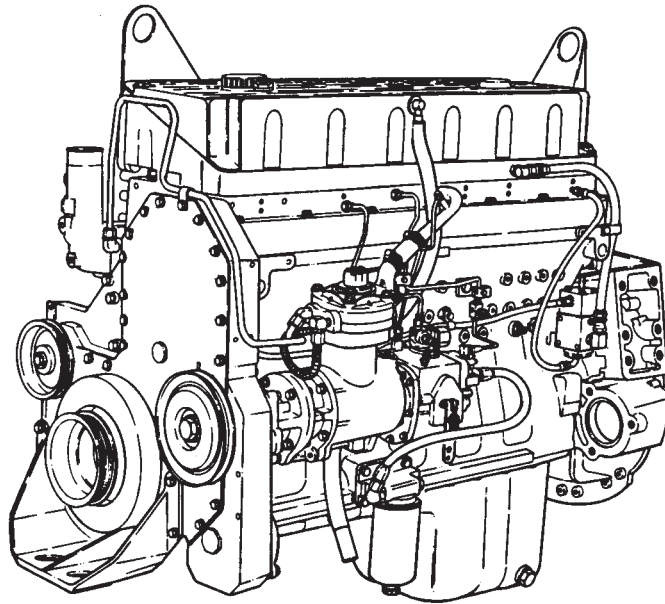
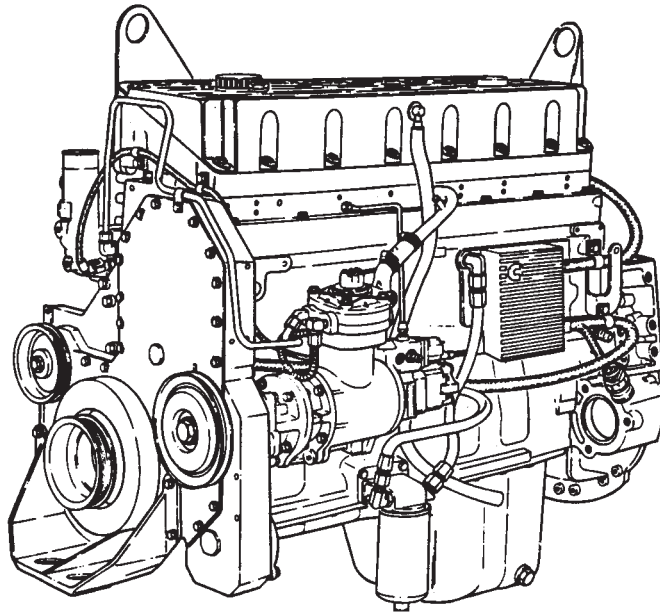




Troubleshooting and Repair Manual M11 Series Engines (STC, CELECT™, CELECT™ Plus Models)



STC



CELECT™/CELECT™ Plus

00200023

Foreword

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

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

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

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

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

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

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

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:



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Section i - Introduction

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About this Manual

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

The material in this manual covers all M11 Series engines. The manual is divided into sections. Each section is equivalent to a group used in Cummins' filmcard system. Some sections contain **reference** numbers and **procedure** numbers. **Reference** numbers provide general information, specifications, diagrams, and service tools where applicable. **Procedure** numbers are used to identify and reference specific repair procedures for correcting the problem.

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

This manual covers all base engine repair procedures and some fuel system repair procedures for the STC fuel system. Repair procedures and fault code diagnosis for the electronic fuel systems (CELECT™ and CELECT™ Plus) is covered in Troubleshooting and Repair Manual, Bulletin No. 3666130.

How to Use the Manual

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

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

Symbols

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



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



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



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



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



INSPECTION is required.



CLEAN the part or assembly.



PERFORM a mechanical or time **MEASUREMENT**.



LUBRICATE the part or assembly.



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



TIGHTEN to a specific torque.



PERFORM an electrical **MEASUREMENT**.



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



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

Simbolos

Los símbolos siguientes son usados en este manual para clarificar el proceso de las instrucciones. Cuando aparece uno de estos símbolos, su significado se especifica en la parte inferior.



ADVERTENCIA - Serios daños personales o daño a la propiedad puede resultar si las instrucciones de Advertencia no se consideran.



PRECAUCION - Daños menores pueden resultar, o de piezas del conjunto o el motor puede averiarse si las instrucciones de Precaución no se siguen.



Indica un paso de **REMOCION** o **DESMONTAJE**.



Indica un paso de **INSTALACION** o **MONTAJE**.



Se requiere **INSPECCION**.



LIMPIESE la pieza o el montaje.



EJECUTESE una **MEDICION** mecánica o del tiempo.



LUBRIQUESE la pieza o el montaje.



Indica que se dará una **LLAVE DE TUERCAS** o el **TAMAÑO DE HERRAMIENTA**.



APRIETESE hasta un par torsor específico.



EJECUTESE una **MEDICION** eléctrica.



Para información adicional refiérase a otro emplazamiento de este manual o a otra publicación anterior.



El componente pesa 23 kg [50 lb] o mas. Para evitar dano corporal empleen una cabria u obtengan ayuda para elevar el componente.

Symbole

In diesem Handbuch werden die folgenden Symbole verwendet, die wesentliche Funktionen hervorheben. Die Symbole haben folgende Bedeutung:



WARNUNG - Wird die Warnung nicht beachtet, dann besteht erhöhte Unfall- und Beschädigungsgefahr.



VORSICHT - Werden die Vorsichtsmassnahmen nicht beachtet, dann besteht Unfall- und Beschädigungsgefahr.



AUSBAU bzw. **ZERLEGEN**.



EINBAU bzw. **ZUSAMMENBAU**.



INSPEKTION erforderlich.



Teil oder Baugruppe **REINIGEN**.



DIMENSION - oder **ZEITMESSUNG**.



Teil oder Baugruppe **ÖLEN**.



WERKZEUGGRÖSSE wird angegeben.



ANZUG auf vorgeschriebenes Drehmoment erforderlich.



Elektrische **MESSUNG DURCHFÜHREN**.



Weitere Informationen an anderer Stelle bzw. in anderen Handbüchern.



Das teil weigt 23 kg [50 lb] oder mehr. Zur Vermeidung von Koerperverletzung winde benutzen oder hilfe beim heben des teils in anspruch nehmen.

Symboles

Les symboles suivants sont utilisés dans ce manuel pour aider à communiquer le but des instructions. Quand l'un de ces symboles apparaît, il évoque le sens défini ci-dessous:



AVERTISSEMENT - De graves lésions corporelles ou des dommages matériels considérables peuvent survenir si les instructions données sous les rubriques "Avertissement" ne sont pas suivies.



ATTENTION - De petites lésions corporelles peuvent survenir, ou bien une pièce, un ensemble ou le moteur peuvent être endommagés si les instructions données sous les rubriques "Attention" ne sont pas suivies.



Indique une opération de **DEPOSE**.



Indique une opération de **MONTAGE**.



L'INSPECTION est nécessaire.



NETTOYER la pièce ou l'ensemble.



EFFECTUER une **MESURE** mécanique ou de temps.



GRAISSER la pièce ou l'ensemble.



Indique qu'une **DIMENSION DE CLE** ou **D'OUTIL** sera donnée.



SERRER à un couple spécifique.



EFFECTUER une **MESURE** électrique.



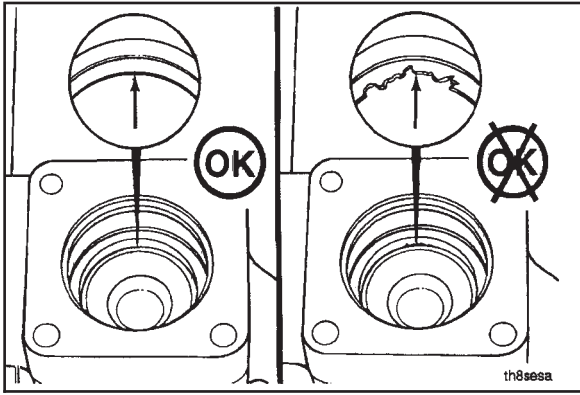
Se reporter à un autre endroit dans ce manuel ou à une autre publication pour obtenir des informations plus complètes.



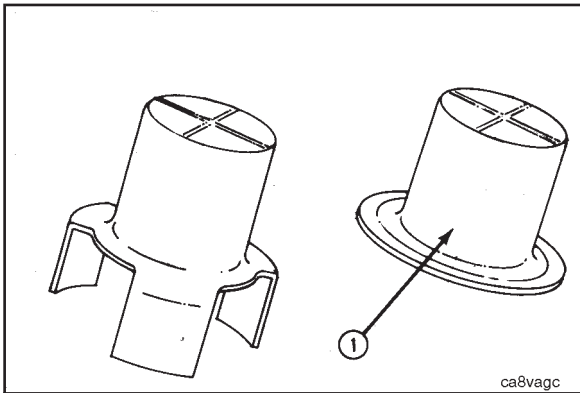
Le composant pèse 23 kg [50 lb] ou davantage. Pour éviter toute blessure, employer un appareil de levage ou demander de l'aide pour le soulever.

Illustrations

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



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



General Safety Instructions

Important Safety Notice



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

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

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

General Repair Instructions

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

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

Air Compressor
Air Controls
Air Shutoff Assemblies
Balance Weights
Cooling Fan
Fan Hub Assembly
Fan Mounting Bracket(s)
Fan Mounting Capscrews
Fan Hub Spindle
Flywheel
Flywheel Crankshaft Adapter

Flywheel Mounting Capscrews
Fuel Shutoff Assemblies
Fuel Supply Tubes
Lifting Brackets
Throttle Controls
Turbocharger Compressor Casing
Turbocharger Oil Drain Line(s)
Turbocharger Oil Supply Line(s)
Turbocharger Turbine Casing
Vibration Damper Mounting Capscrews

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

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

Welding on a Vehicle with an Electronic Controlled Fuel System



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

General Cleaning Instructions

Solvent and Acid Cleaning

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

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

WARNING

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

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

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

Steam Cleaning

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

WARNING

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

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

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

Glass or Plastic Bead Cleaning

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

CAUTION

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

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

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

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

Acronyms and Abbreviations

AFC	Air Fuel Control	km/l	Kilometers per Liter
API	American Petroleum Institute	kPa	Kilopascal
ASA	Air Signal Attenuator	LNG	Liquid Natural Gas
ASTM	American Society of Testing and Materials	LTA	Low Temperature Aftercooling
°C	Celsius	MIP	Mixer Inlet Pressure
CARB	California Air Resources Board	MPa	Megapascal
C.I.D.	Cubic Inch Displacement	mph	Miles Per Hour
CNG	Compressed Natural Gas	mpq	Miles Per Quart
CPL	Control Parts List	N•m	Newton-meter
cSt	Centistokes	NG	Natural Gas
ECM	Electronic Control Module	OEM	Original Equipment Manufacturer
ECS	Emission Control System	ppm	Parts Per Million
EPA	Environmental Protection Agency	psi	Pounds Per Square Inch
EPS	Engine Position Sensor	PTO	Power Takeoff
°F	Fahrenheit	rpm	Revolutions Per Minute
GVW	Gross Vehicle Weight	SAE	Society of Automotive Engineers
Hg	Mercury	SCA	Supplemental Coolant Additive
hp	Horsepower	STC	Step Timing Control
H₂O	Water	VS	Variable Speed
ICM	Ignition Control Module	VSS	Vehicle Speed Sensor

Section E - Engine Identification

Section Contents

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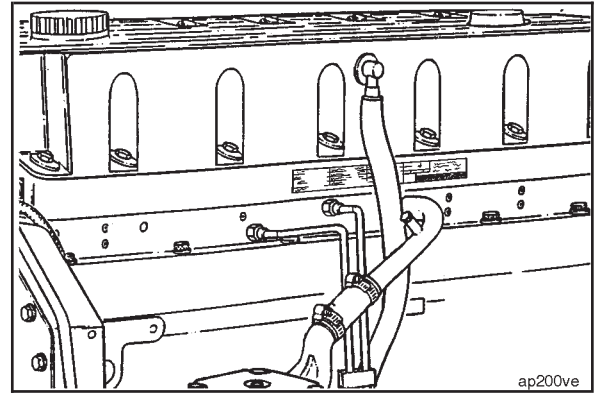
Engine Identification

Engine Dataplate

The engine dataplate shows specific information about your engine. The engine serial number and control parts list (CPL) provide information for ordering parts and service needs. The engine dataplate **must not** be changed unless approved by Cummins Engine Company, Inc.

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

1. Engine Serial Number (ESN)
2. Control Parts List (CPL)
3. Model
4. Horsepower and rpm rating



Engine No. Moteur No.	Advert. HP Puiss. Indiquée(ch)	at	RPM	E.C.S.	NO	IMPORTANT ENGINE INFORMATION: This engine conforms to U.S. EPA and California regulations applicable to 19 Model Year New Heavy Duty Engine. This engine has a primary intended service application as a heavy heavy-duty diesel engine. This engine is certified to operate on diesel fuel.
Family	Peak Torque (FT-LB) Torque Cime	at	RPM	Inj. Timing Code Calge d'injection	PM	
Model Modèle	Fuel rate at Advert. HP Débit Combust. à Puiss. Indiquée		mm 3 stroke	C.I.D./L Pouce Cube	FEL EPA CARB	This engine is not certified for use in an urban bus as defined at 40 CFR 86.083-2. Sales of this engine for use in an urban bus is a violation of Federal law under the Clean Air Act. WARNING: Injury may result and warranty is voided if fuel rate, RPM, or altitudes exceed published maximum values for the model and application. AVERTISSEMENT: Danger de blessures et d'annulation de la garantie en réajustement, tirage ou altitude dépassés, les valeurs maximums annoncées pour ce modèle et son utilisation.
Date of Mfg. Date Fabrication	Valve Lash Cold Jeux Soupapes à Froid	Int. Adm.	Ext. Ech.	CPL		
Idle Speed RPM Vitesse de Ralentir	Inj. Set Courses Inj.		Governed Speed Vitesse Gouvernée		RPM	
Ref. No.						

00200016

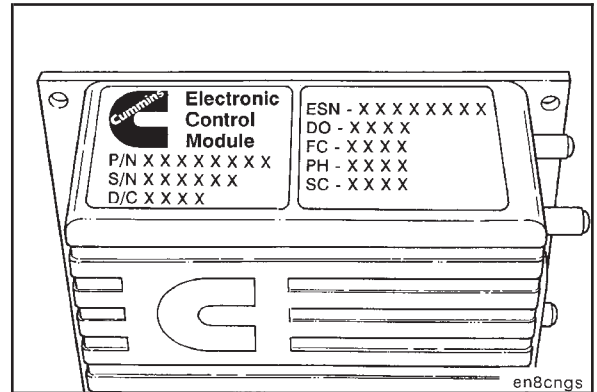
ECM Dataplate

There are two dataplates on the top of the electronic control module (ECM).

NOTE: The ECM referenced here is used with the CELECT™ and CELECT™ Plus fuel systems only.

The dataplate on the left contains the part number (P/N), serial number (S/N) and the date code (D/C) of the ECM.

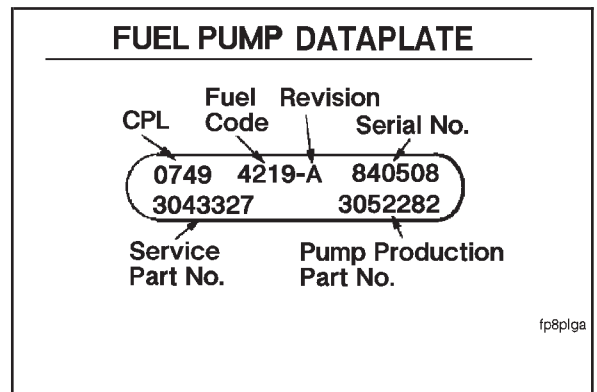
The dataplate on the right contains the engine serial number (ESN), fuel code (FC) and engine calibration information.



Fuel Pump Dataplate

NOTE: The fuel pump dataplate referenced here is the style dataplate used on a Cummins PT (pressure/time) fuel pump. This is the type fuel pump used on a STC fuel system. It is **not** used on fuel pumps with the CELECT™ or CELECT™ Plus fuel systems.

The fuel pump dataplate is located on the top of the fuel pump. It provides information for fuel pump calibration.

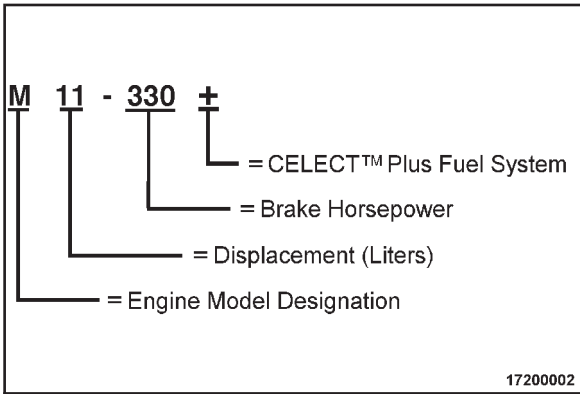


fp8plga

Cummins Engine Nomenclature

Cummins engine nomenclature provides engine data as illustrated in the graphic.

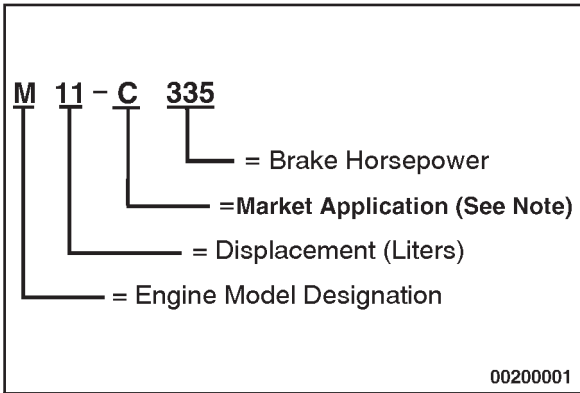
This graphic illustrates nomenclature used with automotive engines.



This graphic illustrates nomenclature used with off-highway (industrial) engines.

NOTE: The following letters designate some of the different market applications for a Cummins engine.

- A = Agriculture
- C = Construction
- G = Generator Drive



Specifications

General Specifications

Horsepower (Refer to engine dataplate)

Engine speed @ Maximum Output:

Governed Speed (rpm)	
Automotive (CELECT™ and CELECT™ Plus)	1800
Vocational (CELECT™ and CELECT™ Plus)	2100
Industrial (STC)	2100

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

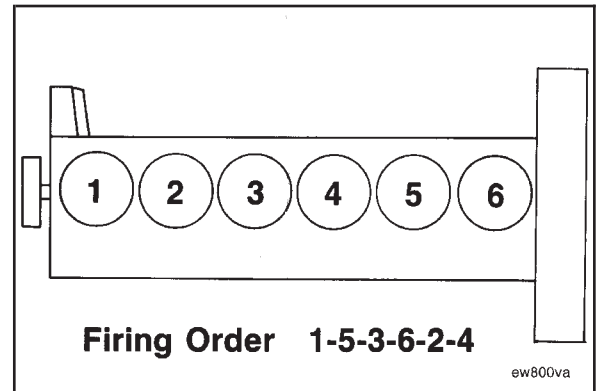
Displacement 10.8 liters [661 C.I.D.]

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

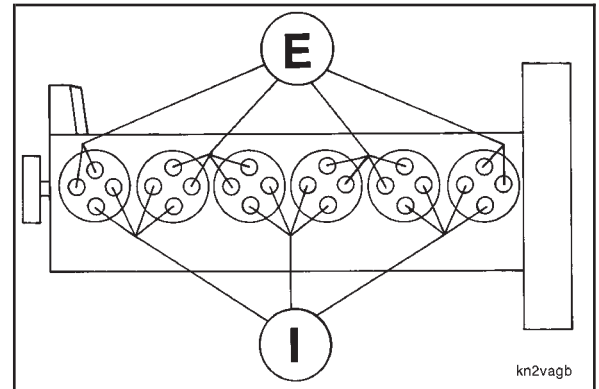
Engine Weight (with standard accessories):

CELECT™ and CELECT™ Plus	
Dry Weight	940 Kg [2070 lb]
Wet Weight	996 Kg [2193 lb]
STC	
Dry Weight	929 Kg [2045 lb]
Wet Weight	981 Kg [2160 lb]

Cylinder Location and Firing Order



Intake and Exhaust Valve Locations



Fuel System

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

Engine Idle Speed

CELECT™	650 to 800 rpm
CELECT™ Plus	600 to 800 rpm

Fuel Inlet Maximum Restriction:

CELECT™ and CELECT™ Plus	
Clean Fuel Filter	152 mm Hg [6 in Hg]
Dirty Fuel Filter	254 mm Hg [10 in Hg]
STC	
Clean Fuel Filter	102 mm Hg [4 in Hg]
Dirty Fuel Filter	204 mm Hg [8 in Hg]

Fuel Drain Line Maximum Restriction

CELECT™ and CELECT™ Plus	89 mm Hg [3.5 in Hg]
STC	
Without Check Valves	63 mm Hg [2.5 in Hg]
With Check Valves	165 mm Hg [6.5 in Hg]

Minimum Fuel Pressure:

During Cranking	172 kPa [25 psi]
1200 rpm	827 kPa [120 psi]

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

Engine Minimum Cranking Speed 150 rpm

Shutoff Valve Solenoid Coil Resistance

12 VDC	7.0 to 8.0 ohms
--------	-----------------

Lubricating Oil System

Oil Pressure:

Low Idle (Minimum Allowable)	70 kPa [10 psi]
At 1200 rpm or Torque Peak (Minimum Allowable)	207 kPa [30 psi]

Oil Capacity of Standard Engine:

Combination Filter	2.6 liters [0.7 U.S. gal.]
Oil Pan (High-Low)	34 - 26.5 liters [9 - 7 U.S. gal.]

Cooling System

Coolant Capacity (Engine Only)

Charge Air Cooled Engines	9.5 liters [2.5 U.S. gal.]
Aftercooled Engines	12.9 liters [3.4 U.S. gal.]

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

Cylinder Block Coolant Pressure (Pressure Cap Removed):

Minimum	
Closed Thermostat - 1800 RPM - No Load	138 kPa [20 psi]
Maximum	
Closed Thermostat	275 kPa [40 psi]

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

Minimum Recommended Operating Coolant Temperature 71°C [160°F]

Maximum Allowable Deaeration Time 35 minutes

Minimum Recommended Pressure Cap 48 kPa [7 psi]

Maximum Allowable Coolant Flow to Accessories — (Liters/Min. [GPM]) 75.7 Liters [20 U.S. gal.]

Coolant Sensing Fan Control:

On	96°C [205°F]
Off	91°C [195°F]

Air Intake System

Maximum Intake Restriction

Clean Air Filter Element	254 mm H ₂ O [10.0 in H ₂ O]
Dirty Air Filter Element	635 mm H ₂ O [25.0 in H ₂ O]

Maximum Temperature Rise Between Ambient Air and Engine Inlet Air:
 (Ambient (Above 0° [32°F])

	17°C [30°F]
--	-------------

Maximum Allowable Pressure Drop From Turbocharger to Intake Manifold

	152 mm Hg [6 in Hg]
--	---------------------

Maximum Allowable Pressure Drop Across Charge Air Cooler

	152 mm Hg [6 in Hg]
--	---------------------

Exhaust System

Maximum Back Pressure From Piping and Silencer (Combined):

Without Catalyst

Hg	76 mm [3 in.]
H ₂ O	1016 mm [40 in.]

With Catalyst

Hg	152 mm [6 in.]
H ₂ O	2082 mm [82 in.]

Exhaust Pipe Size (Normally Acceptable Inside Diameter)

CELECT™ and CELECT™ Plus	127 mm [5 in.]
STC	102 mm [4 in.]

Electrical System

Minimum Recommended Battery Capacity

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

1. The number of plates within a given battery size determines reserve capacity. Reserve capacity determines the length of time which sustained cranking can occur.
2. CCA ratings are based on two 12 volt batteries in series.

A minimum of 6.5 volts at the 3-pin power connector is required to power-up the ECM on CELECT™ and CELECT™ Plus engines.

A minimum of 9 volts at the ECM connector is required to power-up the ECM on CENTRY engines.

