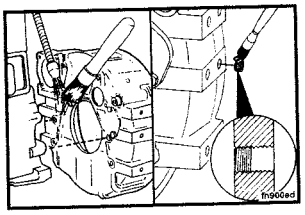
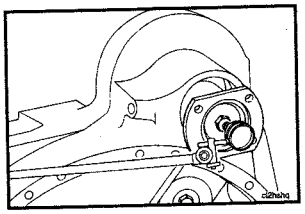
Electrical Equipment - Group 13 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Alternator (013-001)				
Alternator Mounting Capscrews		43 N•m	[32 ft-lb]	
Alternator Link Capscrew		24 N•m	[18 ft-lb]	
Alternator Bracket (013-003)				
Alternator Mounting Bracket Capscrews		24 N•m	[18 ft-lb]	
Starting Motor (013-020)				
Starter Motor Mounting Capscrews		43 N•m	[32 ft-lb]	

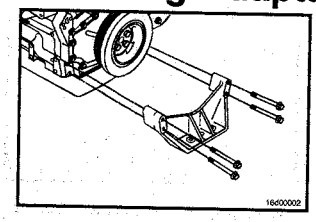
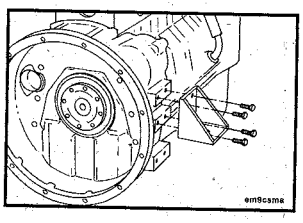
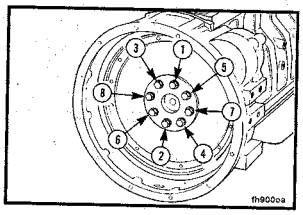
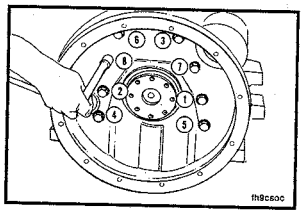
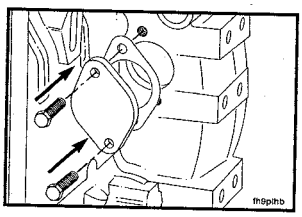
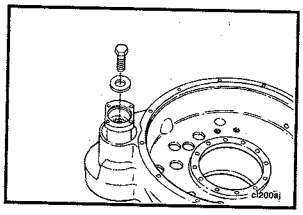
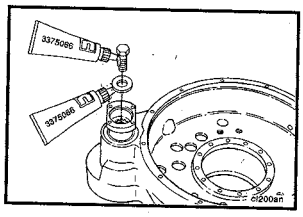
Engine Testing - Group 14 - Specifications

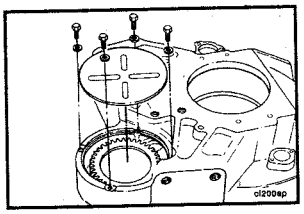
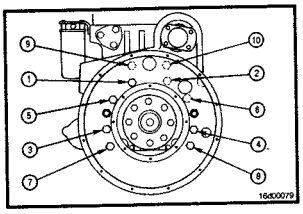
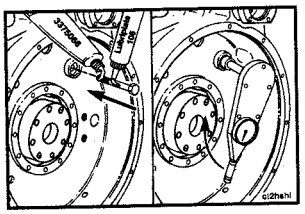
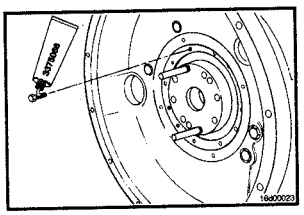
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
 **Engine Run-in (Engine Dynamometer) (014-006)**				
Lubricating Oil Temperature		90 °C	MAX	194 °F
Fuel Temperature		65 °C	MAX	149 °F
 **Engine Testing (In Chassis) (014-008)**				
Turbocharger Actuator Rod Travel		10.8 mm	MIN	0.40 in
		11.8 mm	MAX	0.46 in

Mounting Adaptations - Group 16 - Specifications

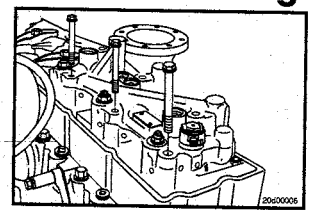
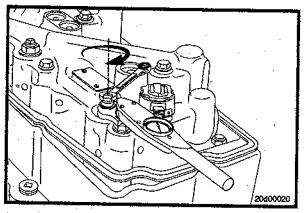
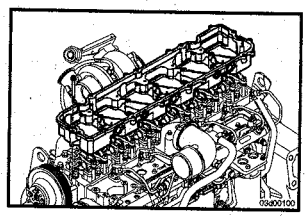
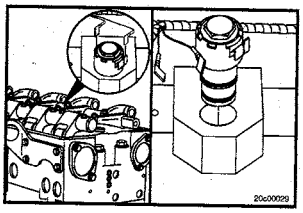
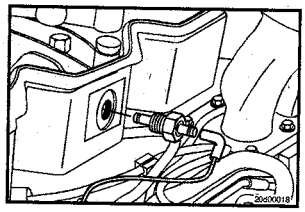
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Flywheel Housing (016-006)					
Set Screw Installation Depth (Flywheel Housing)		3.00 mm	MAX	0.118 in	
Flywheel Housing, REPTO (016-007)					
Shaft End Play		0.0 mm 0.03 mm	MIN MAX	0.0 in 0.001 in	