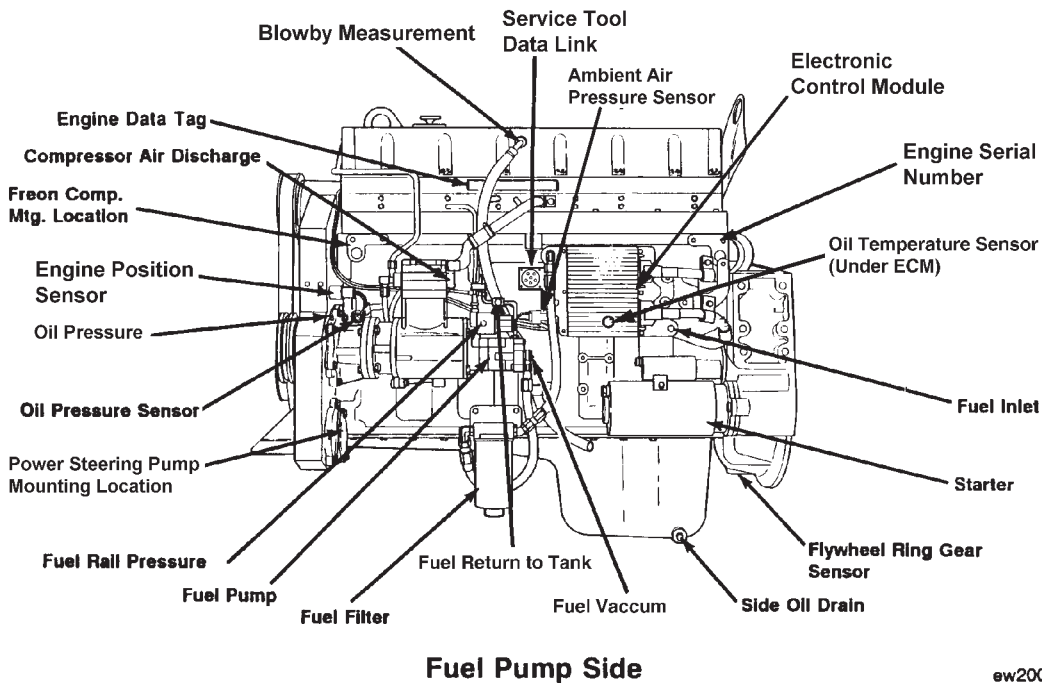
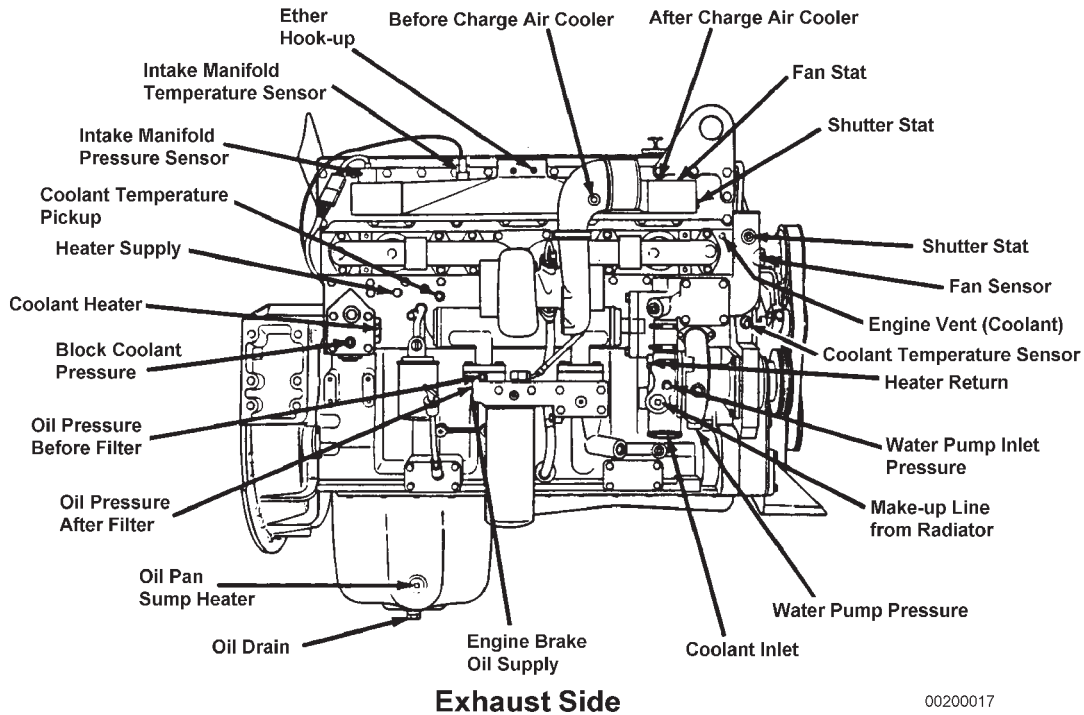
Batteries (Specific Gravity)

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

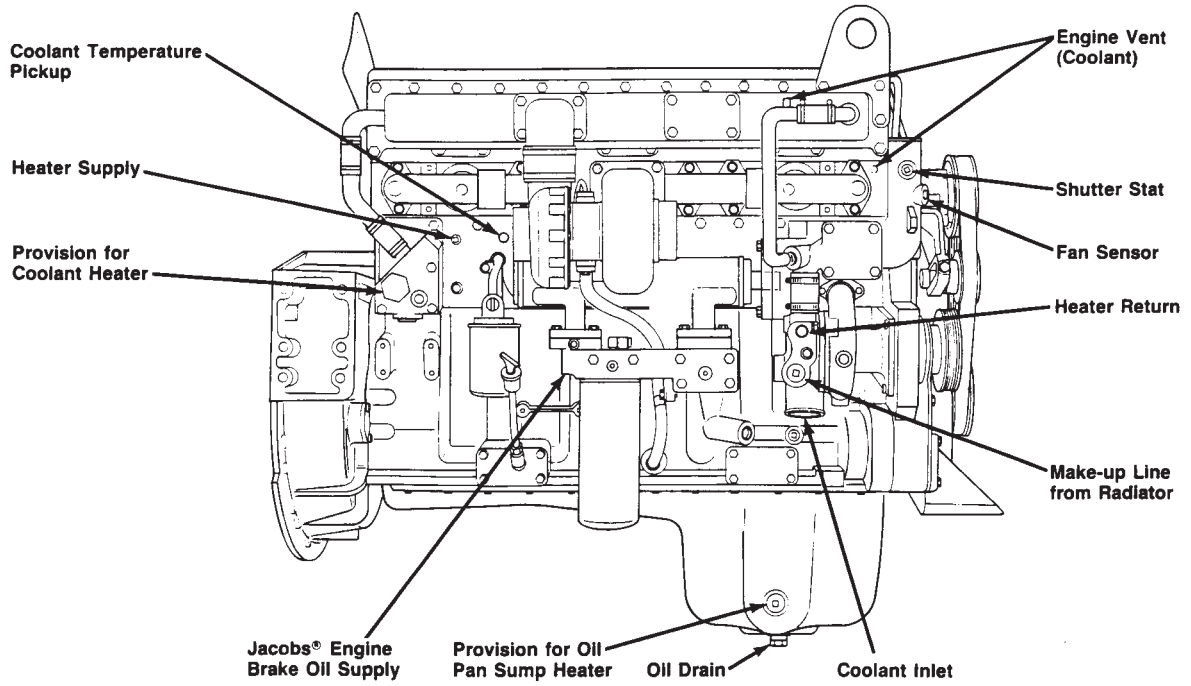
Engine Diagrams

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

CELECT™ and CELECT™ Plus Models

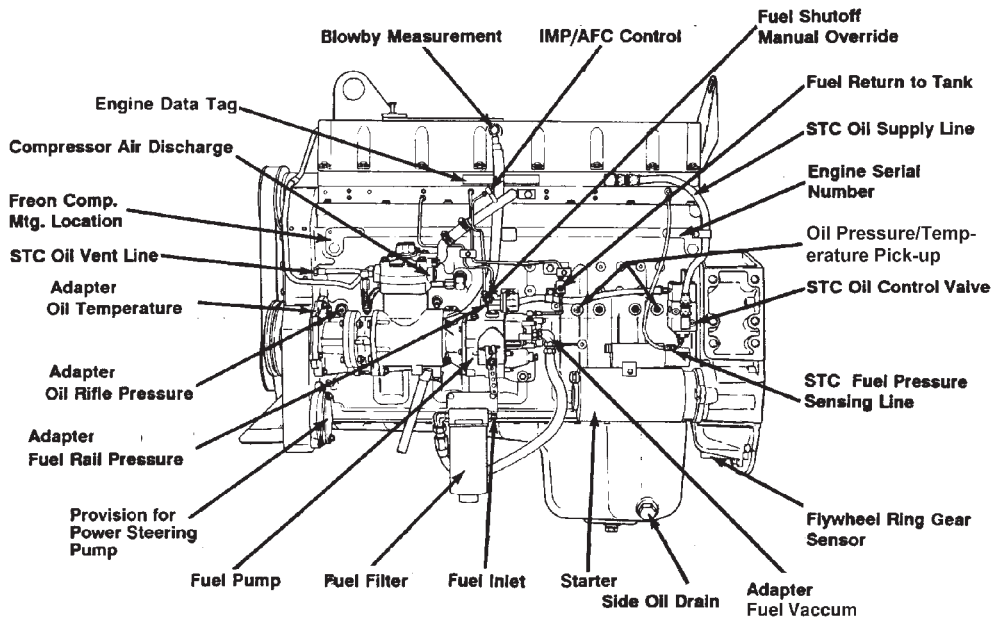


STC Industrial Model



Exhaust Side

00200002



STC Fuel Pump Side

ew200gg

Section TS - Troubleshooting Symptoms

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Procedures and Techniques

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

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

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

Follow these basic troubleshooting steps:

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

Troubleshooting Symptoms Charts

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

Air Compressor Air Pressure Rises Slowly

This is symptom tree T004.

Cause

Correction

Air intake system restriction to air compressor

Replace the air compressor air cleaner (if installed). Check the air intake piping. Check for air intake restriction. Refer to Procedure 010-031.

OK



Air system leaks

Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, and valves. Refer to Procedure 012-019 and the OEM service manuals.

OK



Air governor is malfunctioning or **not** set correctly

Check the air governor for correct operation. Refer to Procedure 012-017.

OK



Carbon buildup is excessive in the air discharge line, check valve, or cylinder head

Check for carbon buildup. Replace the air compressor discharge line if necessary. Refer to Procedure 012-003. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedures 010-040 and 010-049.

OK



E-Type system is **not** plumbed correctly

Install an Econ valve, check valve, and system hoses. Refer to the Master Repair Manual, Holset Air Compressors, Bulletin No. 3666121.

OK



Air system component is malfunctioning

Check the operation of the check valves, alcohol evaporators, air dryers, and other OEM installed air system components. Refer to the manufacturer's instructions.

OK



Unloader valve is malfunctioning

Check the unloader valve and unloader body seal. Refer to Procedure 012-013.

OK

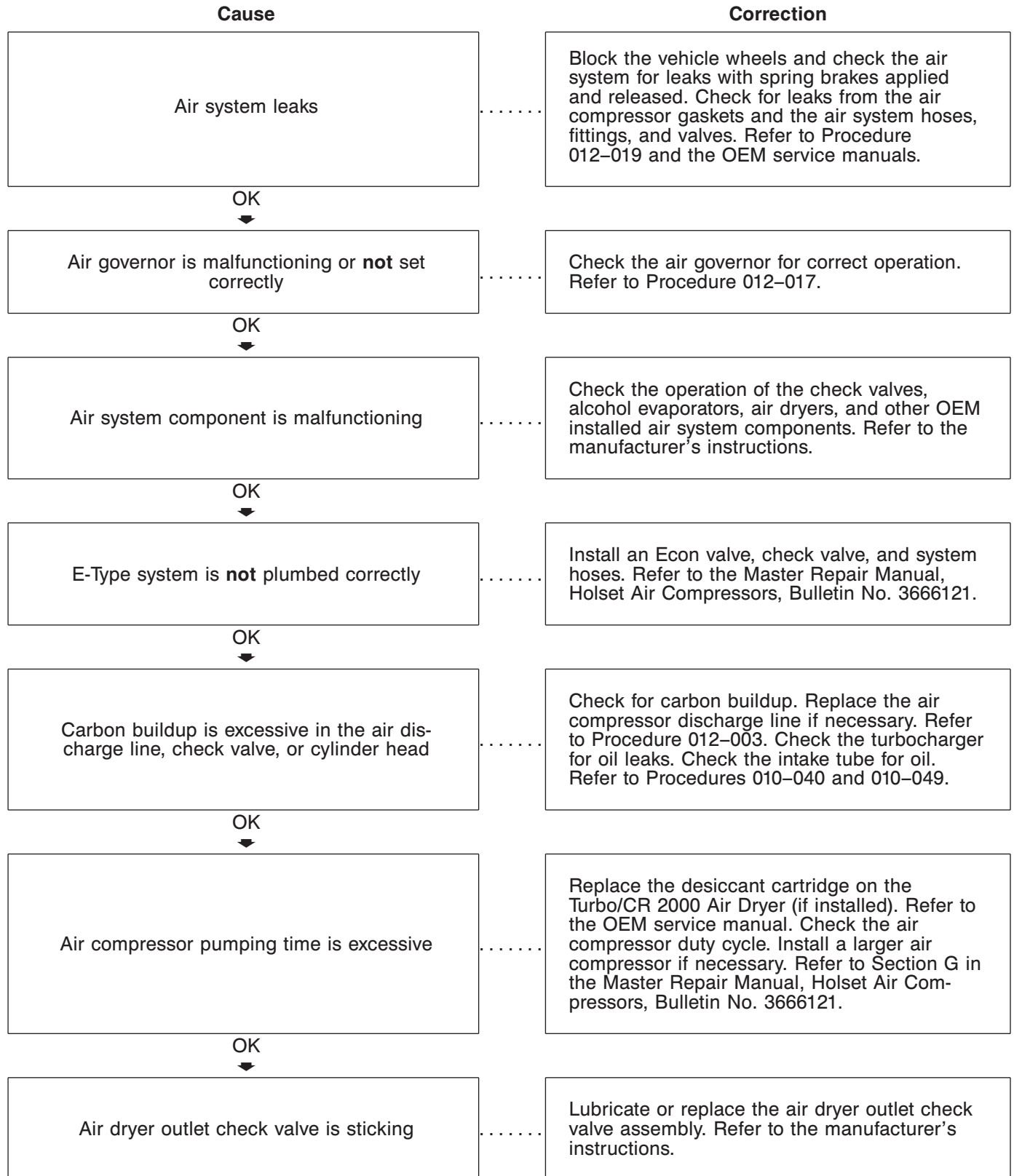


Air compressor intake or exhaust valve leaks air

Inspect the air compressor intake and exhaust valve assemblies. Refer to Procedure 012-103, 012-104, or 012-106.

Air Compressor Cycles Frequently

This is symptom tree T005.



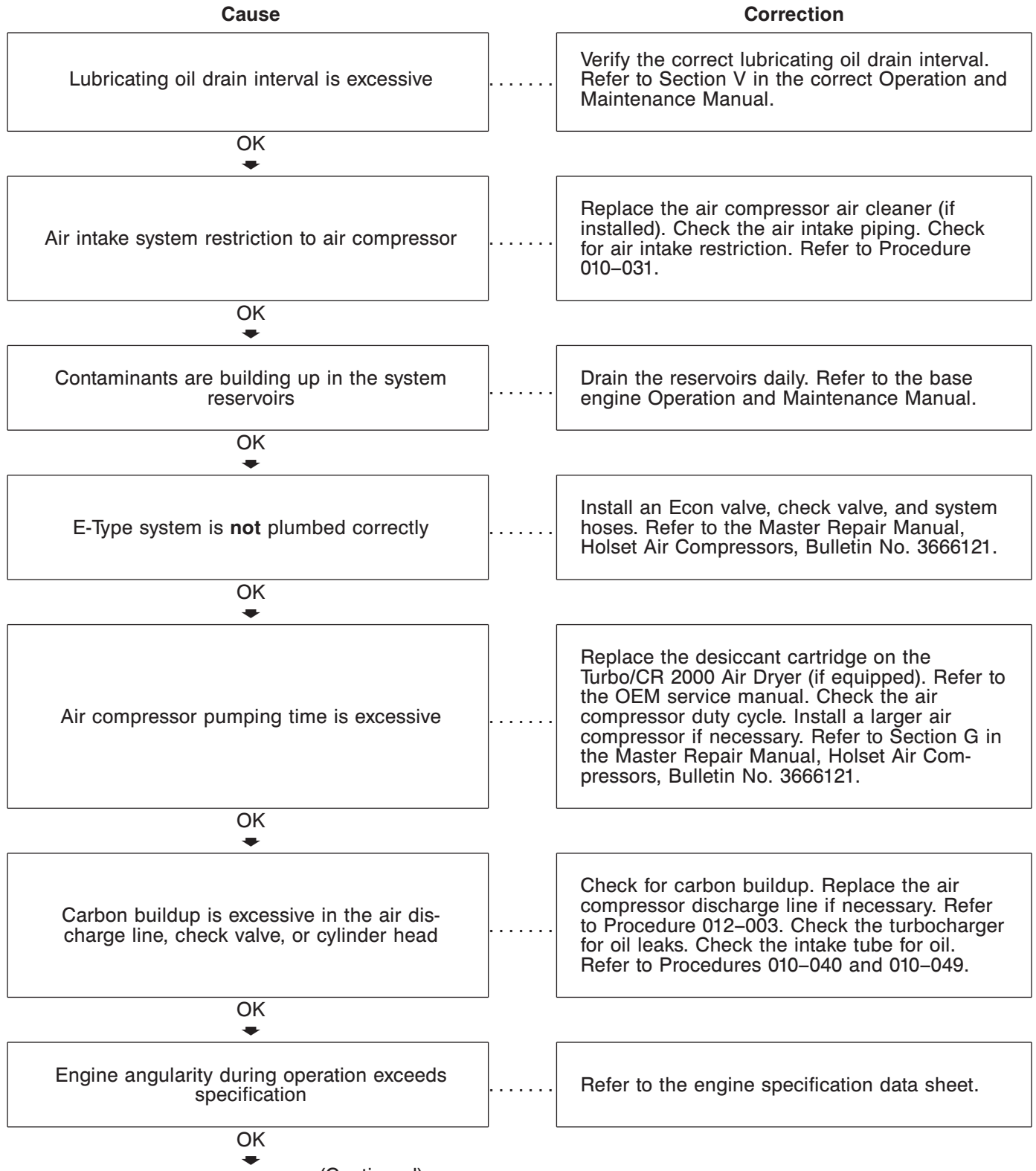
Air Compressor Noise is Excessive

This is symptom tree T006.

Cause	Correction
Carbon buildup is excessive in the air discharge line, check valve, or cylinder head	Check for carbon buildup. Replace the air compressor discharge line if necessary. Refer to Procedure 012-003. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedures 010-040 and 010-049.
OK ↓	
Air compressor is sending air pulses into the air tanks	Install a ping tank between the air dryer and the wet tank. Refer to the manufacturer's instructions.
OK ↓	
Accessory drive is worn (axial end play is out of specification)	Check the accessory drive axial end play. Visually inspect the shaft for wear. Refer to Procedure 009-001.
OK ↓	
Air compressor is excessively worn or internally damaged	Replace or rebuild the air compressor. Refer to Procedure 012-014. Replace the desiccant element on the Turbo/CR 2000 Air Dryer (if equipped). Refer to the manufacturer's instructions.
OK ↓	
Air compressor timing is not correct	Check the air compressor timing. Refer to Procedure 012-014.
OK ↓	
Air compressor drive gear or engine gear train is worn or damaged	Inspect the drive gears and the gear train and repair as necessary. Refer to Procedures 001-036, 001-039, and 001-040.
OK ↓	
Ice buildup in the air system components	Check for ice in low spots of the air discharge line and in the Econ valve, dryer inlet, and elbow fittings.
OK ↓	
Pin bore wear is excessive	Check for pin bore wear. Refer to Procedure 012-010.

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree T007.



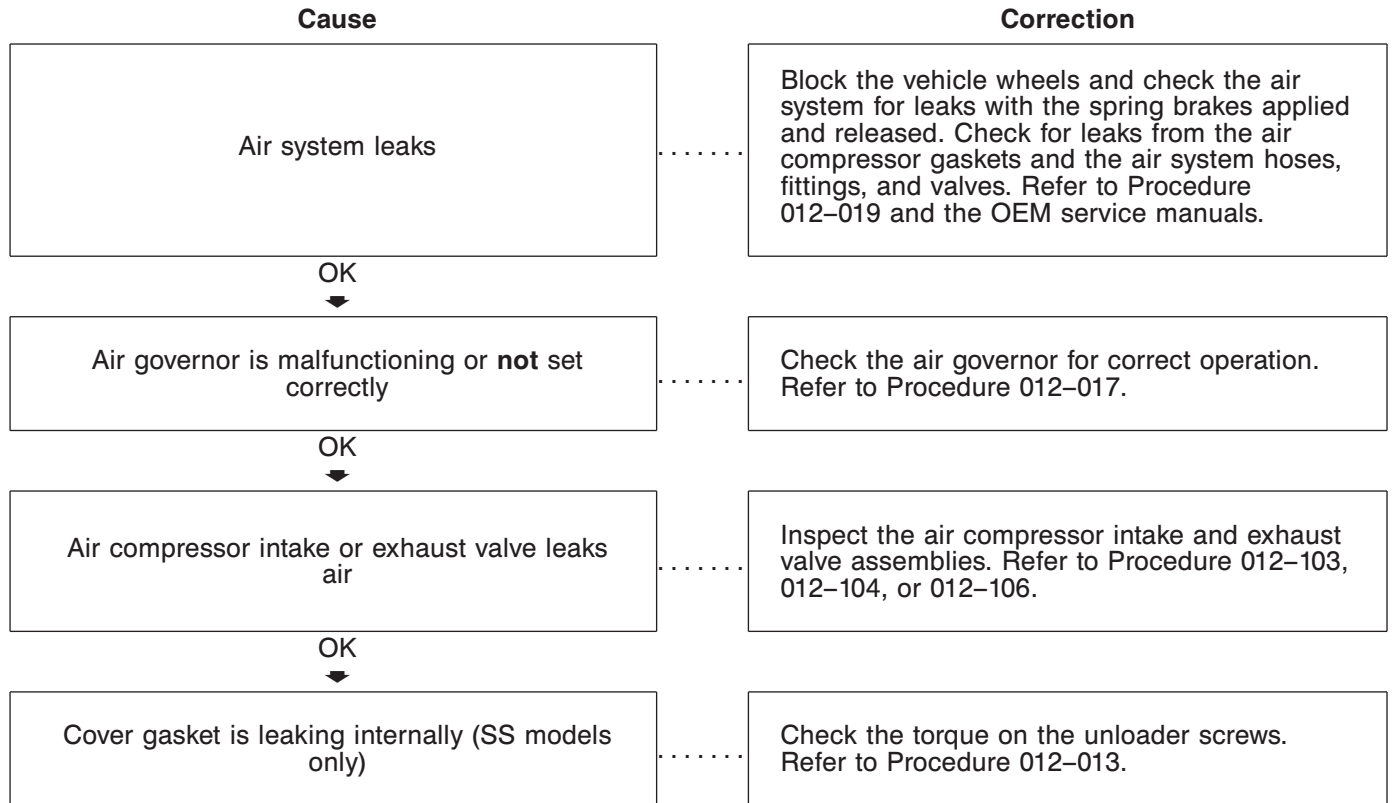
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Air Compressor Pumping Excess Lubricating Oil into the Air System (Continued)

Cause	Correction
Crankcase pressure is excessive	Check for excessive blowby. Refer to Section 14. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.
OK ↓	
Lubricating oil pressure is above specification	Check the oil pressure. Refer to Procedure 007-028.
OK ↓	
Air compressor runs hot	If coolant temperature is above normal, refer to the Coolant Temperature Above Normal — Gradual Overheat symptom tree.
OK ↓	
Lubricating oil drain line is restricted	Remove the air compressor and check the oil drain holes in the air compressor and the accessory drive. Refer to Procedure 012-014 or 012-015.
OK ↓	
Air compressor is excessively worn or internally damaged	Replace or rebuild the air compressor. Refer to Procedure 012-014. Replace the desiccant element on the Turbo/CR 2000 Air Dryer (if equipped). Refer to the manufacturer's instructions.

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

This is symptom tree T008.



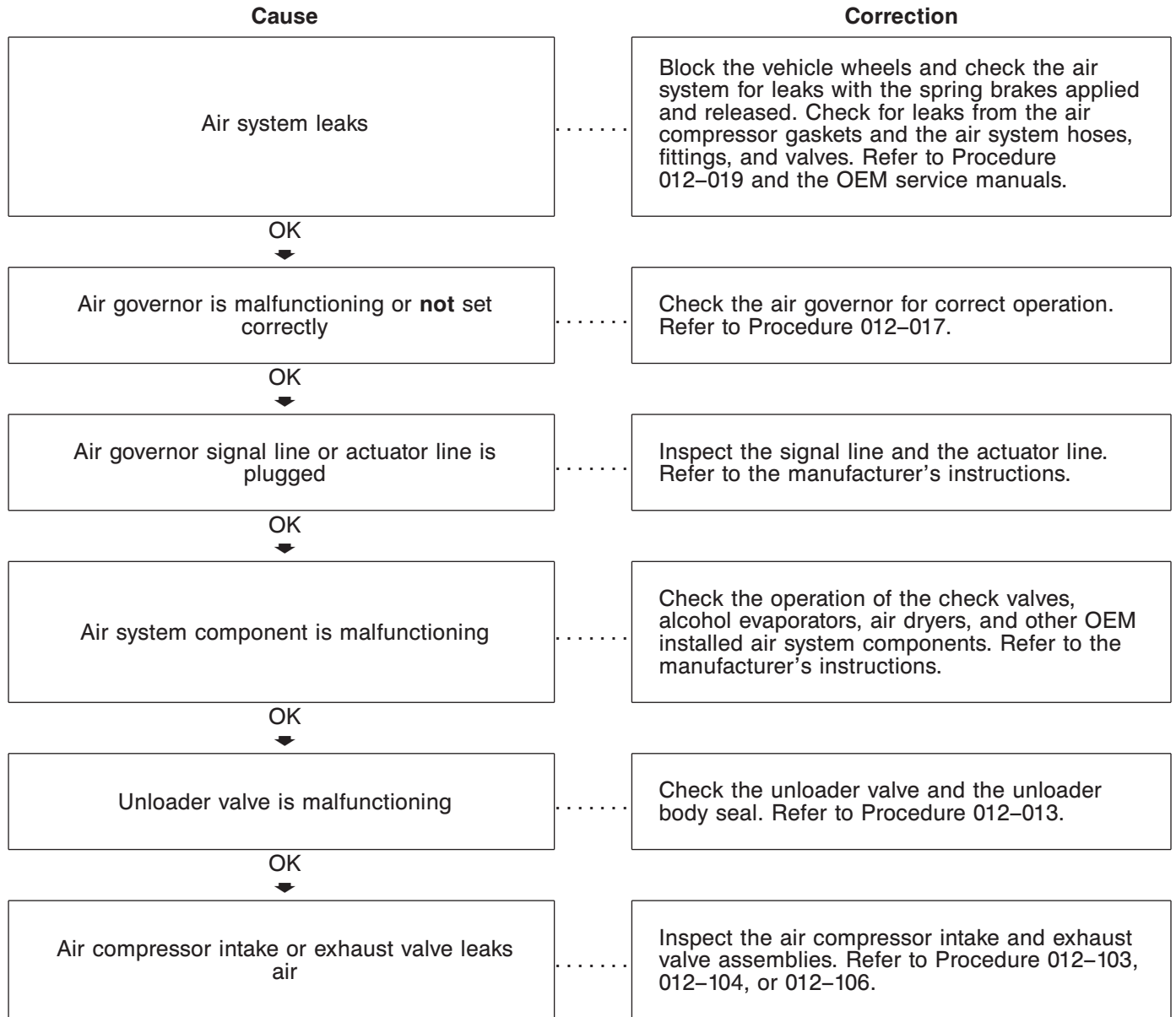
Air Compressor Will Not Pump Air

This is symptom tree T009.

Cause	Correction
Air governor is malfunctioning or not set correctly	Check the air governor for correct operation. Refer to Procedure 012-017.
OK ↓	
Unloader valve is malfunctioning	Check the unloader valve and the unloader body seal. Refer to Procedure 012-013.
OK ↓	
Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to Procedure 012-103, 012-104, or 012-106.
OK ↓	
Air compressor is excessively worn or internally damaged	Replace or rebuild the air compressor. Refer to Procedure 012-014. Replace the desiccant element on the Turbo/CR 2000 Air Dryer (if equipped). Refer to the manufacturer's instructions.
OK ↓	
Cover gasket is ruptured (SS models only)	Check the discharge line for blockage. Refer to Procedure 012-003. Check the cover gasket for flatness. Replace the cover gasket if necessary. Refer to Procedure 012-103, 012-104, or 012-106.

Air Compressor Will Not Stop Pumping

This is symptom tree T010.



Alternator Not Charging or Insufficient Charging

This is symptom tree T013.

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

(Continued)

Alternator Not Charging or Insufficient Charging (Continued)

Cause

Correction

Battery temperature is above specification

Position batteries away from heat sources.
Refer to the OEM service manual.

Alternator Overcharging

This is symptom tree T014.

Cause

Correction

Voltage regulator is malfunctioning

Check the voltage regulator. Replace the voltage regulator if necessary. Refer to the OEM service manual.

OK

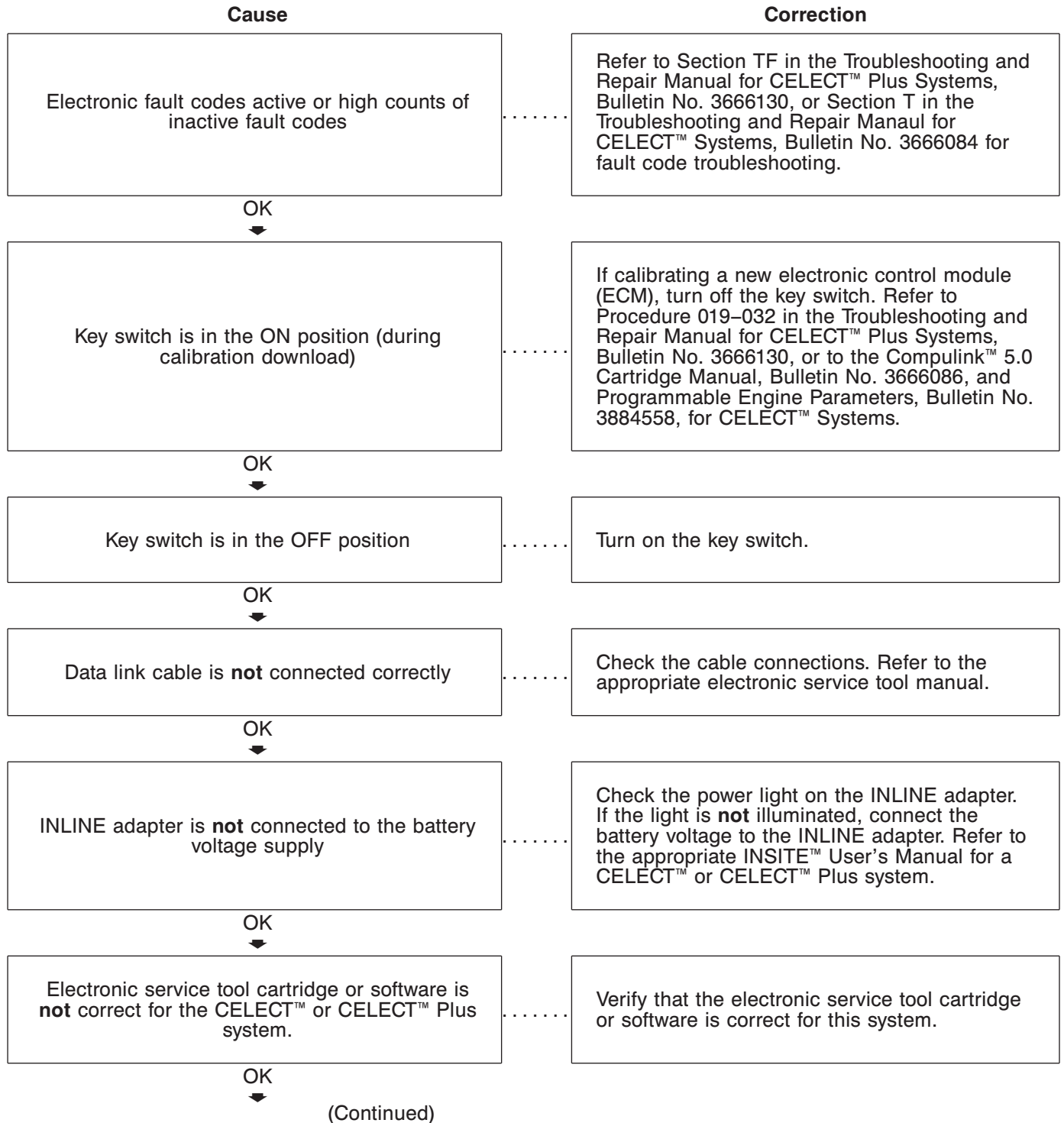


Battery cell is damaged (open circuit)

Check the condition of the batteries. Replace the batteries if necessary. Refer to the OEM service manual.

Communication Error — Electronic Service Tool or Control Device

This is symptom tree T016.



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

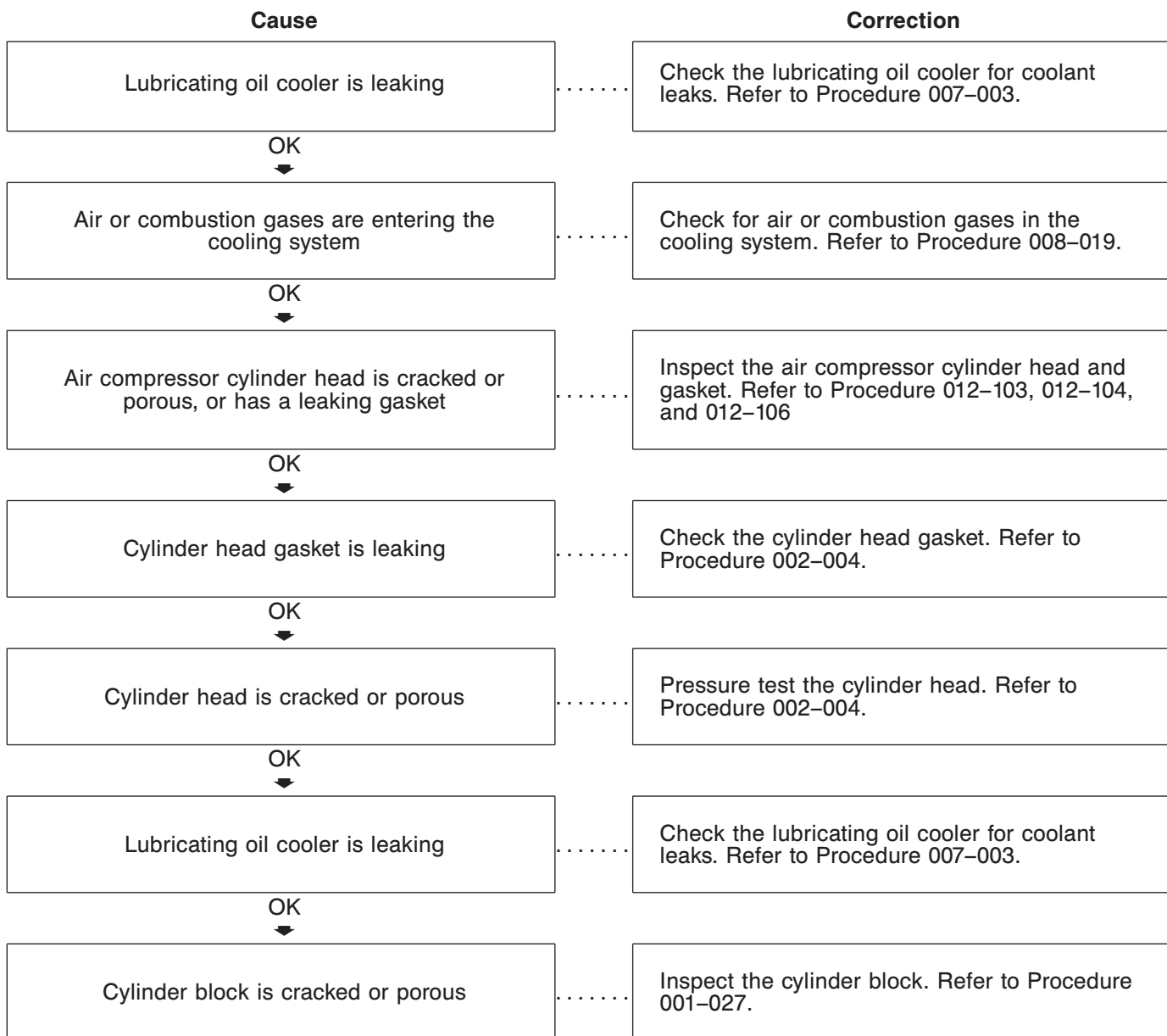
Cause	Correction
Electronic control module (ECM) is not calibrated	Calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or to the Compulink™ 5.0 Cartridge Manual, Bulletin No. 3666086, and Programmable Engine Parameters, Bulletin No. 3884558, for CELECT™ Systems.
OK ↓	
Moisture in the wiring harness connectors	Dry the connectors with Cummins electronic cleaner, Part No. 3824510.
OK ↓	
Key switch circuit is malfunctioning	Check the vehicle key switch circuit. Refer to Procedure 019-064 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 2-05 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Battery voltage supply to the electronic control module (ECM) has been lost	Check the battery connections. Refer to Procedure 013-009 in the base engine Troubleshooting and Repair Manual. Check the fuses and the unswitched battery supply circuit. Refer to Procedures 019-198 and 019-087 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedures 2-03 and 2-04 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Electronic control module (ECM) is not grounded correctly	Check the ECM for correct placement of the star washers. Refer to Procedure 019-031 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 4-01 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Electronic service tool is malfunctioning	Check the electronic service tool. Refer to the appropriate electronic service tool manual.
OK ↓	
(Continued)	

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

Cause	Correction
Monitor devices are connected to the data link	Turn off or disconnect the monitor devices while using the electronic service tool.
OK ↓	
Data link circuit is malfunctioning	Check the data link circuit. Refer to Procedure 019–026 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 1–05 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Data link is locked up	Turn off the key switch and the electronic service tool and disconnect the battery cables for at least 5 seconds. Connect the battery cables and turn on the key switch and the electronic service tool to establish communication.
OK ↓	
Electronic control module (ECM) is malfunctioning	Replace the ECM. Refer to Procedure 019–031 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 4–01 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

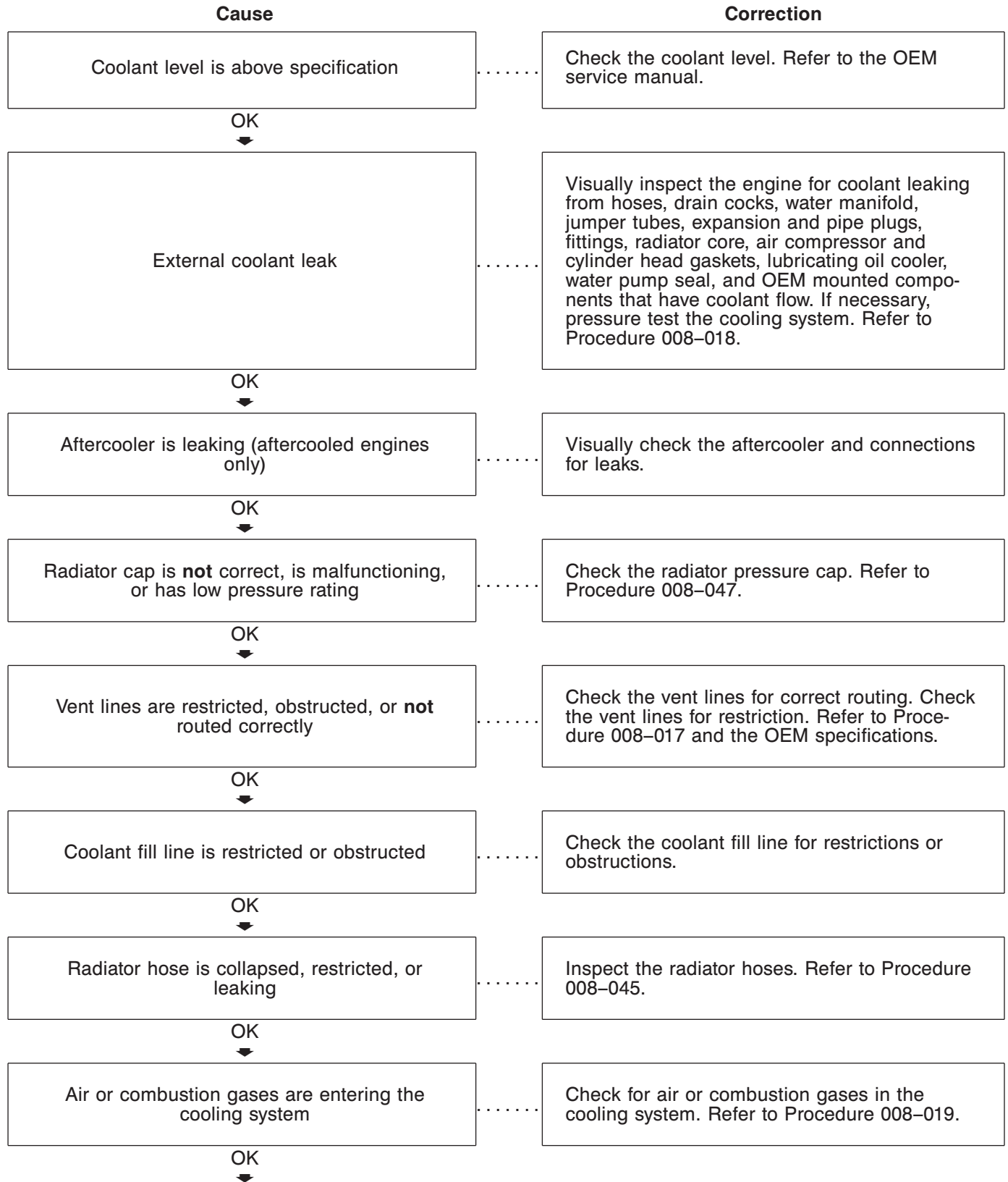
Coolant in the Lubricating Oil

This is symptom tree T025.



Coolant Loss (External)

This is symptom tree T020.



(Continued)

Coolant Loss (External) (Continued)

Cause

Correction

Engine is overheating

Refer to the Coolant Temperature Above Normal symptom tree.

Coolant Loss — Internal

This is symptom tree T021.

Cause	Correction
Air compressor cylinder head is cracked or porous, or has a leaking gasket OK ↓	Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-103, 012-104, or 012-106.
Lubricating oil cooler is leaking OK ↓	Check the lubricating oil cooler for coolant leaks. Refer to Procedure 007-003.
Aftercooler is leaking (aftercooled engines only) OK ↓	Remove and pressure test the aftercooler. Refer to Procedure 010-001.
Air or combustion gases are entering the cooling system OK ↓	Check for air or combustion gases in the cooling system. Refer to Procedure 008-019.
Cylinder head gasket is leaking OK ↓	Check the cylinder head gasket. Refer to Procedure 002-004.
Cylinder head is cracked or porous or an injector sleeve is leaking OK ↓	Pressure test the cylinder head and inspect the injector sleeves. Refer to Procedure 002-004.
Fuel heater is malfunctioning (if equipped) OK ↓	Check the fuel heater and replace if necessary. Refer to the manufacturer's instructions.
Transmission cooler or torque converter cooler is leaking OK ↓	Check the transmission cooler and torque converter cooler for coolant leaks. Refer to the manufacturer's instructions.
Cylinder liner is corroded or cracked, or the cylinder block is cracked or porous	Remove the oil pan. Pressure test the cooling system to check for leaks. Refer to Procedure 001-027.

Coolant Temperature Above Normal — Gradual Overheat

This is symptom tree T022.

Cause

Correction

Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.

OK



Cold weather radiator cover or winterfront is closed

Open the cold weather radiator cover or the winterfront. Maintain a minimum of 775 cm² [120 in²] or approximately 28 cm x 28 cm [11 in x 11 in] of opening at all times.

OK



Coolant level is below specification

Inspect the engine and radiator for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedure 008-018.

OK



Charge air cooler (CAC) fins, radiator fins, or freon condenser fins are damaged or obstructed with debris

Inspect the CAC, freon condenser, and radiator fins. Clean if necessary. Refer to Procedures 010-027 and 008-042.

OK



Radiator hose is collapsed, restricted, or leaking

Inspect the radiator hoses. Refer to Procedure 008-045.

OK



Fan drive belt is loose

Check the belt tension and tighten if necessary. Refer to Procedure 008-002.

OK



Lubricating oil level is above or below specification

Check the oil level. Add or drain oil if necessary. Refer to Procedure 007-043. Check the dipstick calibration. Refer to Procedure 007-009.

OK



Fan shroud is damaged or missing, or the air recirculation baffles are damaged or missing

Inspect the shroud and the recirculation baffles. Repair, replace, or install if necessary. Refer to Procedures 008-038 and 008-048 and the OEM service manual.

OK



(Continued)

Coolant Temperature Above Normal — Gradual Overheat (Continued)

Cause	Correction
Radiator cap is not correct, is malfunctioning, or has low pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047.
OK ↓	
Supplemental coolant additive (SCA) level is above specification or the coolant is overconcentrated with antifreeze	Check the SCA level. Verify the antifreeze concentration. Refer to Cooling System Specifications in Section 8.
OK ↓	
Vent lines are restricted, obstructed, or not routed correctly	Check the vent lines for correct routing. Check the vent lines for restriction. Refer to Procedure 008-017 and the OEM specifications.
OK ↓	
Intake manifold air temperature is above specification	Refer to the Intake Manifold Air Temperature Above Specification symptom tree.
OK ↓	
Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge if necessary. Refer to Procedure 008-004 and the OEM service manual.
OK ↓	
Radiator shutters are not opening completely or the shutterstat setting is wrong	Inspect the radiator shutters. Repair or replace if necessary. Refer to the manufacturer's instructions. Check the shutterstat setting. Refer to Procedure 008-049.
OK ↓	
Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-024, 008-025, 008-026, 008-027, or 008-028.
OK ↓	
Thermostat is not correct or is malfunctioning	Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013.
OK ↓	

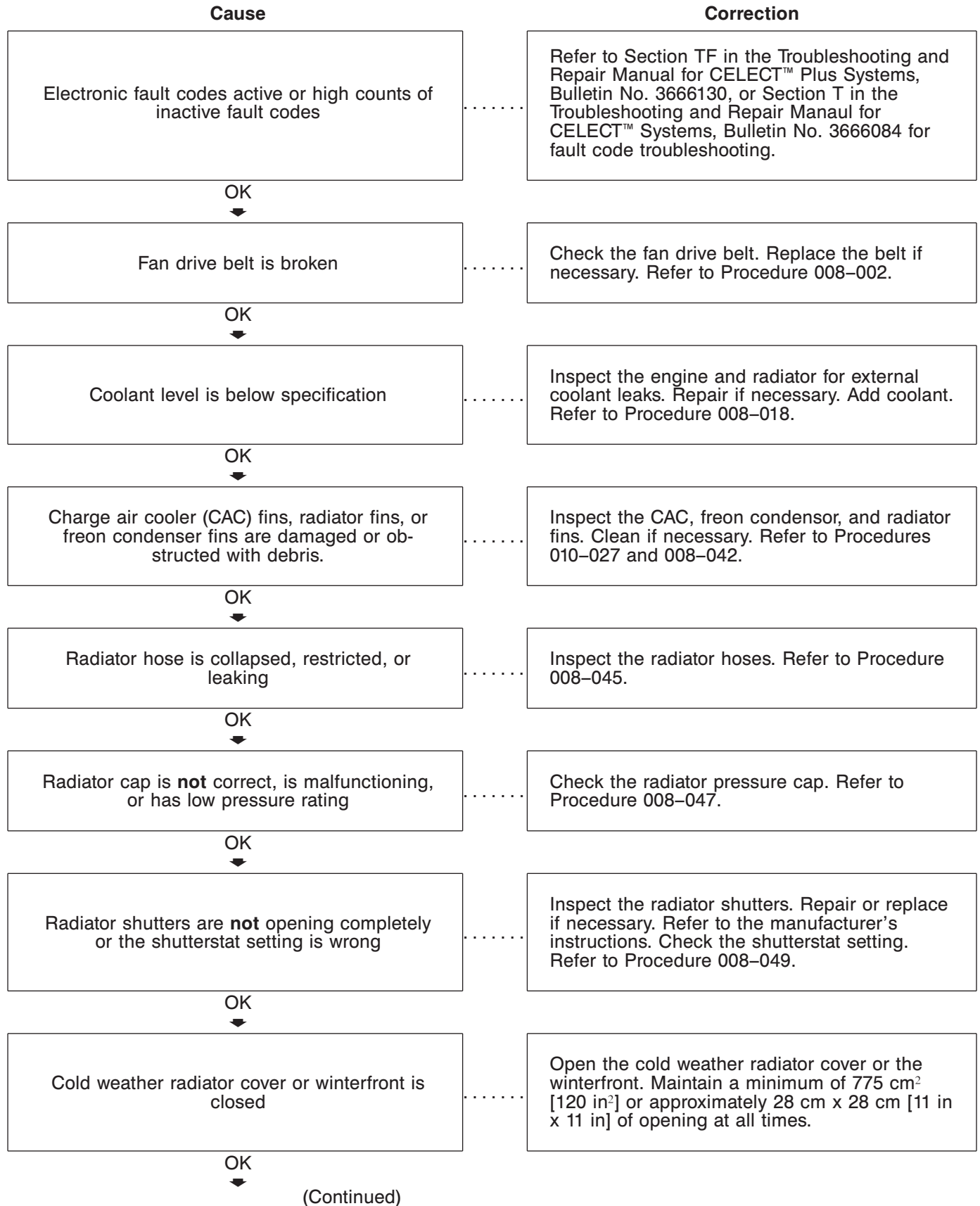
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Coolant Temperature Above Normal — Gradual Overheat (Continued)

Cause	Correction
Air or combustion gases are entering the cooling system	Check for air or combustion gases in the cooling system. Refer to Procedure 008-019.
OK ↓	
Cooling system component is malfunctioning	Perform the Cooling System Diagnostics Test. Refer to Procedure 008-020.
OK ↓	
Water pump is malfunctioning	Check the water pump using the diagnostic test in Procedure 008-020. Replace the water pump if necessary. Refer to Procedure 008-062.
OK ↓	
Radiator core is internally obstructed or damaged, or the check valve or J-tube is malfunctioning	Inspect the radiator and clean if necessary.
OK ↓	
Check valve is damaged (with remote mount engine coolant heater)	Check the check valve. Replace if necessary. Refer to the manufacturer's instructions.
OK ↓	
Engine is overfueled	Check the engine fuel rate. Refer to Engine Testing General Information in Section 14.
OK ↓	
Torque converter is malfunctioning	Check the torque converter. Refer to the OEM service manual.
OK ↓	
Vehicle cooling system is not adequate	Verify that the engine and vehicle cooling systems are using the correct components. Refer to the OEM specifications.

Coolant Temperature is Above Normal — Sudden Overheat

This is symptom tree T023.



Coolant Temperature is Above Normal — Sudden Overheat (Continued)

Cause

Correction

Vent lines or fill line are restricted, obstructed, or **not** routed correctly

Check the vent lines and the fill line for correct routing. Check the vent lines for restriction. Refer to Procedure 008-017 and the OEM specifications.

OK



Fan drive or fan controls are malfunctioning

Check the fan drive and controls. Refer to Procedure 008-024, 008-025, 008-026, 008-027, or 008-028.

OK



Air or combustion gases are entering the cooling system

Check for air or combustion gases in the cooling system. Refer to Procedure 008-019.

OK



Torque converter cooler disc is **not** installed correctly

Check the disc for correct installation. Refer to Procedure 008-062.

OK



Cooling system component is malfunctioning

Perform the Cooling System Diagnostics Test. Refer to Procedure 008-020.

OK



Thermostat is **not** correct or is malfunctioning

Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013.

OK



Water pump is malfunctioning

Check the water pump using the diagnostic test in Procedure 008-020. Replace the water pump if necessary. Refer to Procedure 008-062.

Coolant Temperature is Below Normal

This is symptom tree T024.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.
OK ↓	
Engine is operating at low ambient temperature	Check the winterfront, shutters, and under hood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual for your application. Use intake air from under the hood in cold weather.
OK ↓	
Coolant fill line is not routed correctly	Check the routing of the coolant fill line. Refer to the OEM service manual.
OK ↓	
Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge if necessary. Refer to Procedure 008-004 and the OEM service manual.
OK ↓	
Coolant temperature sensor is malfunctioning	Check the coolant temperature sensor. Refer to Procedure 019-019.
OK ↓	
Radiator shutters are stuck open or opening early	Check the shutter operation. Repair or replace the shutters if necessary. Refer to the OEM service manual and Procedure 008-049.
OK ↓	
Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-024, 008-025, 008-026, 008-027, or 008-028.
OK ↓	
Cooling system component is malfunctioning	Perform the Cooling System Diagnostics Test. Refer to Procedure 008-020.
OK ↓	

(Continued)

Coolant Temperature is Below Normal (Continued)

Cause

Correction

Thermostat is **not** correct or is malfunctioning

Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013.

OK
↓

Thermostat seal is damaged, missing, or **not** installed correctly

Check the thermostat seal. Check the thermostat for correct seating. Refer to Procedure 008-016.