Mounting Adaptations - Group 16 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
 **Engine Support Bracket, Front (016-002)** Front Engine Support Bracket Mounting Capscrews		112 N•m	[83 ft-lb]
 **Engine Support Bracket, Rear (016-003)** Rear Engine Support Bracket Mounting Capscrews		71 N•m	[52 ft-lb]
 **Flywheel (016-005)** Flywheel Capscrews		137 N•m	[101 ft-lb]
 **Flywheel Housing (016-006)** Flywheel Housing Mounting Capscrews		77 N•m	[57 ft-lb]
 Flywheel Housing Access Plate Capscrew		24 N•m	[18 ft-lb]
 **Flywheel Housing, REPTO (016-007)** Flywheel Housing Flat Washer And Capscrew		205 N•m	[150 ft-lb]
 Output Flange Flat Washer And Capscrew		205 N•m	[150 ft-lb]

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Housing Cover Capscrews		18 N•m	[14 ft-lb]	
Flywheel Housing Capscrews		77 N•m	[57 ft-lb]	
Idler Shaft Capscrew		105 N•m	[75 ft-lb]	
Seal Retainer Capscrews	1 2	7 N•m 19 N•m	[60 in-lb] [170 in-lb]	

Vehicle Braking - Group 20 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
 **Engine Brake Assembly (020-004)** Engine Brake Mounting Capscrews		32 N•m	[23 ft-lb]
 Engine Brake Adjusting Locknut		35 N•m	[25 ft-lb]
 **Engine Brake Housing Spacer (020-007)** Engine Brake Spacer Mounting Capscrews		32 N•m	[23 ft-lb]
 **Engine Brake Solenoid Valve (020-012)** Engine Brake Solenoid		20 N•m	[15 ft-lb]
 **Engine Brake Wiring Harness (020-015)** Engine Brake Wiring Harness Receptacle Connector		11 N•m	[97 in-lb]

General Engine

Specifications

Listed below are the general specifications for this engine.

Horsepower	Refer to engine dataplate
Firing Order	1.5.3.6.2.4
Crankshaft Rotation (viewed from front of engine)	**Clockwise**
Displacement	8.3 liters [504.5 in^3]
Displacement	8.9 liters [540 in^3]
Bore and Stroke	
8.3 liters	114 mm [4.49 in] x 135 mm [5.32 in]
8.9 liters	114 mm [4.49 in] x 144.5 mm [5.69 in]
Dry Weight	
8.3 liters	694 kg [1530 lb]
8.9 liters	706 kg [1555 lb]
Wet Weight	
8.3 liters	723 kg [1595 lb]
8.9 liters	738 kg [1625 lb]
Overhead Adjustment	
Intake Valve Adjustment	0.305 mm [0.012 in]
Exhaust Valve Adjustment	0.559 mm [0.022 in]
Engine Brake Adjustment	2.286 mm [0.090 in]

Specifications

Listed below are the general specifications for this engine.

Horsepower	Refer to engine dataplate
Firing Order	1.5.3.6.2.4
Crankshaft Rotation (viewed from front of engine)	**Clockwise**
Displacement	8.3 liters [504.5 in^3]
Displacement	8.9 liters [540 in^3]
Bore and Stroke	
8.3 liters	114 mm [4.49 in] x 135 mm [5.32 in]
8.9 liters	114 mm [4.49 in] x 144.5 mm [5.69 in]
Dry Weight	
8.3 liters	880 kg [1940 lb]
8.9 liters	891 kg [1965 lb]
Dry Weight - Engine with Heat Exchanger System - Average	
8.3 liters	896 kg [1975 lb]
8.9 liters	907 kg [2000 lb]
Overhead Adjustment	
Intake Valve Adjustment	0.305 mm [0.012 in]
Exhaust Valve Adjustment	0.559 mm [0.022 in]