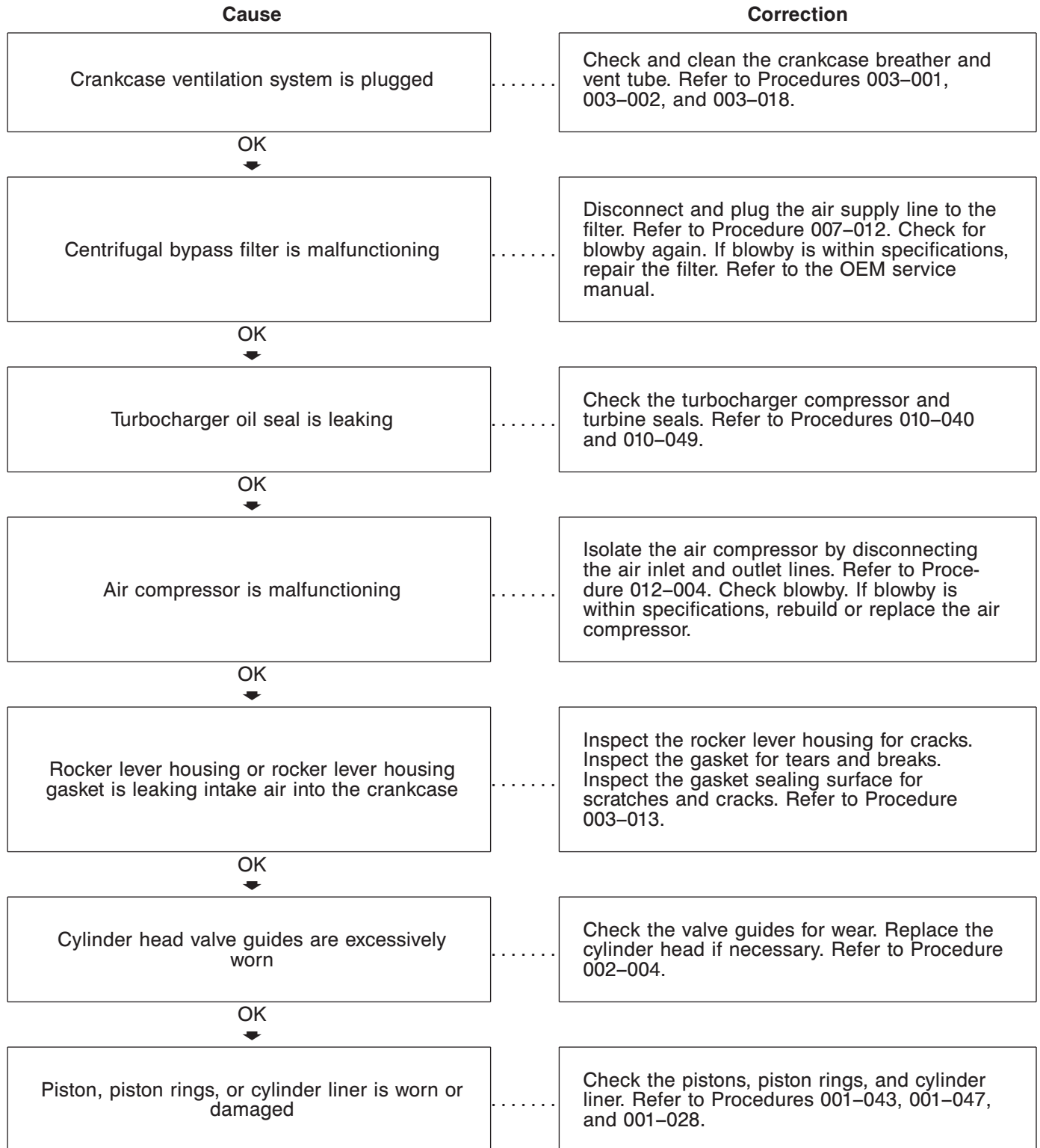
OK
↓

Coolant flow through the radiator is **not** correct

Check for correct coolant flow through the radiator. Refer to Procedure 008-042.

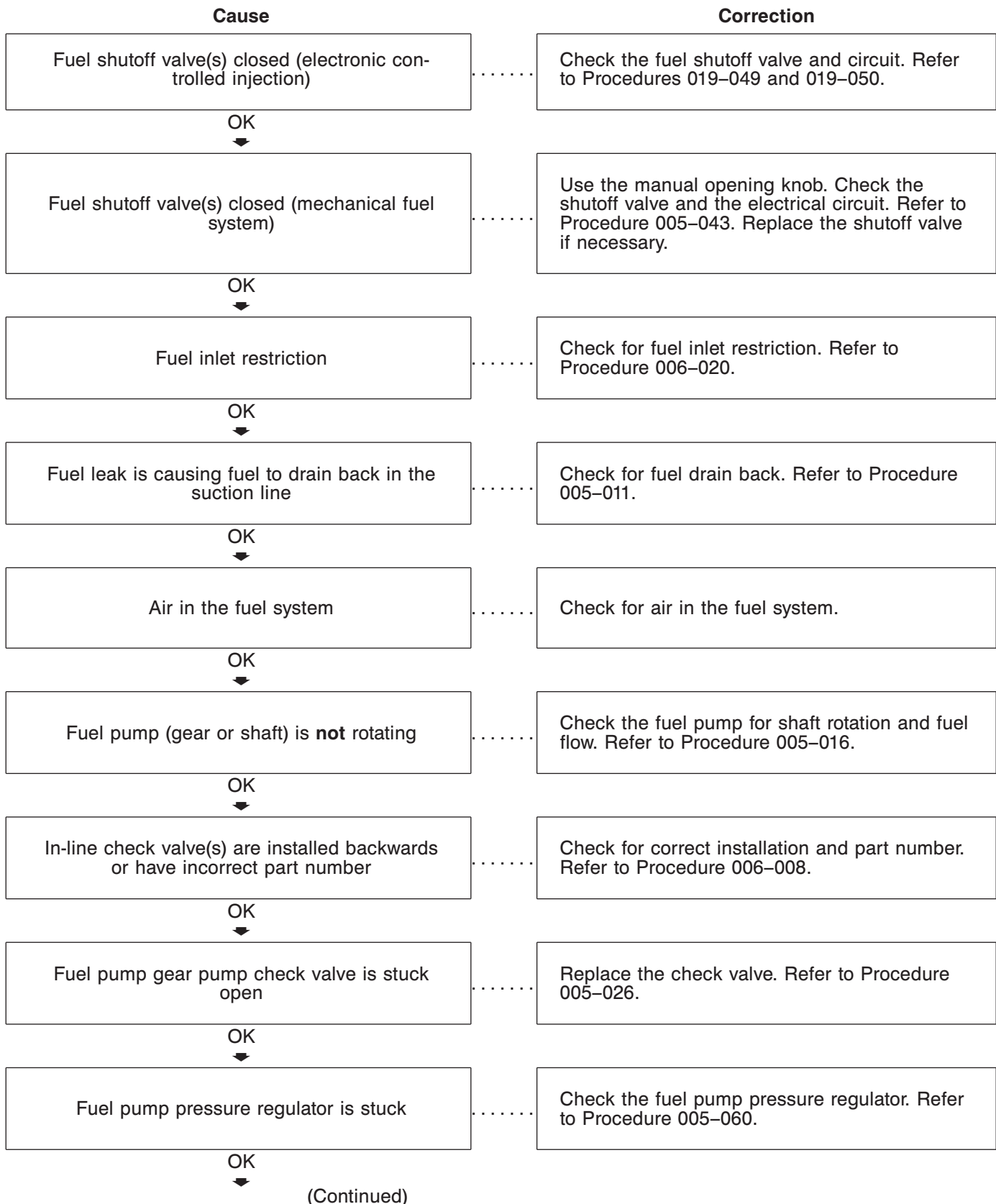
Crankcase Gases (Blowby) Excessive

This is symptom tree T027.



Cranking Fuel Pressure is Low

This is symptom tree T029.



Cranking Fuel Pressure is Low (Continued)

Cause

Injector o-rings are damaged or missing

Correction

Remove and check the injectors. Replace the injector o-rings. Refer to Procedure 006-026.

Engine Acceleration or Response Poor

This is symptom tree T033.

Cause

Correction

Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.

OK



Verify the complaint

Test the engine operation while under load. Perform an engine acceleration test. Perform an engine load test. Observe the percent load with an electronic service tool. Refer to the Driveability/Low Power form.

OK



Perform a throttle response test (if applicable)

Perform a throttle response test. Refer to Procedure 005-055.

OK



Perform a stall speed test (if applicable)

Perform a stall speed test. Refer to Procedure 005-054.

OK



Throttle position sensor or circuit is malfunctioning

Check for foot pedal restriction. Check the throttle position sensor and circuit. Refer to Procedures 019-085 and 019-086 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 1-09 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Programmable parameters or selected features are **not** correct

Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again if necessary. Refer to the appropriate electronic service tool manual.

OK



(Continued)

Engine Acceleration or Response Poor (Continued)

Cause	Correction
Engine protection fault code(s) inactive	View the fault codes and the engine protection data with an electronic service tool. Refer to the appropriate electronic service tool manual. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Electronic control module (ECM) calibration is not correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 4-01 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020.
OK ↓	
Fuel drain line restriction	Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012.
OK ↓	
Intake manifold pressure (boost) sensor or circuit is malfunctioning	Check the boost sensor and circuit. Refer to Procedures 019-061 and 019-062 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3-04 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
(Continued)	

Engine Acceleration or Response Poor (Continued)

Cause

Correction

Coolant temperature sensor is malfunctioning

Check the coolant temperature sensor. Refer to Procedure 019–019 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3–09 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Intake manifold temperature sensor is malfunctioning

Check the intake manifold temperature sensor. Refer to Procedure 019–059 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3–10 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Ambient air pressure sensor is malfunctioning (if equipped)

Check the ambient air pressure sensor. Refer to Procedure 019–004 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3–05 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Throttle pedal is restricted or malfunctioning

Check the percent throttle reading on an electronic service tool. Verify that it reads 100 percent with the throttle pedal depressed. Replace the throttle pedal if necessary. Refer to the OEM service manual.

OK



Throttle linkage adjustment is **not** correct

Check the fuel pump throttle linkage adjustment. Refer to Procedure 005–036.

OK



Engine is operating at low ambient temperature

Check the winterfront, shutters, and under hood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual for your application. Use intake air from under the hood in cold weather.

OK



Air intake system restriction

Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010–031.

OK



(Continued)

Engine Acceleration or Response Poor (Continued)

Cause	Correction
Exhaust system restriction	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ↓	
Air intake or exhaust leaks	Visually inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ↓	
Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK ↓	
Vehicle parasitics are excessive	Check the vehicle brakes for dragging, transmission malfunction, cooling fan operation cycle time, and engine driven units. Refer to the OEM service manuals.
OK ↓	
Fuel temperature is above specification	Fill the fuel tanks. Turn off or bypass the fuel heater, if equipped.
OK ↓	
Fuel grade is not correct for the application or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual for your application.
OK ↓	
Drive train is not correctly matched to the engine	Check for correct gearing and drive train components. Refer to the OEM vehicle specifications.
OK ↓	
Intake manifold pressure (boost) is below specification	Refer to the Intake Manifold Pressure (Boost) is Below Normal symptom tree.
OK ↓	

(Continued)

Engine Acceleration or Response Poor (Continued)

Cause

Correction

Fuel supply line restriction between the fuel pump and the injectors

Check the fuel supply line from the fuel pump to the cylinder head for sharp bends which can cause restrictions. Refer to Procedure 005-024.

OK



Engine is operating above recommended altitude (STC engines only)

Derate the engine by 4 percent for every 300 meters [1000 feet] of altitude above 3600 m [12,000 feet]. Refer to the Engine Data Sheet.

OK



Engine is operating at high ambient temperature

Use outside air to the turbocharger in hot weather.

OK



PT fuel pump AFC operation is malfunctioning or pump is **not** calibrated correctly

Remove the PT fuel pump and check the calibration. Check the AFC for proper operation. Refer to Procedure 005-016 and the PT Fuel Pump Rebuild and Calibration Manual, Bulletin No. 3379084.

OK

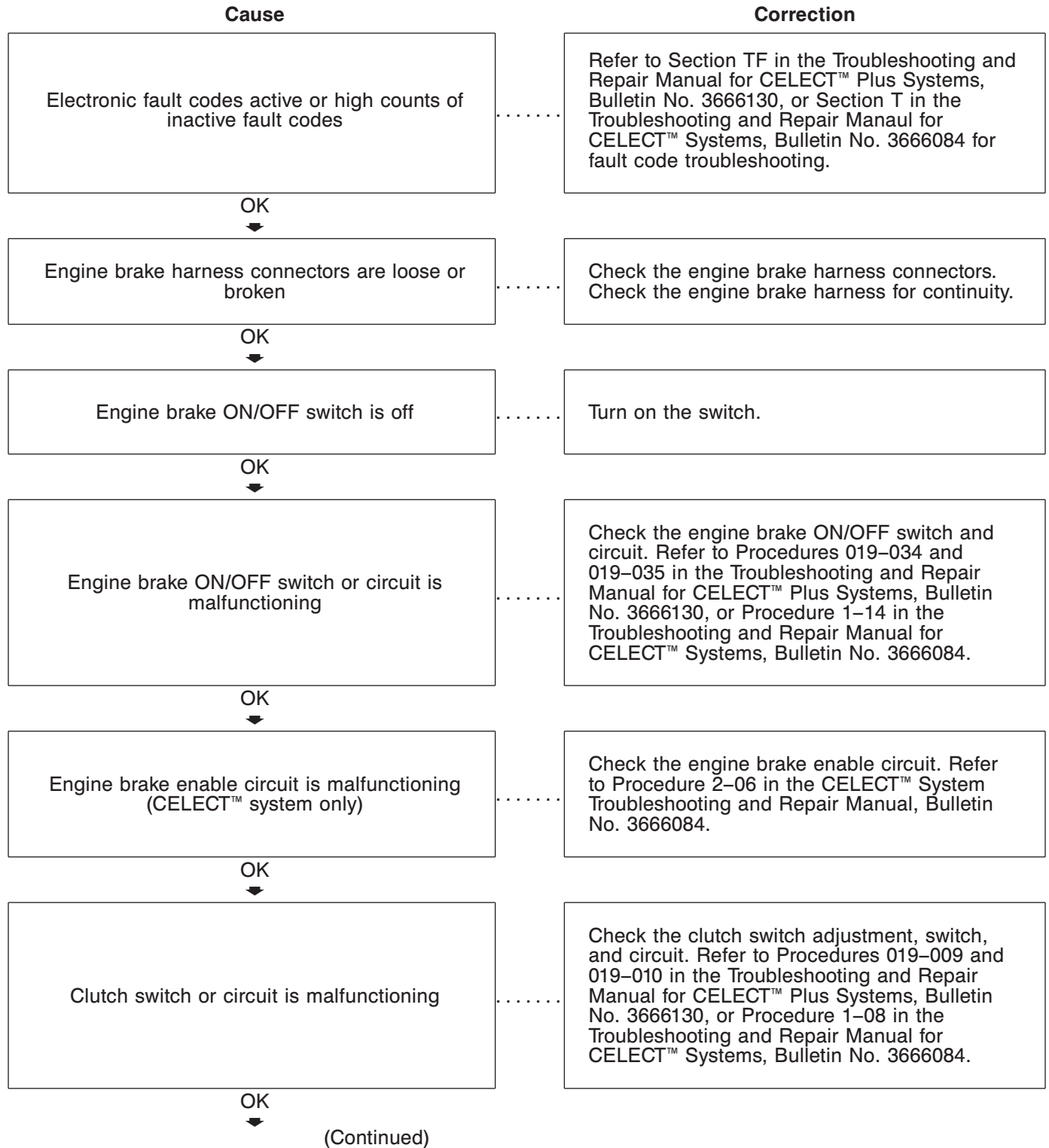


Injector calibration is **not** correct or the fuel supply to the injector is restricted (PT injectors)

Remove the injectors. Check the injectors for the correct calibration. Check the inlet screen for restriction. Check for carbon buildup on the plungers. Refer to Procedure 006-026 and the Injector Specifications Manual, Bulletin No. 3379664.

Engine Brake Does Not Operate (CELECT™ or CELECT™ Plus)

This is symptom tree T036-155.

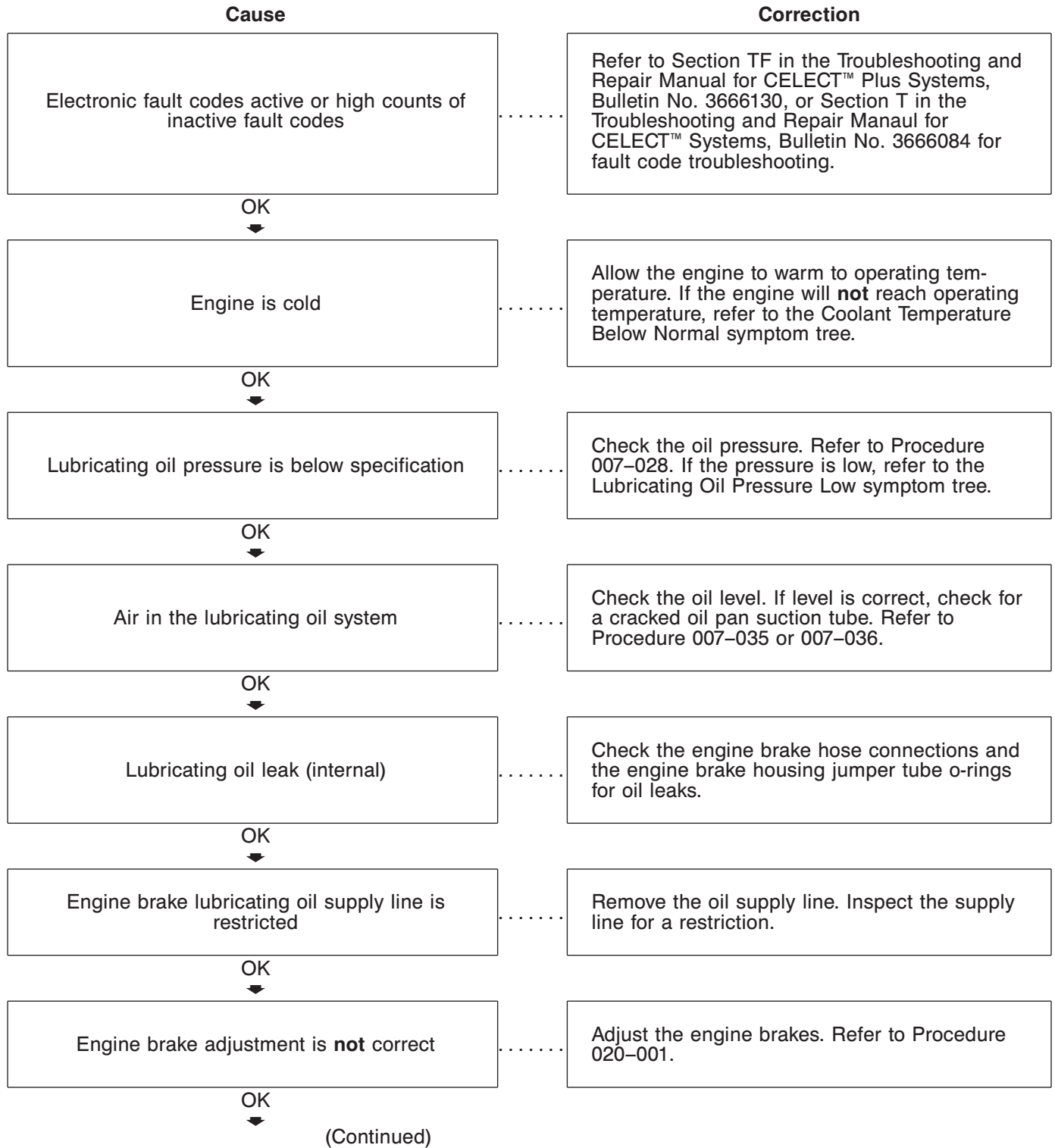


Engine Brake Does Not Operate (CELECT™ or CELECT™ Plus) (Continued)

Cause	Correction
Throttle position sensor or circuit is malfunctioning	Check for foot pedal restriction. Check the throttle position sensor and circuit. Refer to Procedures 019-085 and 019-086 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 1-09 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK	
Service brake pressure switch or circuit is malfunctioning	Check the service brake pressure switch and circuit. Refer to the OEM service manual.
OK	
Engine electrical ground is malfunctioning	Check engine ground to chassis and chassis ground to battery negative post. Refer to the OEM service manuals and Procedure 013-009.
OK	
Solenoid valve is malfunctioning	Check for voltage at the solenoid valve.
OK	
Solenoid valve filter screen is covered with debris	Remove the solenoid valve and clean or replace the screen.
OK	
Lubricating oil leak (internal)	Check the engine brake hose connections and the jumper tube o-rings for oil leaks.
OK	
Engine brake lubricating oil line is plugged	Remove the oil supply line. Inspect the supply line for a blockage.
OK	
Engine brake adjustment is not correct	Adjust the engine brakes. Refer to Procedure 020-001.

Engine Brake — Low Retarding Power or Slow to Activate (CELECT™ or CELECT™ Plus)

This is symptom tree T037-155.



**Engine Brake — Low Retarding Power or Slow to Activate (CELECT™ or CELECT™ Plus)
(Continued)**

Cause

Correction

Engine brake harness connectors are loose or broken

Check for 12 volts at the solenoids. Check the engine brake harness connectors. Check the engine brake harness for continuity. Refer to the wiring diagrams in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Master piston is stuck

Check the master piston for freedom of movement. Replace the master piston if necessary. Refer to the OEM service manual.

OK

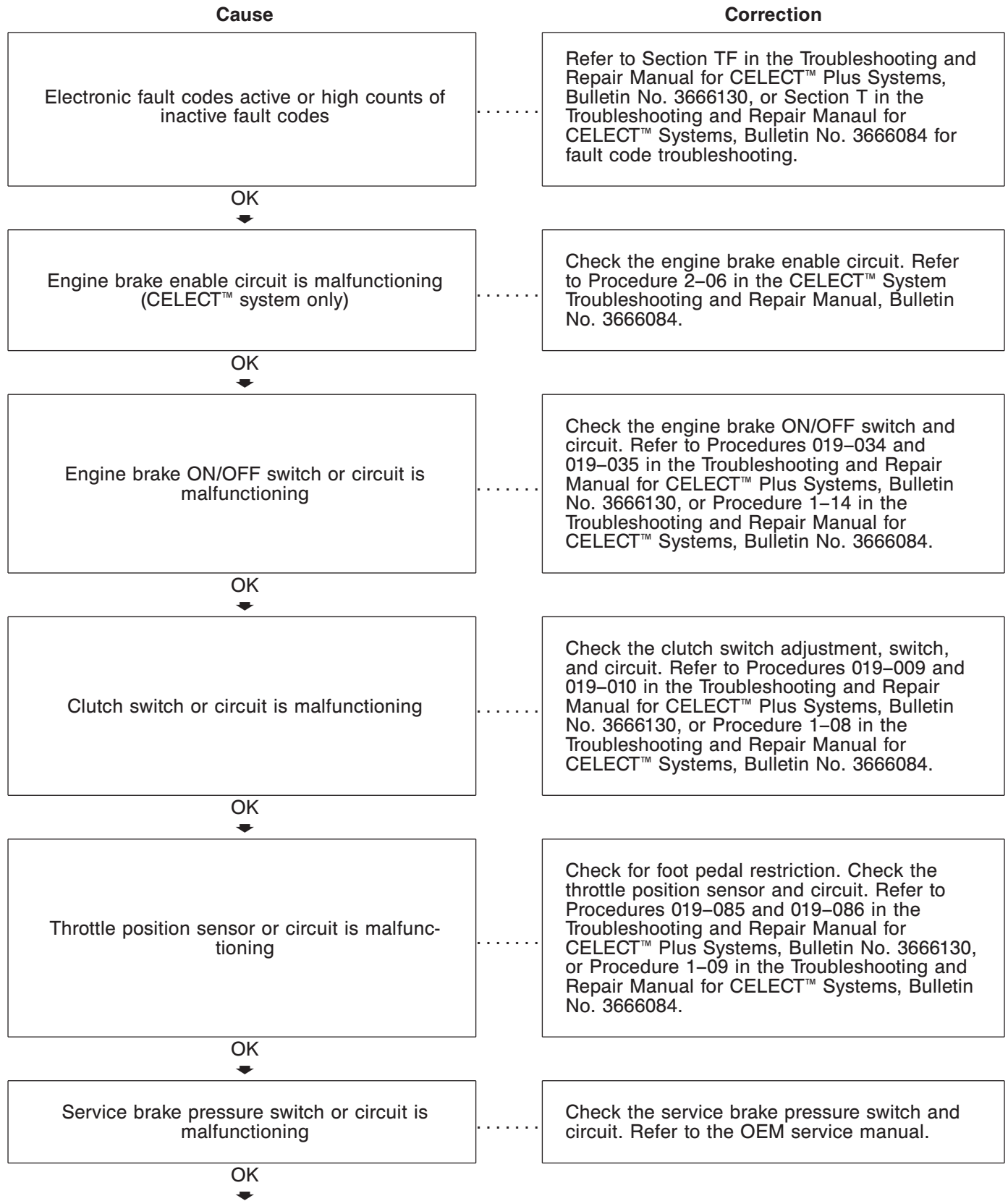


Engine brake solenoid is malfunctioning

Manually depress the solenoid on each housing with the engine at idle. If the engine brakes activate manually, replace the solenoid. Refer to the OEM service manual.

Engine Brake — One or More Cylinders Braking with Power Switch Off (CELECT™ or CELECT™ Plus)

This is symptom tree T038-155.



(Continued)

Engine Brake — One or More Cylinders Braking with Power Switch Off (CELECT™ or CELECT™ Plus) (Continued)

Cause

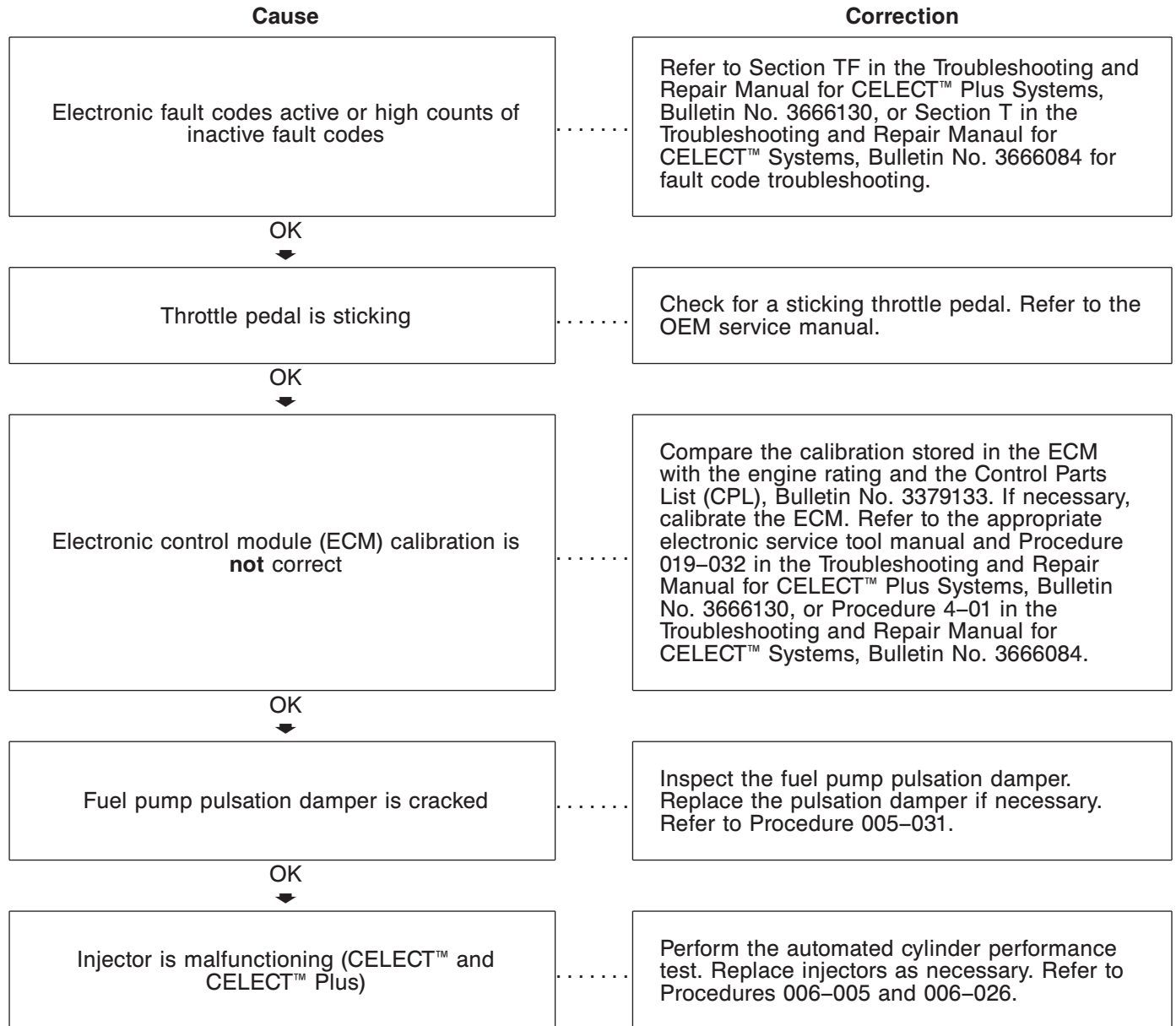
Correction

Engine brake adjustment is **not** correct

Adjust the engine brakes. Refer to Procedure 020-001.

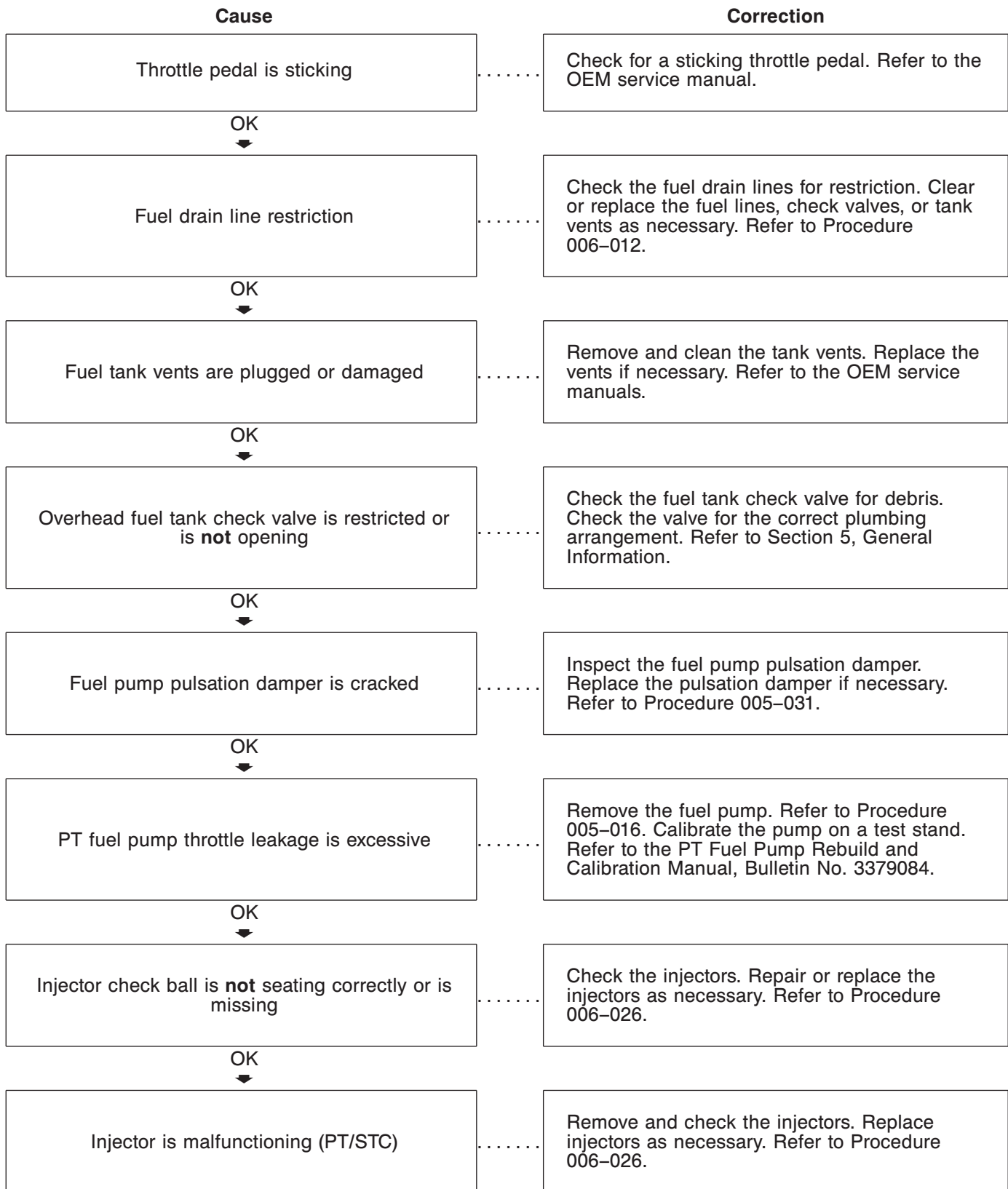
Engine Decelerates Slowly (CELECT™ and CELECT™ Plus)

This is symptom tree T041-155.



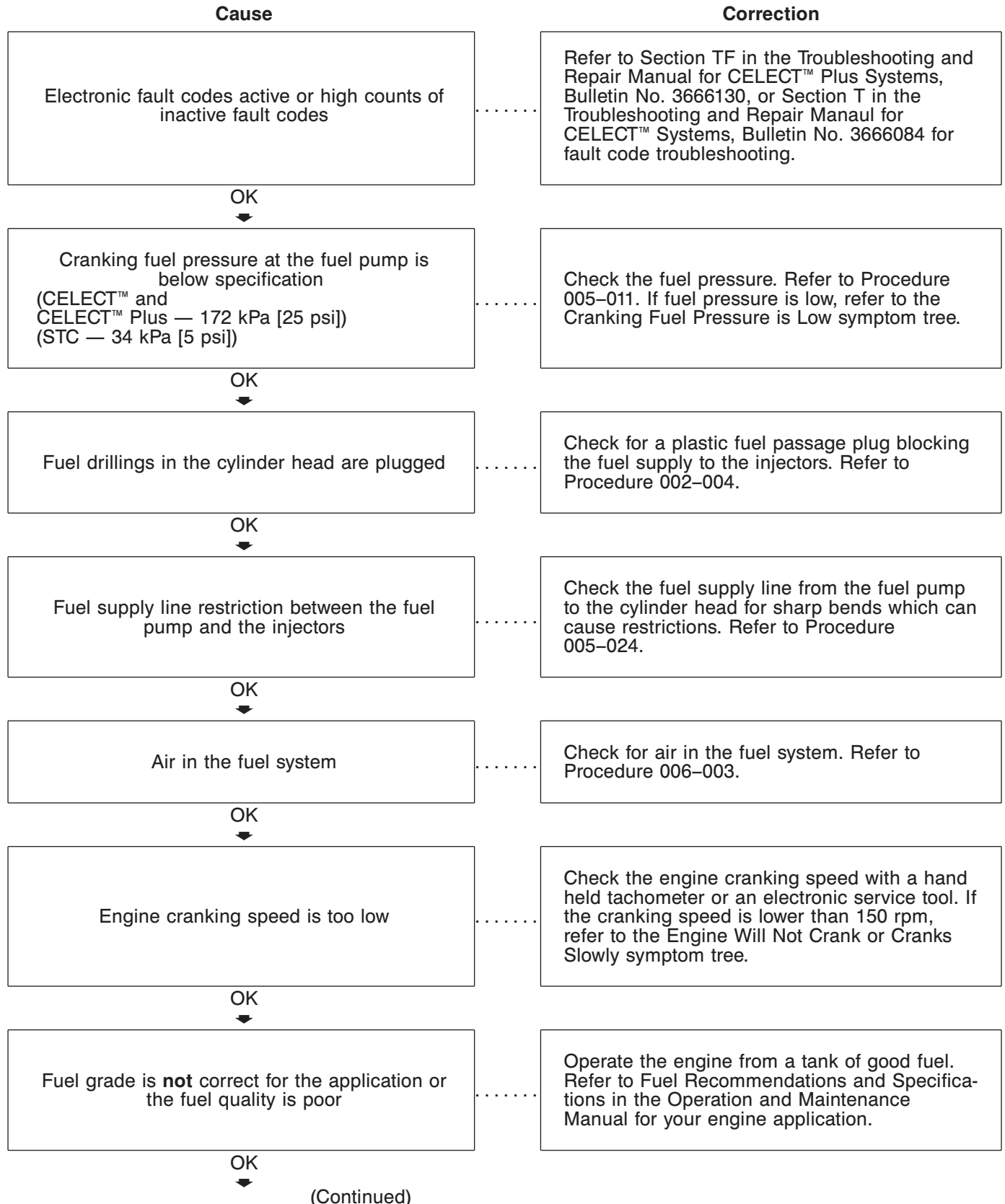
Engine Decelerates Slowly (PT)

This is symptom tree T041-011.



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

This is symptom tree T043.



(Continued)

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

Cause	Correction
Starting aid is necessary for cold weather or starting aid is malfunctioning	Check for correct operation of the starting aid. Refer to the manufacturer's instructions. Refer to Cold Weather Starting Aids in the Operation and Maintenance Manual, for your engine application.
OK	
Air intake system restriction	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK	
PT fuel pump AFC operation is malfunctioning or pump is not calibrated correctly	Remove the PT fuel pump and check the calibration. Check the AFC for proper operation. Refer to Procedure 005-016 and the PT Fuel Pump Rebuild and Calibration Manual, Bulletin No. 3379084.
OK	
Overhead adjustments are not correct	Adjust the overhead settings. Refer to Procedure 003-004.
OK	
Injector o-rings are damaged or missing	Remove and check the injectors. Replace the injector o-rings. Refer to Procedure 006-026.
OK	
Injector is malfunctioning (PT/STC)	Remove and check the injectors. Replace injectors as necessary. Refer to Procedure 006-026.
OK	
Injector is malfunctioning (CELECT™ and CELECT™ Plus)	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-005 and 006-026.
OK	
Engine components are not correct	Compare the Control Parts List (CPL) to the engine components. Replace components that do not meet CPL requirements. Refer to Control Parts List, Bulletin No. 3379133.
OK	

(Continued)

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

Cause

Camshaft end clearance is excessive (electronic controlled fuel systems)

Correction

Check the camshaft end clearance. Refer to Procedure 001-065.

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

This is symptom tree T044.

Cause

Correction

Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.

OK



Cranking fuel pressure at the fuel pump is below specification
(CELECT™ and CELECT™ Plus — 172 kPa [25 psi])
(STC — 34 kPa [5 psi])

Check the fuel pressure. Refer to Procedure 005-011. If the fuel pressure is low, refer to the Cranking Fuel Pressure is Low symptom tree.

OK



In-line check valve(s) are installed backwards or have incorrect part number

Check for correct installation and part number. Refer to Procedure 006-008.

OK



Fuel supply line restriction between the fuel pump and the injectors

Check the fuel supply line from the fuel pump to the cylinder head for sharp bends which can cause restrictions. Refer to Procedure 005-024.

OK



Fuel drillings in the cylinder head are plugged

Check for a plastic fuel passage plug blocking the fuel supply to the injectors. Refer to Procedure 002-004.

OK



Auxiliary shutdown device (Skinner valve) is closed. External governor is malfunctioning or **not** installed correctly

Repair or replace the shutdown device or external governor.

OK



Engine cranking speed is too low

Check the engine cranking speed with a hand held tachometer or electronic service tool. If the cranking speed is lower than 150 rpm, refer to the Engine Will Not Crank or Cranks Slowly symptom tree.

OK



(Continued)

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

Cause	Correction
Battery voltage supply to the electronic control module (ECM) is low, interrupted, or open	Check the battery connections. Refer to Procedure 013-009 in the base engine Troubleshooting and Repair Manual. Check the fuses and the unswitched battery supply circuit. Refer to Procedures 019-198 and 019-087 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedures 2-02 and 2-03 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Air intake system restriction	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ↓	
Exhaust system restriction	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ↓	
Starting motor rotation is not correct	Check the direction of crankshaft rotation. Replace the starting motor if necessary. Refer to Procedure 013-020 and the manufacturer's instructions.
OK ↓	
Injector is malfunctioning (CELECT™ and CELECT™ Plus)	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-005 and 006-026.
OK ↓	
Injector is malfunctioning (PT/STC)	Remove and check the injectors. Replace injectors as necessary. Refer to Procedure 006-026.
OK ↓	
Camshaft is broken	Check the rocker lever movement while rotating the crankshaft. Refer to Procedure 003-004 for instructions to rotate the crankshaft.
OK ↓ (Continued)	

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

Cause

Correction

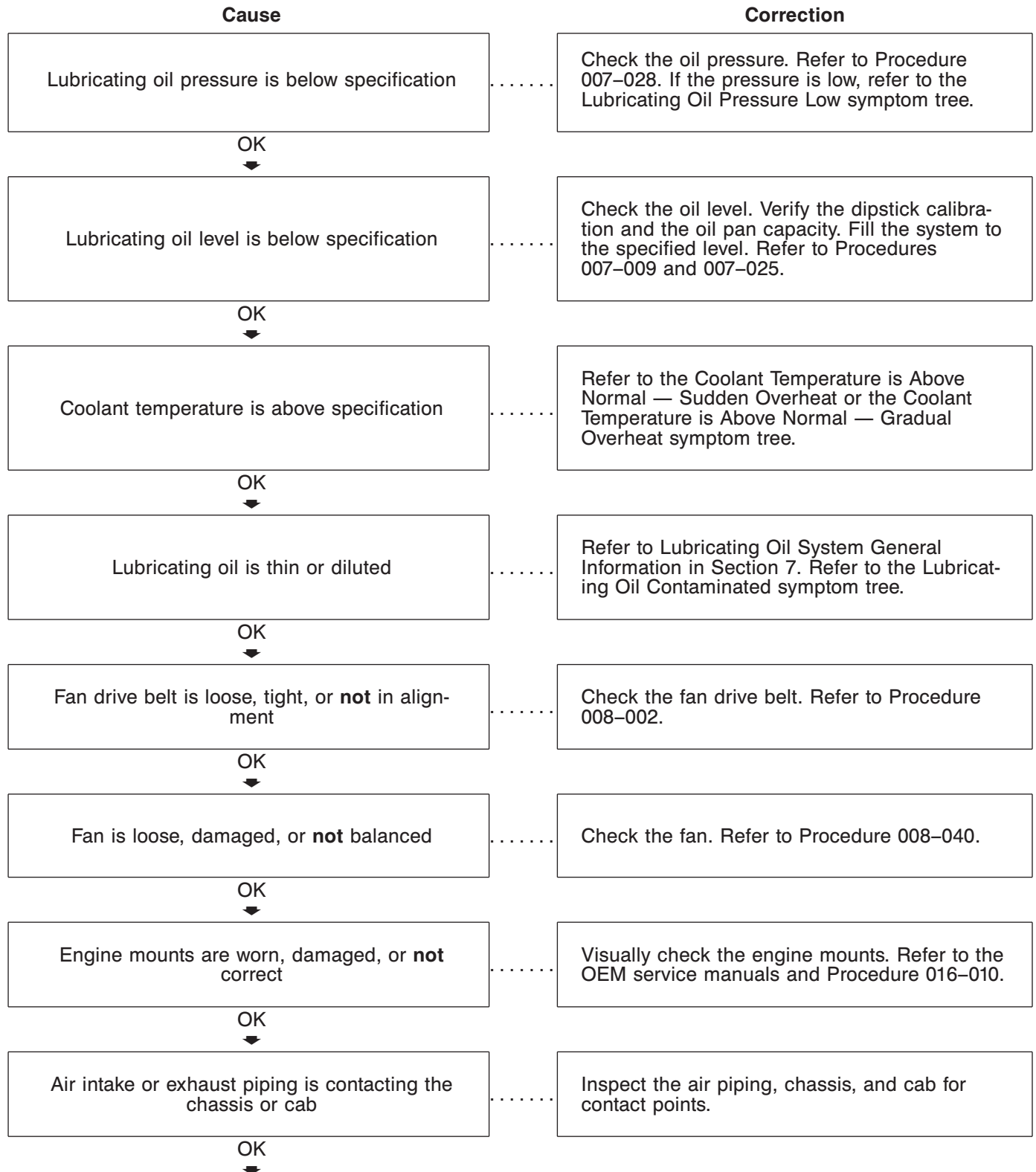
Camshaft end clearance is excessive (electronic controlled fuel system)

Check the camshaft end clearance. Refer to Procedure 001-065.

Engine Noise Excessive

This is symptom tree T047.

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



(Continued)

Engine Noise Excessive (Continued)

Cause	Correction
Air intake or exhaust leaks	Visually inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ↓	
Turbocharger noise	Refer to the Engine Noise Excessive — Turbocharger symptom tree.
OK ↓	
Overhead adjustments are not correct	Adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	
Injector is malfunctioning	Perform the single cylinder cut out test. Replace the injectors as necessary. Refer to Procedures 006-005 and 006-026.
OK ↓	
Overhead components are damaged	Inspect the rocker levers, rocker shafts, cam followers, push rods, and valves for damage or excessive wear. Refer to Procedures 003-009, 004-001, 004-014, and 002-004.
OK ↓	
Accessory drive is worn (axial end play is out of specification)	Check the accessory drive axial end play. Visually inspect the shaft for wear. Refer to Procedure 009-001.
OK ↓	
Static injection timing is not correct	Check the static injection timing. Refer to Procedure 006-025.
OK ↓	
Vibration damper is damaged	Check the vibration damper. Refer to Procedure 001-052.
OK ↓	
Air compressor noise is excessive	Refer to the Engine Noise Excessive — Air Compressor symptom tree.
OK ↓	

(Continued)

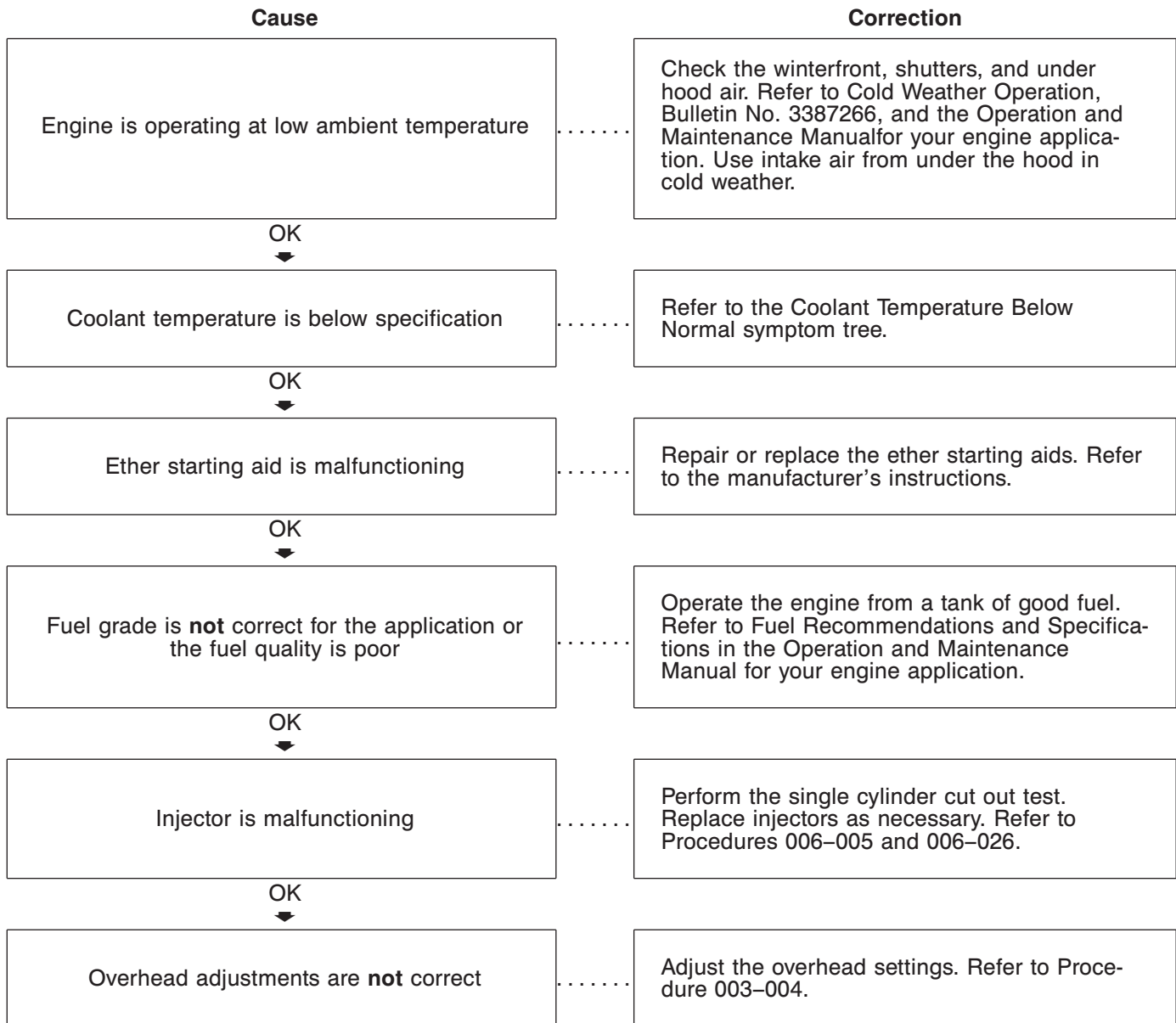
Engine Noise Excessive (Continued)

Cause	Correction
Fan clutch, hydraulic pump, or freon compressor noise is excessive	Isolate each component and check for noise. Refer to the OEM service manuals.
OK	
Drive train noise is excessive	Disconnect the drive train. Check for engine noise. Refer to the OEM service manual.
OK	
Gear train backlash is excessive or the gear teeth are damaged	Check the gear backlash and the gear teeth. Refer to Procedures 001-036, 001-039, and 001-040.
OK	
Main bearing or connecting rod bearing noise	Refer to the Engine Noise Excessive — Main Bearing symptom tree.
OK	
Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-004 or 016-005.
OK	
Piston, piston rings, or cylinder liner is worn or damaged	Refer to the Engine Noise Excessive — Piston symptom tree.
OK	
Rear Engine Power Take-Off (REPTO) noise is excessive	Disassemble and repair the REPTO as necessary. Refer to the Engine Shop Manual, Bulletin No. 3666075.

Engine Noise Excessive — Combustion Knocks

This is symptom tree T048.