Fuel System

Specifications

Cummins Common Rail Fuel System

Maximum Fuel Return Line Pressure.....254 mm Hg [10 in Hg]
Maximum Fuel Inlet Restriction (gear pump inlet).....254 mm Hg [10 in Hg]
Maximum Fuel Inlet Restriction - Dirty Filter (OEM connection point).....152 mm Hg [6 in Hg]
Minimum Gear Pump Pressure (during cranking).....69 kPa [10 psi]
Maximum Filter Pressure Drop.....138 kPa [20 psi]
Minimum Lift Pump Pressure (gear pump inlet during cranking).....35 kPa [5 psi]
Minimum Engine Cranking Speed.....150 rpm

CAPS Fuel System

Maximum Fuel Inlet Restriction at Rated (measured at lift pump inlet).....102 mm Hg [4 in Hg]
Maximum Fuel Inlet Restriction at Rated (measured at CAPS pump inlet).....254 mm Hg [10 in Hg]
Minimum Lift Pump Pressure.....35 kPa [5 psi]
Maximum Filter Pressure Drop at Rated.....102 mm Hg [4 in Hg]
Minimum Gear Pump Pressure (during cranking).....69 kPa [10 psi]
Minimum Engine Cranking Speed.....150 rpm

Lubricating Oil System

Specifications

All Applications Except Marine

Oil Pressure
- At Low Idle (minimum allowable) ..... 69 kPa [10 psi]
- At Rated Speed (minimum allowable) ..... 207 kPa [30 psi]

Regulated Oil Pressure ..... 517 kPa [75 psi]
Lubricating Oil Filter Capacity ..... 3.78 liters [4 qt]
Oil Pan Capacity, Low to High (8.3 liter engines)
- Standard Oil Pan ..... 15.1 to 18.9 liters [16 to 20 qt]
- Standard Oil Pan with Cylinder Block Stiffener Plate ..... 16.1 to 19.9 liters [17 to 21 qt]

Total System Capacity (Oil Pan and New Oil Filter) (8.3 liter engines)
- Standard Oil Pan ..... 22.7 liters [24 qt]
- Standard Oil Pan with Cylinder Block Stiffener Plate ..... 23.7 liters [25 qt]

Oil Pan Capacity, Low to High (8.9 liter engines)
- Standard Oil Pan ..... 18.9 to 22.7 liters [20 to 24 qt]
- Standard Oil Pan with Cylinder Block Stiffener Plate ..... 19.9 to 23.7 liters [21 to 25 qt]

Total System Capacity (Oil Pan and New Oil Filter) (8.9 liter engines)
- Standard Oil Pan ..... 26.5 liters [28 qt]
- Standard Oil Pan with Cylinder Block Stiffener Plate ..... 27.4 liters [29 qt]

Marine Applications

Oil Pressure
- At Low Idle (minimum allowable) ..... 69 kPa [10 psi]
- At Rated Speed (minimum allowable) ..... 207 kPa [30 psi]

Regulated Oil Pressure ..... 517 kPa [75 psi]
Lubricating Oil Filter Capacity ..... 3.78 liters [4 qt]
Oil Pan Capacity, Low to High (8.3 liter engines)
- Standard Oil Pan ..... 13.2 to 17.0 liters [3.5 to 4.5 gal]

Total System Capacity (Oil Pan and New Oil Filter) (8.3 liter engines)
- Standard Oil Pan ..... 19.7 liters [5.2 gal]

Oil Pan Capacity, Low to High (8.9 liter engines)
- Standard Oil Pan ..... 18.9 to 22.7 liters [5 to 6 gal]

Total System Capacity (Oil Pan and New Oil Filter) (8.9 liter engines)
- Standard Oil Pan ..... 25.4 liters [6.7 gal]

Cooling System

Specifications

All Applications Except Marine

Coolant Capacity (engine **only**).....11.1 liters [11.7 qt]
Standard Modulating Thermostat Range.....82 to 93°C [180 to 200°F]
Minimum Recommended Pressure Cap.....48 kPa [7 psi]
Minimum Fill Rate (without low-level alarm).....19 liters/min [5 gpm]
Maximum Deaeration Time.....25 minutes
Winterfronts - Automotive **Only**
Air Passage Area.....774 cm^2 [120 in^2]

Marine Applications

Coolant Capacity (engine **only**).....11.1 liters [11.7 qt]
Coolant Capacity (engine including heat exchanger).....29 liters [7.75 gal]
Standard Modulating Thermostat Range.....68 to 75°C [155 to 167°F]
Minimum Recommended Pressure Cap.....103 kPa [15 psi]
Minimum Seawater Flow (with heat exchanger option).....83 liters/min [22 gpm]

Air Intake System

Specifications

⚠CAUTION⚠

Engine intake air must be filtered to prevent dirt and debris from entering the engine. If the air intake piping is damaged or loose, unfiltered air will enter the engine and cause premature wear.

Maximum Intake Restriction (clean air filter element).....254 mm H_2O [10.0 in H_2O]
Maximum Intake Restriction (dirty air filter element).....635 mm H_2O [25.0 in H_2O]
Charge Air Cooler Restriction (maximum).....152 mm Hg [6.0 in Hg]

Exhaust System

Specifications

Maximum Exhaust Back Pressure.....76 mm Hg [3 in Hg]

Electrical System

Specifications

Minimum Recommended Battery Capacity:.....0.00075 ohms

System Voltage	Ambient Temperatures	
	• 18°C [0°F]	
	Cold Cranking Amperes	Reserve Capacity* (Minutes)
12-VDC	1800	640
24-VDC**	900	320

* The number of plates within a given battery size determines reserve capacity. Reserve capacity is the length of time for which a battery at 27°C [80°F] can supply 25 amperes at 10.5 volts or greater.

** CCA ratings are based on two 12-VDC batteries in series.

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

Maximum Starting Circuit Resistance
12-VDC System.....0.00075 ohms
24-VDC System.....0.00200 ohms

Compressed Air System

Specifications

Cummins 18.7 CFM Model

Cylinders....1
Compressor Swept Volume @ 1250 RPM....6.6 l/sec. [14.0 cfm]
Piston Displacement....31 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 116 STOR
  Air Inlet....25.4 mm [1 in] Nominal
  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 [8.56 in]
Width, Overall (Approximate)....142 mm [5.59 in]
Length, Overall (Approximate)....216 mm [8.50 in]
Weight (Approximate)....15 kg [35.0 lb]

Engine Testing

Specifications

Engine Blowby Specifications.....30.5 cm H_2O [12.0 in H_2O]

Cummins/Fleetguard® Filter Specifications

General Information

Fleetguard® is a subsidiary of Cummins Inc. Fleetguard® filters are developed through joint testing at Cummins and Fleetguard®. Fleetguard® filters are standard on new Cummins engines. Cummins Inc. recommends their use.

Fleetguard® products meet all Cummins Source Approval Test standards to provide the quality filtration necessary to achieve the engine's design life. If other brands are substituted, the purchaser should insist on products that the supplier has tested to meet Cummins high-quality standards.

Cummins can **not** be responsible for problems caused by non-genuine filters that do **not** meet Cummins performance or durability requirements.

NOTE: LF9009 **must** be used. A venturi type filter **must** be used in order to benefit from the bypass filtration section of the oil filter. Do **not** use LF3000. Engine durability will be reduced by using the wrong lubricating oil filter.

Drive Belt Tension

Tension Chart

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.

Capscrew Markings and Torque Values

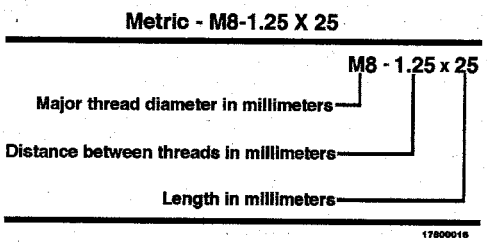
General Information

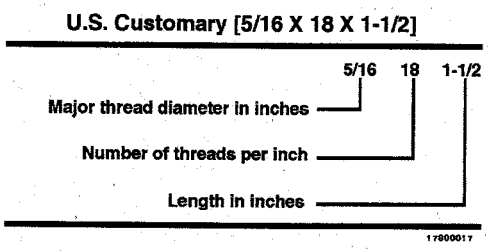
⚠CAUTION⚠

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:

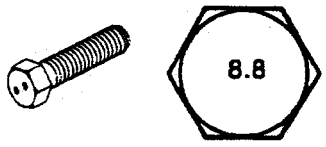
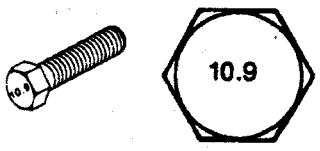
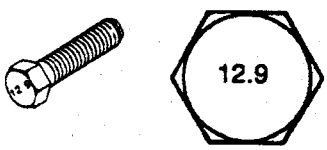




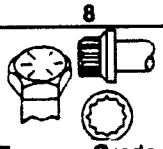
NOTES:

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

Fraction, Decimal, Millimeter Conversions

Conversion Chart

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

Conversion Factor: 1 inch = 25.4 mm

Newton-Meter to Foot-Pound Conversions

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.					

Pipe Plug Torque Values

Torque Table

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

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

General Information

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
		5.20mm
M6x1		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
		9.80mm
M11x1.5		W
7/16-14		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

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Weights and Measures - Conversion Factors

Conversion Chart

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

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