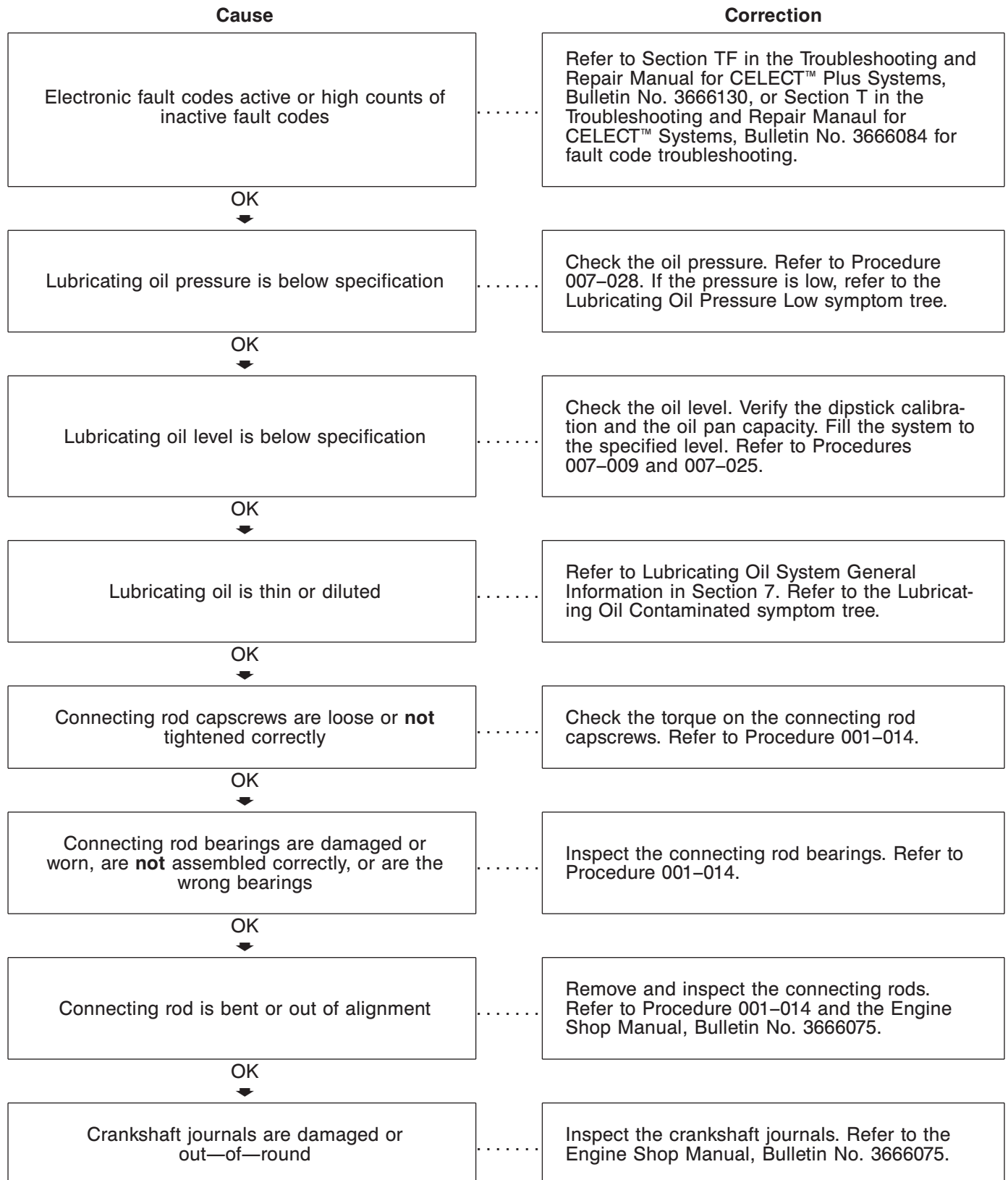
NOTE: Refer to Engine Noise Diagnostic Procedures — General Information at the end of this section before using this symptom tree.



Engine Noise Excessive — Connecting Rod

This is symptom tree T049.

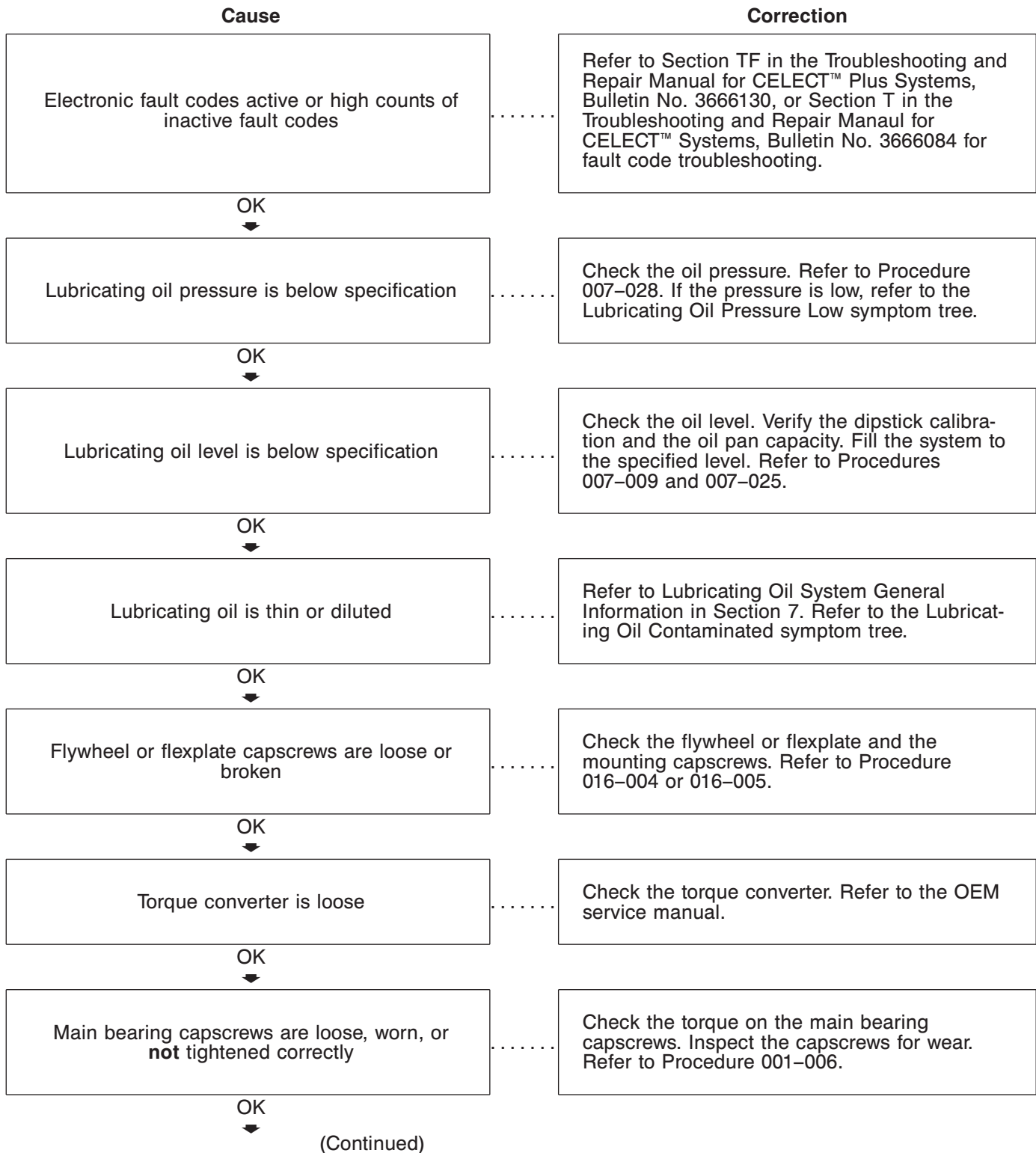
NOTE: Refer to Engine Noise Diagnostic Procedures — General Information at the end of this section before using this symptom tree.



Engine Noise Excessive — Main Bearing

This is symptom tree T050.

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



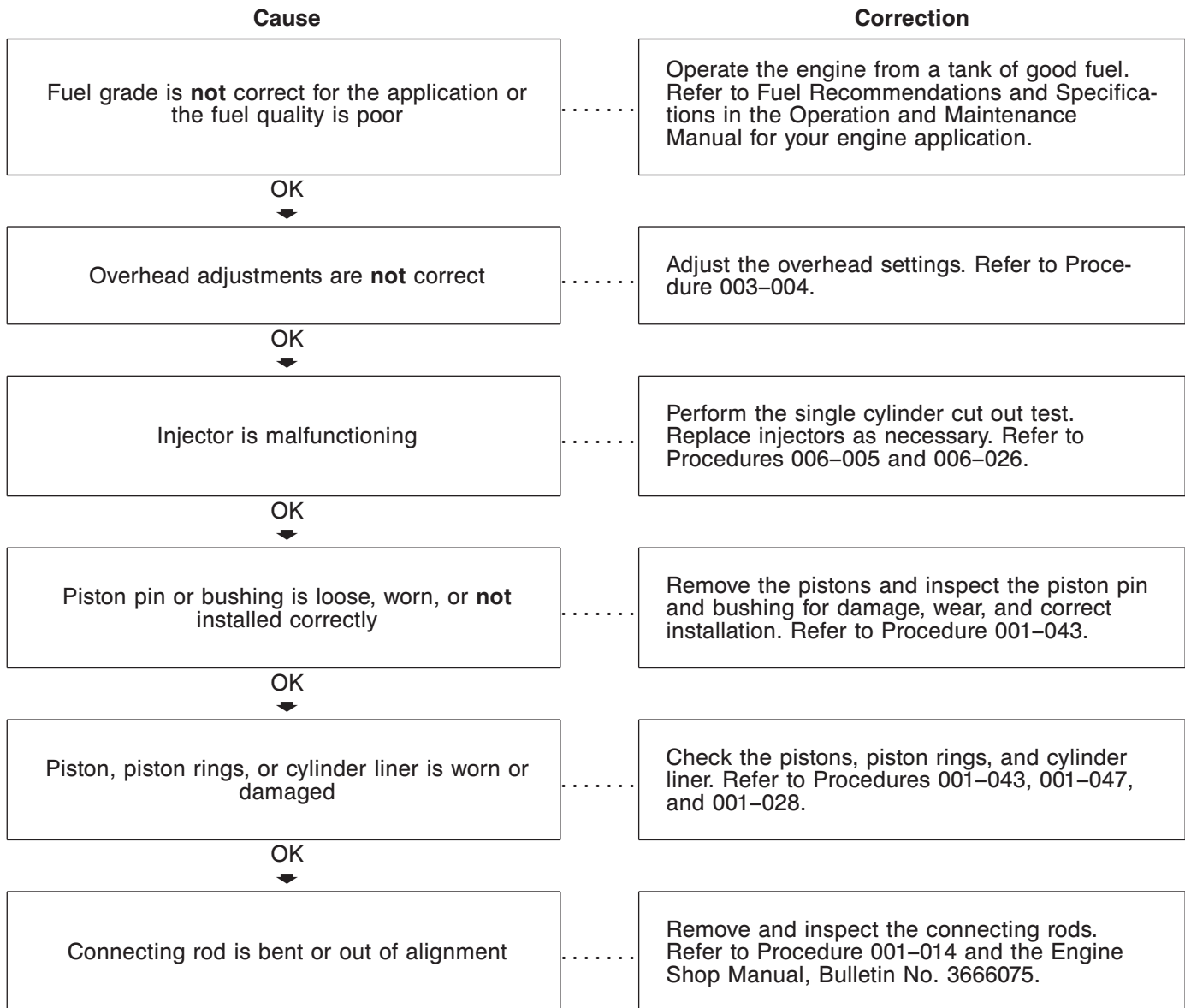
Engine Noise Excessive — Main Bearing (Continued)

Cause	Correction
Main bearings are damaged or worn, or the wrong bearings are installed	Inspect the main bearings for damage, excessive wear, and the correct part number. Refer to Procedure 001-006.
OK ↓	
Crankshaft journals are damaged or out-of-round	Inspect the crankshaft journals. Refer to the Engine Shop Manual, Bulletin No. 3666075.

Engine Noise Excessive — Piston

This is symptom tree T051.

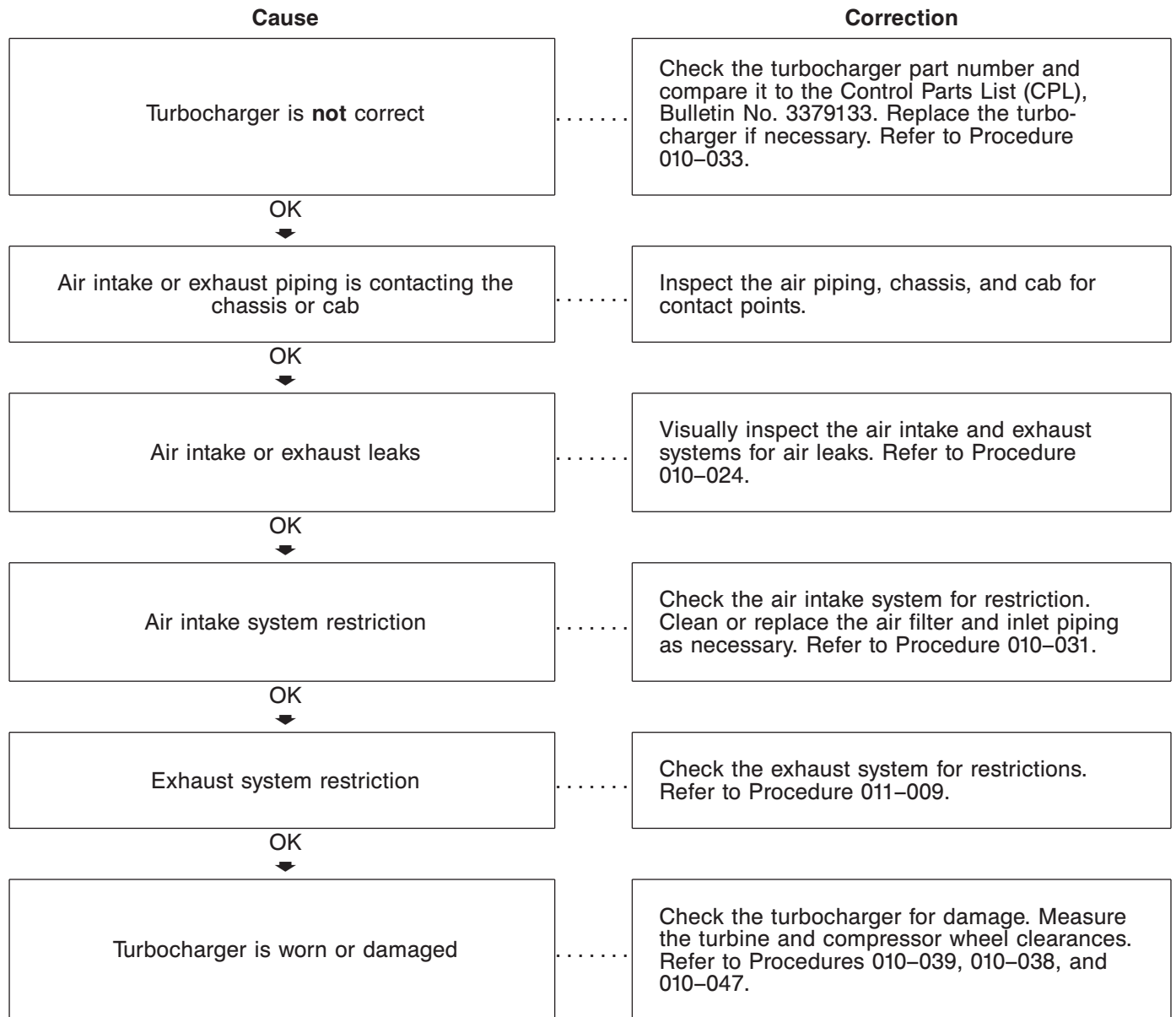
NOTE: Refer to Engine Noise Diagnostic Procedures — General Information at the end of this section before using this symptom tree.



Engine Noise Excessive — Turbocharger

This is symptom tree T052.

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



Engine Power Output Low (CELECT™ or CELECT™ Plus)

This is symptom tree T057-155.

Cause

Correction

Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.

OK



Interview the operator to verify the complaint

Refer to Driveability — General Information, the Driveability/Low Power Customer Complaint Form, and the Driveability Checklist at the end of Section TS. Follow the instructions on the forms before continuing with this tree.

OK



Electronic control module (ECM) calibration is **not** correct

Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019–032 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 4–01 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Programmable parameters or selected features are **not** correct

Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again if necessary. Refer to the appropriate electronic service tool manual.

OK



Drive train is **not** correctly matched to the engine

Check for correct gearing and drive train components. Refer to the OEM vehicle specifications.

OK



Lubricating oil level is above specification

Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedures 007–009 and 007–025.

OK



(Continued)

Engine Power Output Low (CELECT™ or CELECT™ Plus) (Continued)

Cause	Correction
Fuel grade is not correct for the application or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual for your engine application.
OK ↓	
Air intake or exhaust leaks	Visually inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ↓	
Fuel inlet temperature to pump is above specification (above 71°C [160°F])	Fill the fuel tank, turn off or bypass the fuel heaters, and check the fuel cooler. Refer to the OEM service manuals.
OK ↓	
Air intake system restriction	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ↓	
Intake manifold air temperature is above specification	Refer to the Intake Manifold Air Temperature Above Specification symptom tree.
OK ↓	
Charge air cooler (CAC) is malfunctioning	Inspect the CAC for air restriction or leaks. Refer to Procedure 010-027.
OK ↓	
Intake manifold pressure (boost) is below specification	Refer to the Intake Manifold Pressure (Boost) is Below Normal symptom tree.
OK ↓	
Throttle position sensor or circuit is malfunctioning	Check for foot pedal restriction. Check the throttle position sensor and circuit. Refer to Procedures 019-085 and 019-086 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 1-09 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK
↓

(Continued)

Engine Power Output Low (CELECT™ or CELECT™ Plus) (Continued)

Cause

Correction

Tachometer or speedometer is **not** calibrated or is malfunctioning

Compare the vehicle tachometer and speedometer readings with an electronic service tool reading. Check the calibration values for the flywheel teeth, rear axle ratio, and tire revolutions. Adjust the values if necessary. Refer to the appropriate electronic service tool manual. Calibrate or replace the tachometer or speedometer as necessary. Refer to the OEM service manuals.

OK



Engine is operating above recommended altitude (3600 m [12,000 ft])

Engine derates for altitude. Refer to the Engine Data Sheet for specifications.

OK



Engine protection fault code(s) inactive

View the fault codes and the engine protection data with an electronic service tool. Refer to the appropriate electronic service tool manual. Refer to the corresponding fault code in Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Vehicle speed sensor (VSS) or circuit is malfunctioning

Use an electronic service tool to monitor the vehicle speed while the vehicle is **not** moving. Refer to the appropriate electronic service tool manual. If the monitor shows speed, check the sensor and circuit. Refer to Procedures 019-090 and 019-091 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedures 1-02 and 1-03 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Intake manifold temperature sensor is malfunctioning

Check the intake manifold temperature sensor. Refer to Procedure 019-059 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3-10 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



(Continued)

Engine Power Output Low (CELECT™ or CELECT™ Plus) (Continued)

Cause	Correction
Coolant temperature sensor is malfunctioning	Check the coolant temperature sensor. Refer to Procedure 019-019 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3-09 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Ambient air pressure sensor is malfunctioning (if equipped)	Check the ambient air pressure sensor. Refer to Procedure 019-004 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3-05 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Intake manifold pressure (boost) sensor is malfunctioning	Check the boost sensor. Refer to Procedure 019-061 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3-04 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Governor setting is not correct in the programmable parameters	Verify if the driver is accustomed to the automotive governor or the VS governor. Change the governor setting if necessary. Refer to the appropriate electronic service tool manual.
OK ↓	
Fuel supply pressure is below specification	Measure the fuel supply pressure. Refer to Procedure 005-011. If the fuel pressure is low, refer to the Operating Fuel Pressure is Low symptom tree.
OK ↓	
Fuel supply line restriction between the fuel pump and the injectors	Check the fuel supply line from the fuel pump to the cylinder head for sharp bends which can cause restrictions. Refer to Procedure 005-024.
OK ↓	

(Continued)

Engine Power Output Low (CELECT™ or CELECT™ Plus) (Continued)

Cause

Correction

Turbocharger wheel clearance is out of specification

Check the radial bearing clearance and axial clearance. Inspect the turbocharger. Repair or replace the turbocharger if necessary. Refer to Procedures 010-038 and 010-047.

OK



Engine components are **not** correct

Compare the Control Parts List (CPL) to the engine components. Replace components that do **not** meet CPL requirements. Refer to Control Parts List, Bulletin No. 3379133.

OK



Overhead adjustments are **not** correct

Adjust the overhead settings. Refer to Procedure 003-004.

OK



Crankcase pressure is excessive

Check for excessive blowby. Refer to Section 14. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.

OK



Engine is operating at high ambient temperature

Use outside air to the turbocharger in hot weather.

OK



Engine is operating at low ambient temperature

Check the winterfront, shutters, and under hood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual, for your engine application. Use intake air from under the hood in cold weather.

OK



Fuel temperature is above specification (above 71°C [160°F])

Fill the fuel tanks. Turn off or bypass the fuel heater, if equipped.

OK



Fuel drillings in the cylinder head are plugged

Check for a plastic fuel passage plug blocking the fuel supply to the injectors. Refer to Procedure 002-004.

OK



(Continued)

Engine Power Output Low (CELECT™ or CELECT™ Plus) (Continued)

Cause

Correction

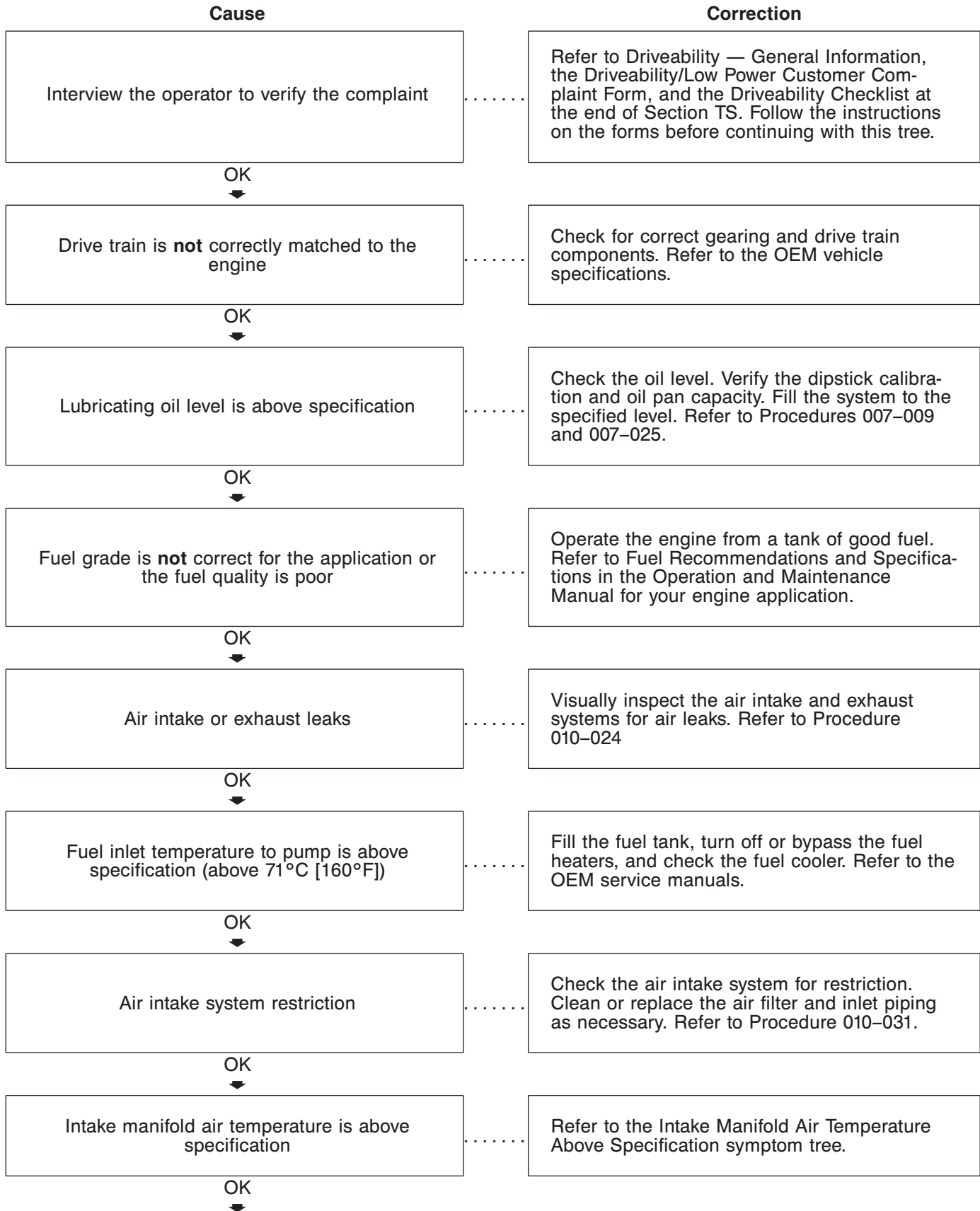
Load is excessive for engine horsepower rating

.....

Reduce the vehicle load or use a lower gear.

Engine Power Output Low (PT)

This is symptom tree T057-011.



(Continued)

Engine Power Output Low (PT) (Continued)

Cause	Correction
Charge air cooler (CAC) is malfunctioning	Inspect the CAC for air restriction or leaks. Refer to Procedure 010-027.
OK ↓	
Intake manifold pressure (boost) is below specification	Refer to the Intake Manifold Pressure (Boost) is Below Normal symptom tree.
OK ↓	
Throttle linkage adjustment is not correct	Check the fuel pump throttle linkage adjustment. Refer to Procedure 005-036.
OK ↓	
Tachometer is not calibrated or is malfunctioning	Compare the vehicle tachometer reading with a hand tachometer or an electronic service tool reading. Calibrate or replace the tachometer as necessary. Refer to the OEM service manuals.
OK ↓	
Engine is operating above recommended altitude (STC engines only)	Derate the engine by 4 percent for every 300 meters [1000 feet] of altitude above 3600 meters [12,000 feet]. Refer to the Engine Data Sheet.
OK ↓	
Engine components are not correct	Compare the Control Parts List (CPL) to the engine components. Replace components that do not meet CPL requirements. Refer to Control Parts List, Bulletin No. 3379133.
OK ↓	
Fuel supply pressure is below specification	Measure the fuel supply pressure. Refer to Procedure 005-011. If the fuel pressure is low, refer to the Operating Fuel Pressure is Low symptom tree.
OK ↓	
Fuel supply line restriction between the fuel pump and the injectors	Check the fuel supply line from the fuel pump to the cylinder head for sharp bends which can cause restrictions. Refer to Procedure 005-024.
OK ↓	

(Continued)

Engine Power Output Low (PT) (Continued)

Cause	Correction
Turbocharger wheel clearance is out of specification	Check the radial bearing clearance and axial clearance. Inspect the turbocharger. Repair or replace the turbocharger if necessary. Refer to Procedures 010-038 and 010-047.
OK ↓	
Crankcase pressure is excessive	Check for excessive blowby. Refer to Section 14. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.
OK ↓	
Overhead adjustments are not correct	Adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	
Engine is operating at high ambient temperature	Use outside air to the turbocharger in hot weather.
OK ↓	
Engine is operating at low ambient temperature	Check the winterfront, shutters, and under hood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual for your engine application. Use intake air from under the hood in cold weather.
OK ↓	
Fuel temperature is above specification (above 71°C [160°F])	Fill the fuel tanks. Turn off or bypass the fuel heater, if equipped.
OK ↓	
AFC signal line is restricted or leaking	Check the AFC signal line for restriction and leaks. Refer to the Injector Specifications Manual, Bulletin No. 3810344.
OK ↓	
Injector calibration is not correct or the fuel supply to the injector is restricted (PT injectors)	Remove the injectors. Check the injectors for the correct calibration. Check the inlet screen for restriction. Check for carbon build up on the plungers. Refer to Procedure 006-026 and the Injector Specifications Manual, Bulletin No. 3379664.

OK
↓

(Continued)

Engine Power Output Low (PT) (Continued)

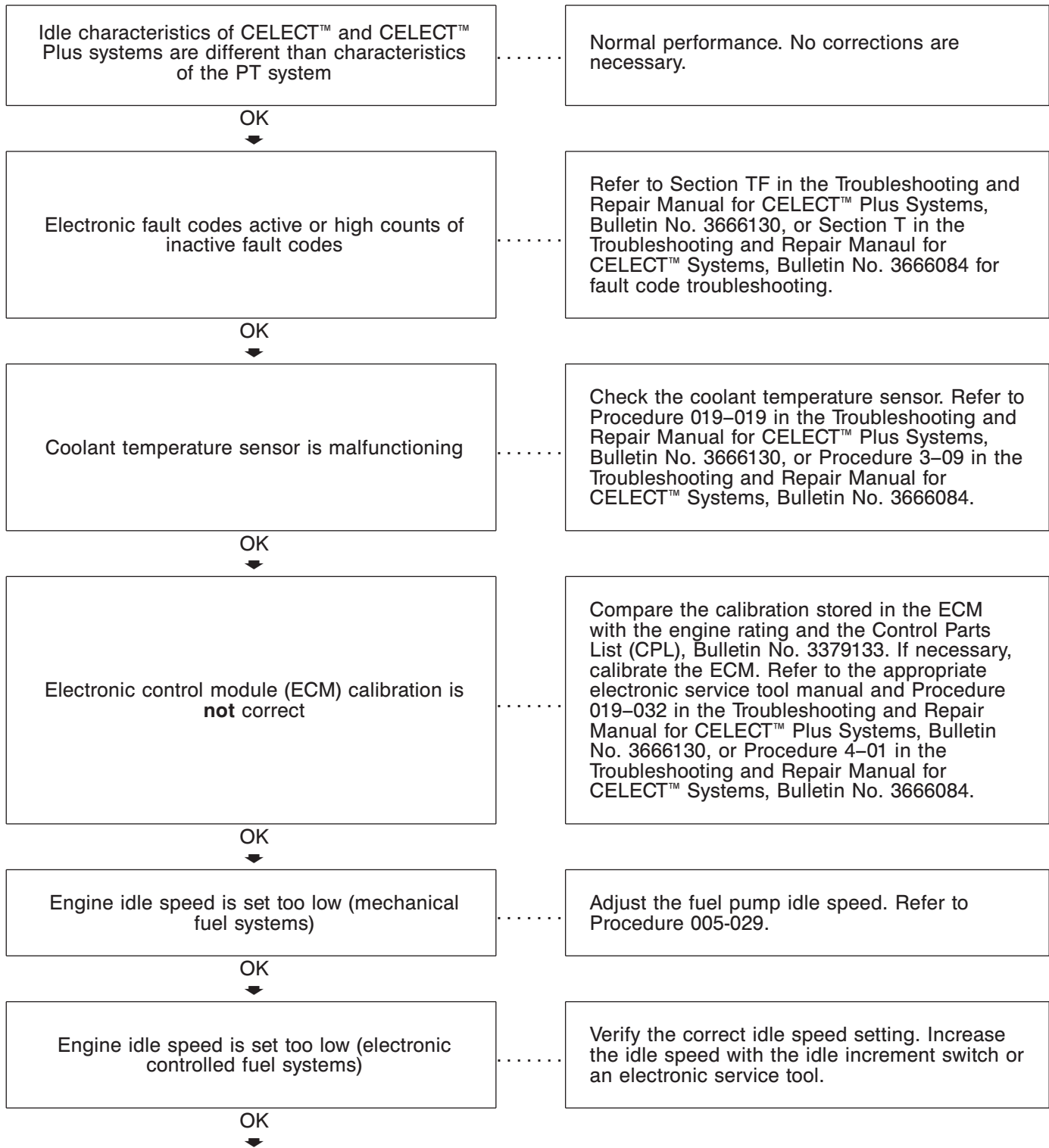
Cause	Correction
Fuel drillings in the cylinder head are plugged	Check for a plastic fuel passage plug blocking the fuel supply to the injectors. Refer to Procedure 002-004.
OK ↓	
Load is excessive for engine horsepower rating	Reduce the vehicle load or use a lower gear.

Engine Runs Rough at Idle

This is symptom tree T061.

Cause

Correction



(Continued)

Engine Runs Rough at Idle (Continued)

Cause	Correction
Engine is operating above recommended altitude (STC engines only)	Derate the engine by 4 percent for every 300 meters [1000 feet] of altitude above 3600 m [12,000 feet]. Refer to the Engine Data Sheet.
OK ↓	
Engine is operating at low ambient temperature	Check the winterfront, shutters, and under hood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual, for your engine application. Use intake air from under the hood in cold weather.
OK ↓	
Fuel supply pressure is below specification	Measure the fuel supply pressure. Refer to Procedure 005-011. If the fuel pressure is low, refer to the Operating Fuel Pressure is Low symptom tree.
OK ↓	
Fuel pump pulsation damper is cracked	Inspect the fuel pump pulsation damper. Replace the pulsation damper if necessary. Refer to Procedure 005-031.
OK ↓	
Fuel grade is not correct for the application or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual for your engine application.
OK ↓	
White smoke is present	Check the STC plumbing to each cylinder for restriction or loss of flow. Refer to Procedures 006-045 and 006-046.
OK ↓	
Engine mounts are worn, damaged, or not correct	Visually check the engine mounts. Refer to the OEM service manuals and Procedure 016-010.
OK ↓	
Overhead adjustments are not correct	Adjust the overhead settings. Refer to Procedure 003-004.

OK
↓
(Continued)

Engine Runs Rough at Idle (Continued)

Cause	Correction
Injector is malfunctioning (CELECT™ and CELECT™ Plus)	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-005 and 006-026.
OK ↓	
Injector is malfunctioning (PT/STC)	Remove and check the injectors. Replace injectors as necessary. Refer to Procedure 006-026.
OK ↓	
Static injection timing is not correct	Check the static injection timing. Refer to Procedure 006-025.
OK ↓	
Camshaft end clearance is excessive (electronic controlled fuel system)	Check the camshaft end clearance. Refer to Procedure 001-065.
OK ↓	
Cylinder head valve leak	Check the cylinder head for fuel leaks between the valves and valve seats. Refer to Procedure 002-004.
OK ↓	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-051. Remove the oil pan and inspect for damaged camshaft, cam followers, push rods, pistons, and liners. Refer to Procedure 007-025.

Engine Runs Rough or Misfires

This is symptom tree T062.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.
OK ↓	
Condition occurs only at idle	Refer to the Engine Runs Rough at Idle symptom tree.
OK ↓	
Engine is operating at low ambient temperature	Check the winterfront, shutters, and under hood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual for your engine application. Use intake air from under the hood in cold weather.
OK ↓	
Fuel grade is not correct for the application or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual for your engine application.
OK ↓	
Fuel pump pulsation damper is cracked	Inspect the fuel pump pulsation damper. Replace the pulsation damper if necessary. Refer to Procedure 005-031.
OK ↓	
Electronic control module (ECM) calibration is not correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 4-01 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK
↓

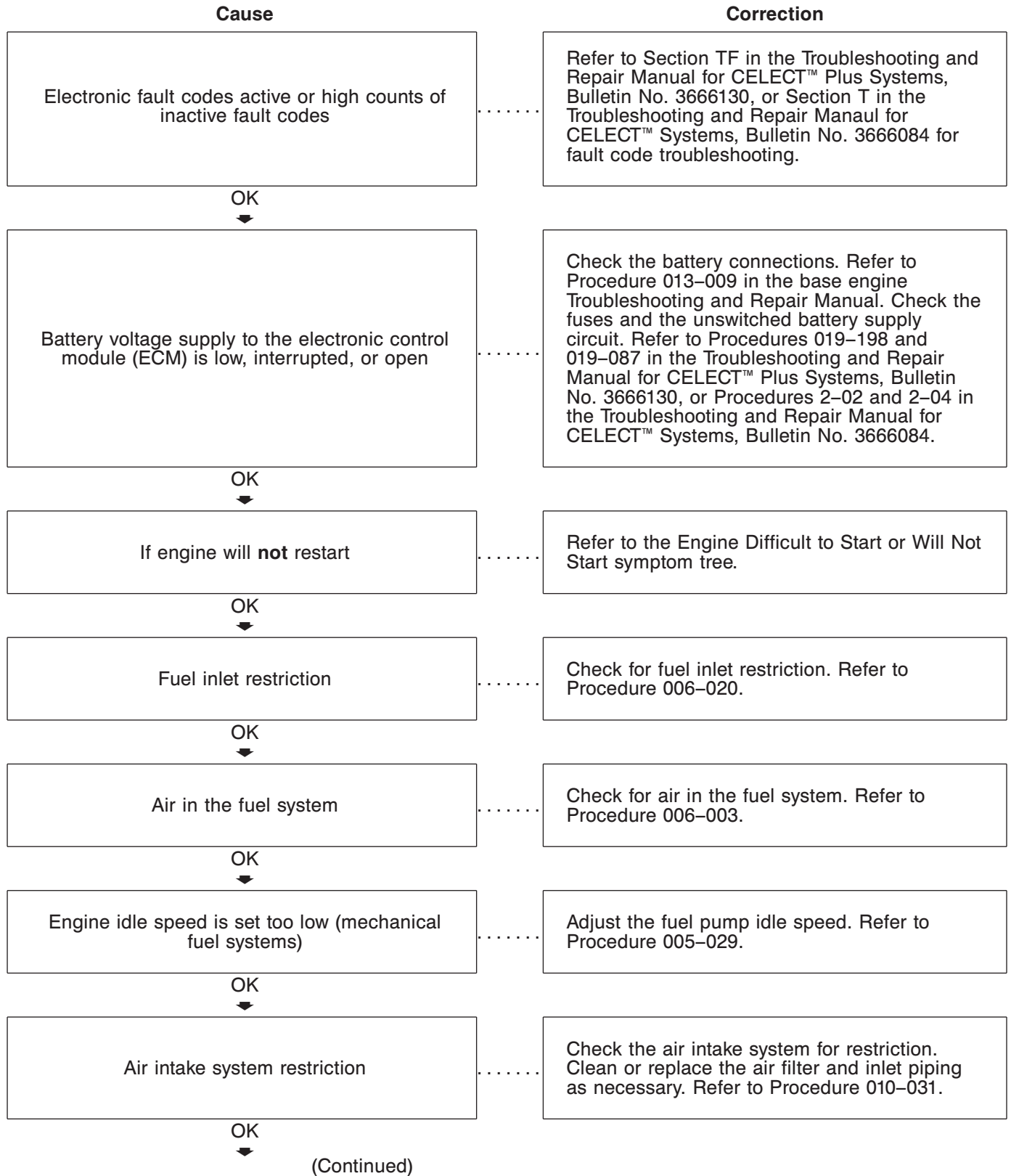
(Continued)

Engine Runs Rough or Misfires (Continued)

Cause	Correction
Engine mounts are worn, damaged or not correct	Visually check the engine mounts. Refer to the OEM service manuals and Procedure 016-010.
OK ↓	
Injector is malfunctioning (CELECT™ and CELECT™ Plus)	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-005 and 006-026.
OK ↓	
Injector is malfunctioning (PT/STC)	Remove and check the injectors. Replace injectors as necessary. Refer to Procedure 006-026.
OK ↓	
Camshaft is damaged	Inspect the camshaft for damage. Refer to Procedure 001-008.
OK ↓	
Overhead adjustments are not correct	Adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	
Static injection timing is not correct	Check the static injection timing. Refer to Procedure 006-025.
OK ↓	
Cylinder head valve leak	Check the cylinder head for fuel leaks between the valves and valve seats. Refer to Procedure 002-004.
OK ↓	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-051. Remove the oil pan and inspect for damaged camshaft, cam followers, push rods, pistons, and liners. Refer to Procedure 007-025.

Engine Shuts Off Unexpectedly or Dies During Deceleration

This is symptom tree T064.



Engine Shuts Off Unexpectedly or Dies During Deceleration (Continued)

Cause	Correction
Exhaust system restriction	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ↓	
OEM engine protection system is malfunctioning	Isolate the OEM engine protection system. Follow the OEM service manuals to check for a malfunction.
OK ↓	
Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to Procedure 013-009 in the base engine Troubleshooting and Repair Manual, Procedure 019-087 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 2-04 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084, and the OEM service manual.
OK ↓	
Fuel shutoff valve(s) closed (electronic controlled injection)	Check the fuel shutoff valve and circuit. Refer to Procedures 019-049 and 019-050 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedures 2-09 and 2-10 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Fuel shutoff valve (FSOV) is closed	Check for loose wires. Check for power (12 volts) to the fuel shutoff valve solenoid.
OK ↓	
Fuel pump is malfunctioning	Check the fuel pump output pressure, pulsation damper, and pressure regulator. Replace the fuel pump if necessary. Refer to Procedures 005-016 and 005-031.
OK ↓	
Fuel grade is not correct for the application or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual for your engine application.
OK ↓ (Continued)	

Engine Shuts Off Unexpectedly or Dies During Deceleration (Continued)

Cause	Correction
Engine brakes are malfunctioning	Check the engine brake operation, adjustment, and solenoid resistance. Repair or adjust as necessary. Refer to Procedure 020-001.
OK ↓	
Injector is malfunctioning (CELECT™ and CELECT™ Plus)	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-005 and 006-026.
OK ↓	
Injector is malfunctioning (PT/STC)	Remove and check the injectors. Replace injectors as necessary. Refer to Procedure 006-026.
OK ↓	
Camshaft end clearance is excessive	Check the camshaft end clearance. Refer to Procedure 001-065.
OK ↓	
Static injection timing is not correct	Check the static injection timing. Refer to Procedure 006-025.

Engine Speed Surges at Low or High Idle

This is symptom tree T066.

Cause

Correction

Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.

OK



Air in the fuel system

Check for air in the fuel system. Refer to Procedure 006-003.

OK



Fuel level low in the tank

Fill the supply tank.

OK



Fuel inlet restriction

Check for fuel inlet restriction. Refer to Procedure 006-020.

OK



Engine idle speed is set too low (electronic controlled fuel systems)

Verify the correct idle speed setting. Increase the idle speed with the idle increment switch or an electronic service tool.

OK



Engine idle speed is set too low (mechanical fuel systems)

Adjust the fuel pump idle speed. Refer to Procedure 005-029.

OK



Electronic control module (ECM) calibration is **not** correct

Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 4-01 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



(Continued)

Engine Speed Surges at Low or High Idle (Continued)

Cause	Correction
Fuel drain line restriction	Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012.
OK ↓	
Injector is malfunctioning (CELECT™ and CELECT™ Plus)	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-005 and 006-026.
OK ↓	
Engine position sensor (EPS) or circuit is malfunctioning	Check the engine position sensor and circuit. Refer to Procedures 019-038 and 019-039 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3-02 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Injector is malfunctioning (PT/STC)	Remove and check the injectors. Replace injectors as necessary. Refer to Procedure 006-026.
OK ↓	
Automotive and variable speed (VS) governor idle speeds are set too close (STC engines only)	Adjust the automotive and VS idle speeds. Refer to Procedures 005-028 and 005-029.
OK ↓	
PT fuel pump calibration is not correct	Remove the fuel pump. Check the calibration. Refer to Procedure 005-016 and the PT Fuel Pump Rebuild and Calibration Manual, Bulletin No. 3379084.
OK ↓	
PT fuel pump is not assembled correctly	Check the fuel pump for correct assembly and installation. Refer to Procedure 005-016 and the PT Fuel Pump Rebuild and Calibration Manual, Bulletin No. 3379084.
OK ↓	

(Continued)

Engine Speed Surges at Low or High Idle (Continued)

Cause

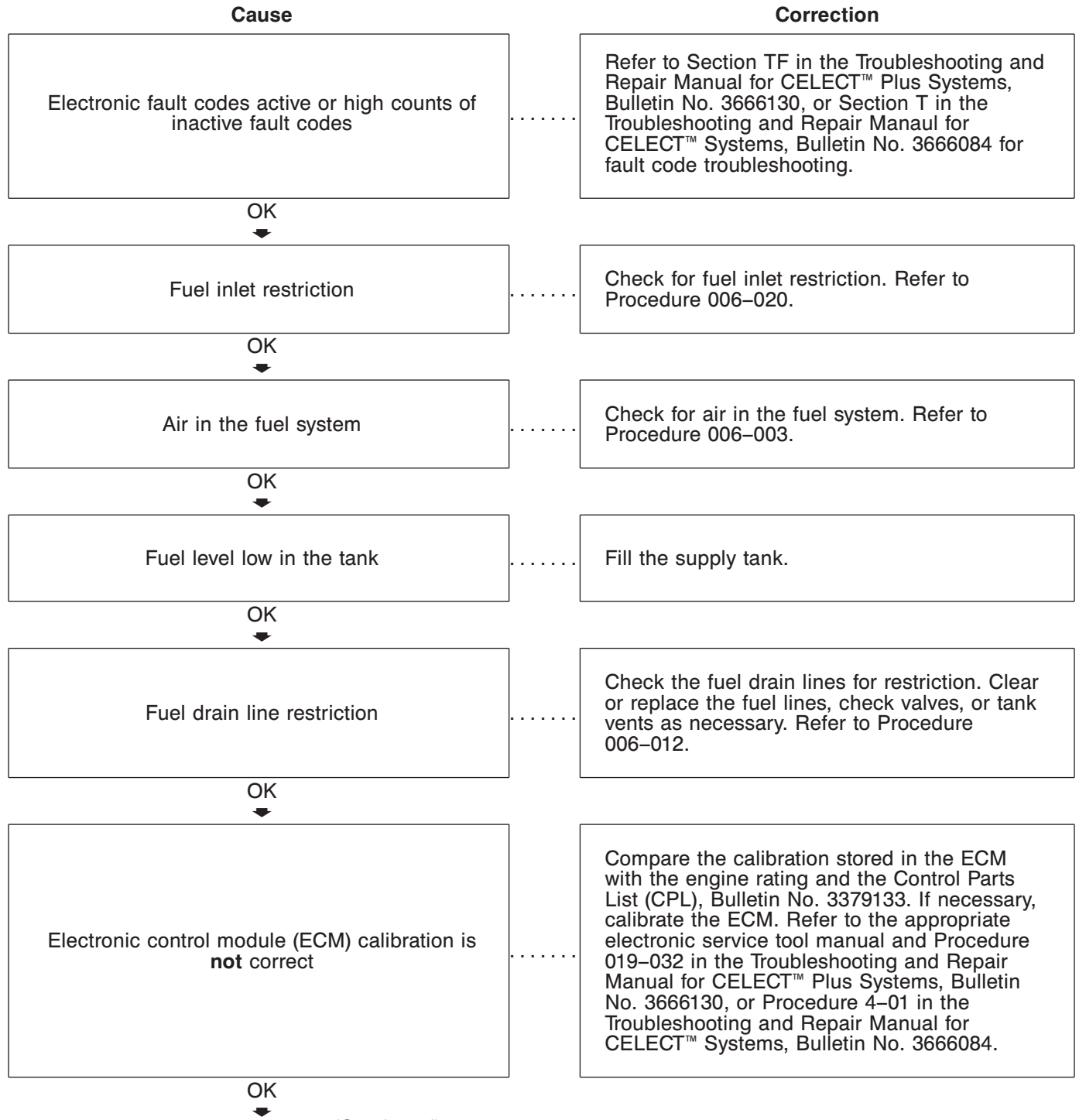
Correction

Camshaft end clearance is excessive (electronic controlled fuel system)

Check the camshaft end clearance. Refer to Procedure 001-065.

Engine Speed Surges Under Load or in Operating Range

This is symptom tree T067.



(Continued)

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

Cause

Correction

Throttle pedal is worn or failed (CELECT™ or CELECT™ Plus)

Inspect the throttle pedal for correct operation. Check the throttle position sensor and circuit. Refer to Procedures 019-085 and 019-086 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 1-09 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Cruise control/PTO selector switch or circuit is malfunctioning

Check the cruise control/PTO selector switch and circuit. Refer to Procedures 019-023 and 019-024 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedures 1-12 and 1-14 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Engine position sensor (EPS) or circuit is malfunctioning

Check the engine position sensor and circuit. Refer to Procedures 019-038 and 019-039 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3-02 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Vehicle speed sensor (VSS) or circuit is malfunctioning

Check the vehicle speed sensor and circuit. Refer to Procedures 019-090 and 019-091 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 1-02 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Injector is malfunctioning

Perform the single cylinder cut out test. Replace the injectors as necessary. Refer to Procedures 006-005 and 006-026.

OK



Fuel pump pulsation damper is cracked

Inspect the fuel pump pulsation damper. Replace the pulsation damper if necessary. Refer to Procedure 005-031.

OK



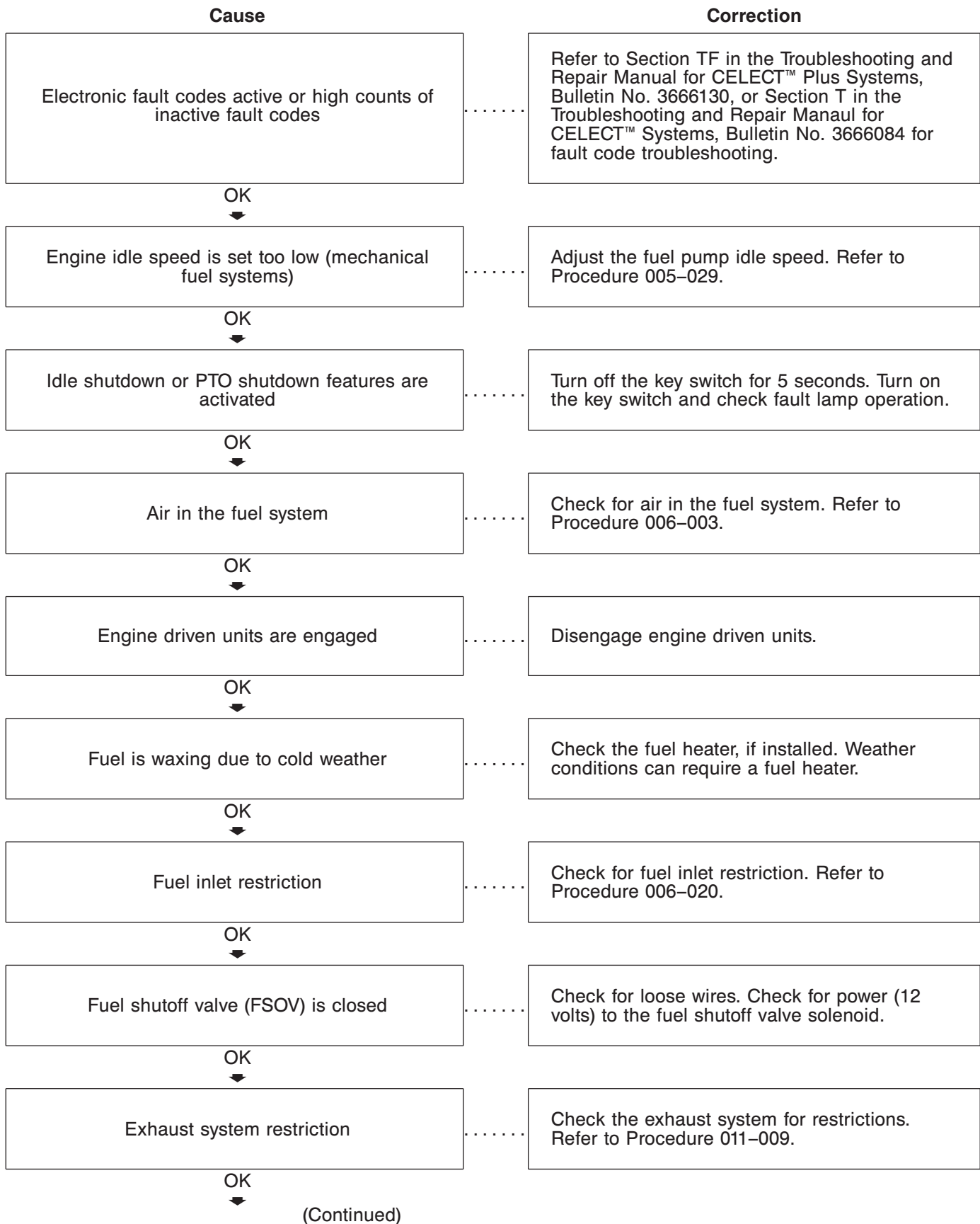
(Continued)

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

Cause	Correction
Automotive and variable speed (VS) governor idle speeds are set too close (STC engine only)	Adjust the automotive and VS idle speeds. Refer to Procedures 005-028 and 005-029.
OK ↓	
PT fuel pump calibration is not correct	Remove the fuel pump. Check the calibration. Refer to Procedure 005-016 and the PT Fuel Pump Rebuild and Calibration Manual, Bulletin No. 3379084.
OK ↓	
PT fuel pump is not assembled correctly	Check the fuel pump for correct assembly and installation. Refer to Procedure 005-016 and the PT Fuel Pump Rebuild and Calibration Manual, Bulletin No. 3379084.
OK ↓	
Camshaft end clearance is excessive (electronic controlled fuel system)	Check the camshaft end clearance. Refer to Procedure 001-065.

Engine Starts But Will Not Keep Running

This is symptom tree T072.



(Continued)

Engine Starts But Will Not Keep Running (Continued)

Cause	Correction
Air intake system restriction	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ↓	
Fuel grade is not correct for the application or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual for your engine application.
OK ↓	
Fuel pump is malfunctioning	Check the fuel pump output pressure. Replace the fuel pump if necessary. Refer to Procedure 005-016.
OK ↓	
Engine brake adjustment is not correct	Adjust the engine brakes. Refer to Procedure 020-001.
OK ↓	
Injector cup spray holes are plugged	Remove and clean the injectors. Refer to Procedure 006-026.
OK ↓	
Static injection timing is not correct	Check the static injection timing. Refer to Procedure 006-025.

Engine Vibration Excessive

This is symptom tree T075.

Cause

Correction

Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.

OK



If engine is misfiring

Refer to the Engine Runs Rough or Misfires symptom tree.

OK



Engine idle speed is set too low (electronic controlled fuel systems)

Verify the correct idle speed setting. Increase the idle speed with the idle increment switch or an electronic service tool.

OK



Engine idle speed is set too low (mechanical fuel systems)

Adjust the fuel pump idle speed. Refer to Procedure 005-029.

OK



Fan is loose, damaged, or **not** balanced

Check the fan. Refer to Procedure 008-040.

OK



Belt driven accessories are malfunctioning

Check the fan hub, alternator, freon compressor, and hydraulic pump for interference. Isolate belt driven accessories and check for vibration.

OK



Engine mounts are worn, damaged, or **not** correct

Visually check the engine mounts. Refer to the OEM service manuals and Procedure 016-010..

OK



Vibration damper is damaged

Check the vibration damper. Refer to Procedure 001-052.

OK



(Continued)

Engine Vibration Excessive (Continued)

Cause	Correction
Drive train components are malfunctioning or are not correct	Compare the drive train components to the engine and equipment specifications. Isolate the drive train components and check for vibrations. Refer to the OEM specifications.
OK ↓	
Power Take-Off (PTO) is damaged	Check the PTO for damage and correct installation. Refer to the manufacturer's instructions.
OK ↓	
Gear driven accessories are malfunctioning	Check the hydraulic pump and air compressor. Isolate gear driven accessories and check for vibration.
OK ↓	
Flywheel housing is not aligned correctly	Check the flywheel housing alignment. Refer to Procedure 016-006.
OK ↓	
Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-004 or 016-005.

Engine Will Not Crank or Cranks Slowly (Air Starter)

This is symptom tree T077.

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

(Continued)

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

Cause

Internal engine damage

Correction

Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-051. Remove the oil pan and inspect for damaged camshaft, cam followers, push rods, pistons, and liners. Refer to Procedure 007-025.

Engine Will Not Crank or Cranks Slowly (Electric Starter)

This is symptom tree T078.

Cause	Correction
<p>Battery voltage is low</p>	<p>Check the batteries and the unswitched battery supply circuit. Refer to Procedure 013-009 in the base engine Troubleshooting and Repair Manual, Procedure 019-087 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedures 2-02 and 2-04 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084, and the OEM service manual.</p>
<p>OK ↓</p>	
<p>Battery cables or connections are loose, broken, or corroded (excessive resistance)</p>	<p>Check the battery cables and connections. Refer to Procedure 013-009.</p>
<p>OK ↓</p>	
<p>Engine driven units are engaged</p>	<p>Disengage engine driven units.</p>
<p>OK ↓</p>	
<p>Lubricating oil temperature is below specification</p>	<p>Install an oil pan heater or drain the oil and fill the system with warm oil.</p>
<p>OK ↓</p>	
<p>Lubricating oil does not meet specifications for operating conditions</p>	<p>Change the oil and filters. Refer to Procedures 007-025 and . Use the oil type recommended in Section V of the Engine Operation and Maintenance Manual.</p>
<p>OK ↓</p>	
<p>Crankshaft rotation is impaired</p>	<p>Check the crankshaft for ease of rotation. Refer to Procedure 001-016.</p>
<p>OK ↓</p>	
<p>Battery capacity is below specification</p>	<p>Refer to Electrical System Specifications in Section . Replace the batteries if necessary.</p>
<p>OK ↓</p>	
<p>Battery cables are not the correct gauge or length</p>	<p>Replace the battery cables with a larger gauge or shorter length cables. Refer to Electrical System Specifications in Section 13.</p>
<p>OK ↓</p>	

(Continued)

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

Cause	Correction
Starting circuit component is malfunctioning	Check the starting circuit components. Refer to the OEM service manual.
OK ↓	
Starting motor pinion or ring gear is damaged	Remove the starting motor and visually inspect the gear. Refer to Procedure 013-020 and the manufacturer's instructions.
OK ↓	
Hydraulic lock in a cylinder	Remove the injectors and rotate the crankshaft. Look for the source of fluid in the cylinder. Refer to Procedures 006-026 and 001-016.
OK ↓	
Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-051. Remove the oil pan and inspect for damaged camshaft, cam followers, push rods, pistons, and liners. Refer to Procedure 007-025.

Engine Will Not Shut Off

This is symptom tree T081.

Cause

Correction

Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.

OK



Key switch circuit is malfunctioning

Check the vehicle key switch circuit. Refer to Procedure 019-064 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 2-05 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



PT fuel pump fuel shutoff valve manual opening is engaged

Check the manual opening knob to make sure it is in the fully **counterclockwise** position. Refer to Procedure 005-043 and the PT Fuel Pump Rebuild and Calibration Manual, Bulletin No. 3379084.

OK



Fuel shutoff valve (FSOV) solenoid or circuit is malfunctioning (electronic controlled fuel systems)

Check the fuel shutoff valve solenoid and circuit. Refer to Procedures 019-049 and 019-050 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedures 2-09 and 2-10 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Fuel shutoff valve (FSOV) is stuck open

Verify that the solenoid or coil is **not** being energized by a short in the wiring. Remove the FSOV and check the valve disc and spring washer. Refer to the Shop Manual, Bulletin No. 3666075.

OK



Fuel drain line restriction

Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012.

OK



(Continued)

Engine Will Not Shut Off (Continued)

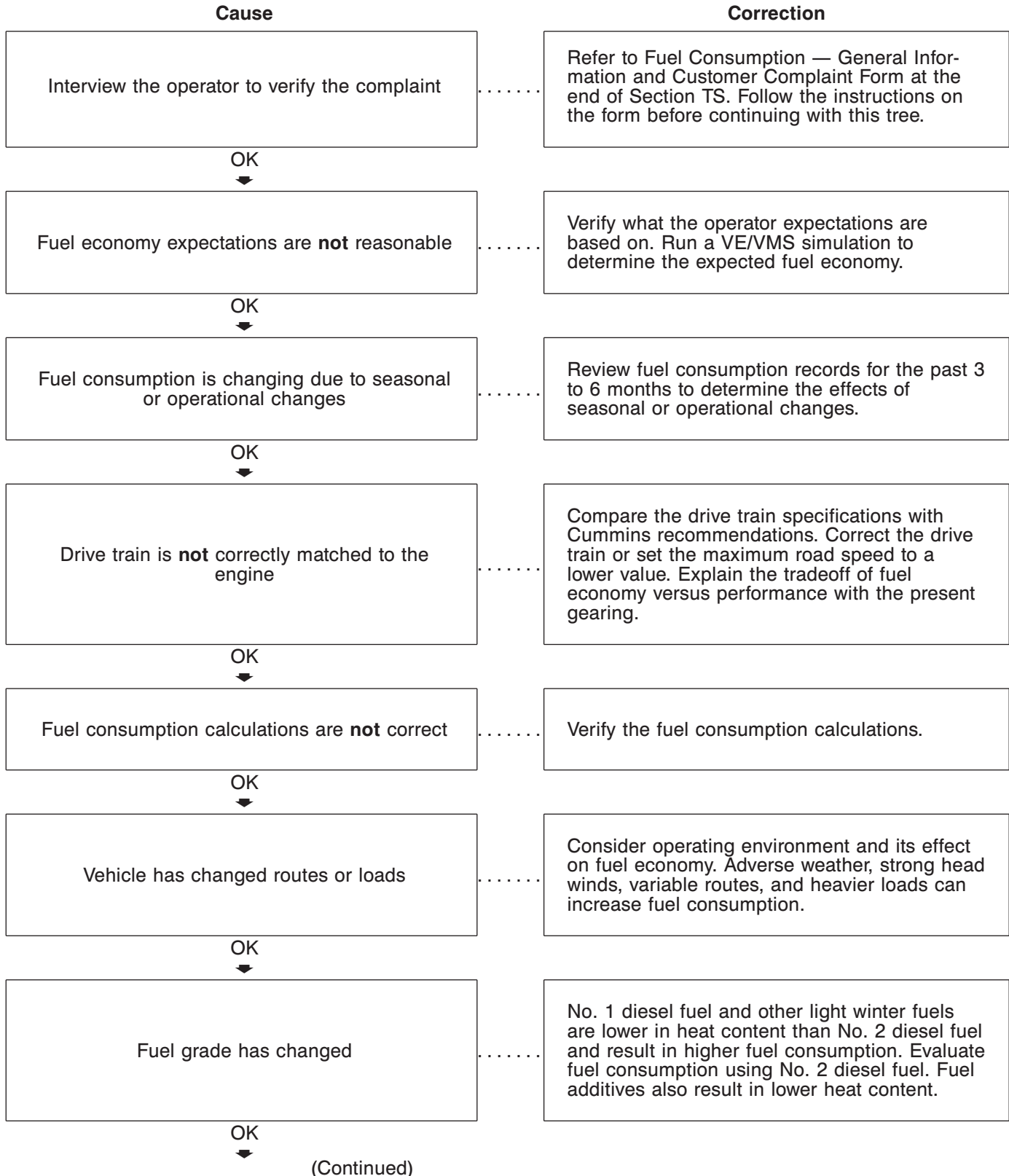
Cause	Correction
Overhead fuel tank check valve is restricted or is not opening	Check the fuel tank check valve for debris. Check the valve for the correct plumbing arrangement. Refer to Section 5, General Information.
OK ↓	
Injector check ball is not seating correctly or is missing	Check the injectors. Repair or replace the injectors as necessary. Refer to Procedure 006-026.
OK ↓	
Engine is running on fumes drawn into the air intake	Check the air intake ducts. Locate and isolate the source of the fumes. Repair as necessary. Refer to the OEM service manuals.
OK ↓	
Fuel tank vents are plugged or damaged	Remove and clean the tank vents. Replace the vents if necessary. Refer to the OEM service manuals.

Fuel Consumption Excessive (CELECT™ and CELECT™ Plus)

This is symptom tree T087-155.

NOTE: For heavy duty automotive applications, continue with this tree or refer to Troubleshooting Excessive Fuel Consumption Complaints, Bulletin No. 3666094.

NOTE: If the fuel consumption complaint also includes a driveability or low power complaint, refer to the Driveability/Low Power Customer Complaint Form at the end of Section TS.



(Continued)

Fuel Consumption Excessive (CELECT™ and CELECT™ Plus) (Continued)

Cause	Correction
Coolant temperature is below specification	Refer to the Coolant Temperature Below Normal symptom tree.
OK ↓	
Lubricating oil temperature is below specification	Install an oil pan heater or drain the oil and fill the system with warm oil.
OK ↓	
Vehicle or trailer brakes are dragging	Check the brakes for dragging. Refer to the OEM service manual.
OK ↓	
Wheel alignment is not correct	Check the wheel alignment. Refer to the OEM service manual and the manufacturer's instructions.
OK ↓	
Tires on the tractor or trailer are new	New tires add up to 3 percent to rolling radius. Verify tire revolutions per mile with new tires and calculate fuel consumption. For electronic engines, enter the correct value for tire revolutions per mile in the electronic control module (ECM).
OK ↓	
Hubometer or odometer is miscalibrated	Check the hubometer and odometer calibrations. Calibrate or replace the hubometer or odometer if necessary. Calculate fuel consumption with new mileage figures.
OK ↓	
Tires on the tractor or trailer are worn or have low pressure	Check the tires on the tractor and trailer. Repair or inflate the tires as necessary. Evaluate fuel consumption again.
OK ↓	
Fuel consumption has increased after an engine repair	Evaluate the engine repair to determine its effect on fuel consumption. Check part numbers to make sure the correct parts were used. Refer to the Control Parts List (CPL), Bulletin No. 3379133.

OK
↓
(Continued)

Fuel Consumption Excessive (CELECT™ and CELECT™ Plus) (Continued)

Cause

Correction

Operator technique is **not** correct

Verify road speeds, shift rpm, cruise control speeds, and engine operating speed with the operator.

OK



Fuel leak

Check the fuel lines, fuel connections, and fuel filters for leaks. Refer to Procedures 006-024 and 006-013. Check the fuel lines to the supply tanks. Refer to OEM service manuals.

OK



Vehicle speed sensor (VSS) has been tampered with

Check the vehicle speed sensor and circuit for tampering. Check for Fault Code 242. Repair the circuit as necessary. Refer to Procedures 019-090 and 019-091 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedures 1-02 and 1-03 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Lubricating oil level is above specification

Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedures 007-009 and 007-025.

OK



Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.

OK



Programmable parameters or selected features are **not** correct or are **not** set the same as the values in comparable vehicles

Check the programmable parameters and the selected features with an electronic service tool. Make sure that gear down protection road speeds are set to the same values as in comparable vehicles. Refer to the appropriate electronic service tool manual.

OK



(Continued)

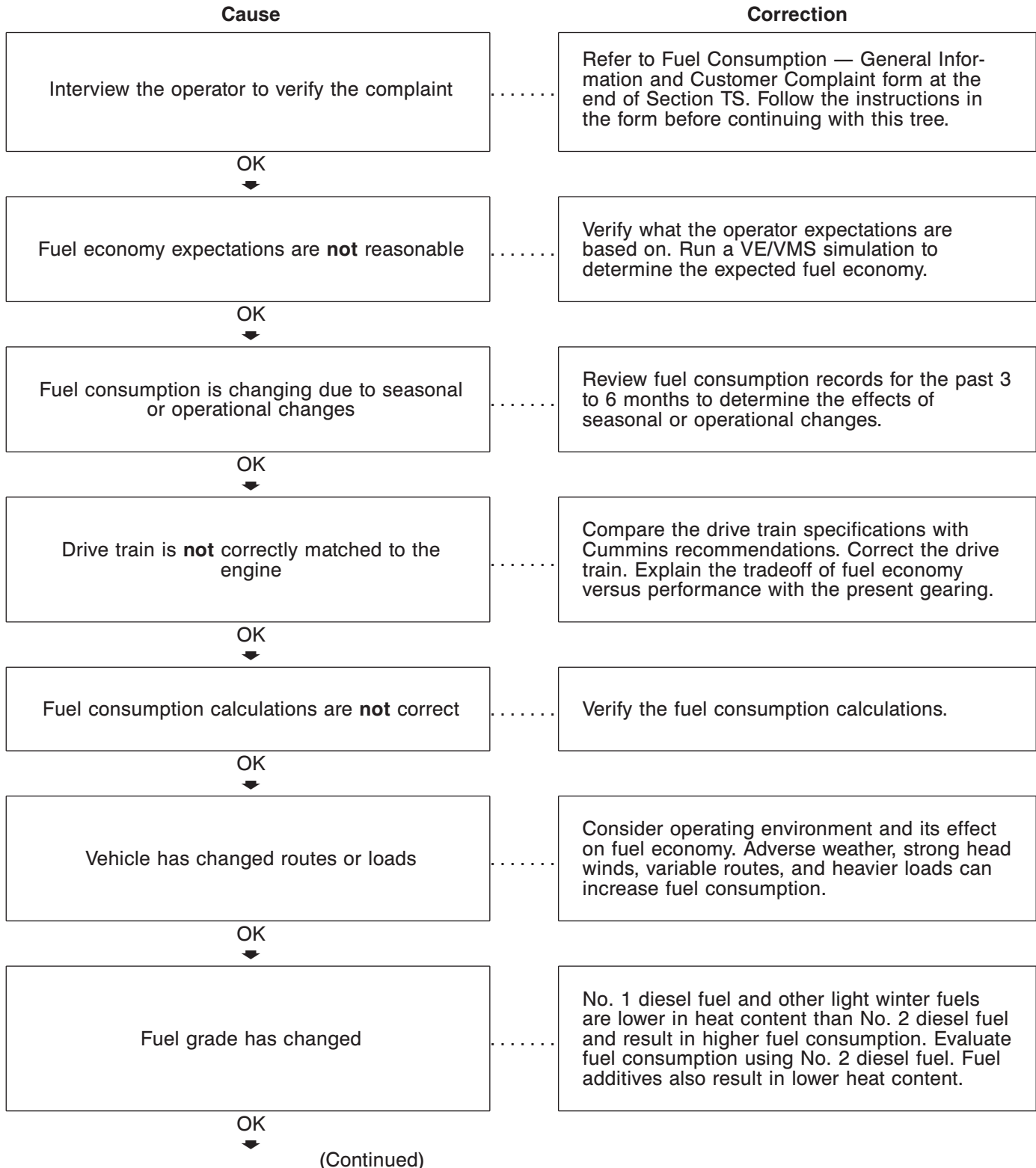
Fuel Consumption Excessive (CELECT™ and CELECT™ Plus) (Continued)

Cause	Correction
Electronic control module (ECM) calibration is not correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 4-01 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Air intake system restriction	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ↓	
Exhaust system restriction	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ↓	
Intake manifold pressure (boost) is below specification	Refer to the Intake Manifold Pressure (Boost) is Below Normal symptom tree.
OK ↓	
Air intake or exhaust leaks	Visually inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ↓	
Charge air cooler (CAC) is malfunctioning	Inspect the CAC for air restriction or leaks. Refer to Procedure 010-027.

Fuel Consumption Excessive (PT)

This is symptom tree T087-011.

NOTE: If the fuel consumption complaint also includes a driveability or low power complaint, refer to the Driveability/Low Power Customer Complaint Form at the end of Section TS.



(Continued)

Fuel Consumption Excessive (PT) (Continued)

Cause	Correction
Coolant temperature is below specification	Refer to the Coolant Temperature Below Normal symptom tree.
OK ↓	
Lubricating oil temperature is below specification	Install an oil pan heater or drain the oil and fill the system with warm oil.
OK ↓	
Vehicle or trailer brakes are dragging	Check the brakes for dragging. Refer to the OEM service manual.
OK ↓	
Wheel alignment is not correct (tractor or trailer)	Check the wheel alignment. Refer to the OEM service manual and the manufacturer's instructions.
OK ↓	
Tires on the tractor or trailer are new	New tires add up to 3 percent to rolling radius. Verify tire revolutions per mile with new tires and calculate fuel consumption. For electronic engines, enter the correct value for tire revolutions per mile in the electronic control module (ECM).
OK ↓	
Hourmeter is miscalibrated	Check the hourmeter. Calibrate or replace the hourmeter if necessary. Calculate fuel consumption with new figures.
OK ↓	
Tires on the tractor or trailer are worn or have low pressure	Check the tires on the tractor and trailer. Repair or inflate the tires as necessary. Evaluate fuel consumption again.
OK ↓	
Fuel consumption has increased after an engine repair	Evaluate the engine repair to determine its effect on fuel consumption. Check part numbers to make sure the correct parts were used. Refer to the Control Parts List (CPL), Bulletin No. 3379133.
OK ↓	

(Continued)

Fuel Consumption Excessive (PT) (Continued)

Cause	Correction
Operator technique is not correct	Explain the correct engine operation to the operator. Refer to the Operation and Maintenance Manual for your engine application.
OK ↓	
Fuel leak	Check the fuel lines, fuel connections, and fuel filters for leaks. Refer to Procedures 006-024 and 006-013. Check the fuel lines to the supply tanks. Refer to the OEM service manuals.
OK ↓	
Lubricating oil level is above specification	Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedures 007-009 and 007-025.
OK ↓	
Air intake system restriction	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ↓	
Exhaust system restriction	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK ↓	
Intake manifold pressure (boost) is below specification	Refer to the Intake Manifold Pressure (Boost) is Below Normal symptom tree.
OK ↓	
Air intake or exhaust leaks	Visually inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ↓	
Charge air cooler (CAC) is malfunctioning	Inspect the CAC for air restriction or leaks. Refer to Procedure 010-027.
OK ↓	
(Continued)	

Fuel Consumption Excessive (PT) (Continued)

Cause	Correction
Injector cup is damaged or is not correct	Check the injector cups for damage and for correct part numbers. Refer to Procedure 006-026.
OK ↓	
Overhead adjustments are not correct	Adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	
Fuel drain line is bent	Check the fuel drain line. Repair if necessary. Refer to Procedure 006-013.
OK ↓	
Injector calibration is not correct	Calibrate the injectors. Refer to Procedure 006-026.
OK ↓	
Static injection timing is not correct	Check the static injection timing. Refer to Procedure 006-025.
OK ↓	
Step timing control (STC) oil control valve is damaged	Remove and inspect the STC valve. Refer to Procedure .
OK ↓	
Fuel grade is not correct for the application or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual for your engine application.

Fuel in the Coolant

This is symptom tree T091.

Cause

Correction

Bulk coolant supply is contaminated

Check the bulk coolant supply. Drain the coolant and replace with non-contaminated coolant. Replace the coolant filters. Refer to Procedure 008-018.

OK



Fuel heater is malfunctioning

Check the fuel heater and replace if necessary. Refer to the manufacturer's instructions.

OK



Cylinder head is cracked or porous or an injector sleeve is leaking

Pressure test the cylinder head and inspect the injector sleeves. Refer to Procedure 002-004.

Fuel in the Lubricating Oil

This is symptom tree T092.

Cause	Correction
Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with non-contaminated oil. Replace the oil filters. Refer to Procedure 007-025 and.
OK ↓	
Engine idle time is excessive	Low oil and coolant temperatures can be caused by long idle time (greater than 10 minutes). Shut off the engine rather than idle for long periods. If idle time is necessary, raise the idle speed. Refer to the Operation and Maintenance Manual for your engine application.
OK ↓	
Fuel drain line restriction	Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012.
OK ↓	
Top injector o-ring or injector timing plunger is damaged	Perform the fluorescent dye tracer test to find the bad injector. Replace the injector or o-ring. Refer to Procedure 006-026.
OK ↓	
Injector adapter wall is damaged behind the balance orifice	Check the injectors for damage. Refer to Procedure 006-026.
OK ↓	
Injector cup is damaged or is not correct	Check the injector cups for damage and for correct part numbers. Refer to Procedure 006-026.
OK ↓	
Fuel pump gear pump main shaft seals are leaking	Check the gear pump main shaft and seals. Refer to the Engine Shop Manual, Bulletin No. 3666075.
OK ↓	
Cylinder head is cracked or porous	Pressure test the cylinder head. Refer to Procedure 002-004.

OK
↓
(Continued)

Fuel in the Lubricating Oil (Continued)

Cause

Correction

STC oil control valve is damaged

Remove and inspect the STC valve. Refer to Procedure .

Intake Manifold Air Temperature Above Specification

This is symptom tree T096.

Cause	Correction
Intake manifold temperature sensor is malfunctioning	Check the intake manifold temperature sensor. Refer to Procedure 019–059 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3–10 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Intake manifold temperature gauge is malfunctioning	Test the temperature gauge. Refer to the OEM service manual.
OK ↓	
Vehicle speed is too low for adequate cooling with high engine load	Reduce the engine load. Increase the engine (fan) rpm by downshifting.
OK ↓	
Radiator shutters are not opening completely or the shutterstat setting is wrong	Inspect the radiator shutters. Repair or replace if necessary. Refer to the manufacturer’s instructions. Check the shutterstat setting. Refer to Procedure 008–049.
OK ↓	
Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 775 cm ² [120 in ²] or approximately 28 cm x 28 cm [11 in x 11 in] of opening at all times.
OK ↓	
Charge air cooler (CAC) fins, radiator fins, or freon condenser fins are damaged or obstructed with debris.	Inspect the CAC, freon condenser, and radiator fins. Clean if necessary. Refer to Procedures 010–027 and 008–042.
OK ↓	
Fan shroud is damaged or missing, or the air recirculation baffles are damaged or missing	Inspect the shroud and the recirculation baffles. Repair, replace, or install if necessary. Refer to Procedures 008–038 and 008–048 and the OEM service manual.
OK ↓	
Fan drive belt is loose	Check the belt tension and tighten if necessary. Refer to Procedure 008–002.

OK
↓
(Continued)

Intake Manifold Air Temperature Above Specification (Continued)

Cause

Correction

Fan drive or fan controls are malfunctioning

Check the fan drive and controls. Refer to Procedure 008-024, 008-025, 008-026, 008-027, or 008-028.

OK
↓

Fan is **not** an adequate size for the application

Verify that the fan is the correct size. Refer to the engine and OEM specifications.

Intake Manifold Pressure (Boost) is Below Normal

This is symptom tree T097.

Cause	Correction
Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.
OK ↓	
Turbocharger is not correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin No. 3379133. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK ↓	
Turbocharger is worn or damaged	Check the turbocharger for damage. Measure the turbine and compressor wheel clearances. Refer to Procedures 010-039, 010-038, and 010-047.
OK ↓	
Air intake or exhaust leaks	Visually inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK ↓	
Rocker lever housing gasket is leaking	Check the rocker lever housing gasket. Refer to Procedure 003-013.
OK ↓	
Air compressor connection is loose or damaged	Check the connection between the manifold and the air compressor. Repair or replace if necessary.
OK ↓	
Air intake system restriction	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK ↓	
Exhaust system restriction	Check the exhaust system for restrictions. Refer to Procedure 011-009.

OK
↓
(Continued)

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

Cause

Correction

Charge air cooler (CAC) is malfunctioning

Inspect the CAC for air restriction or leaks.
Refer to Procedure 010-027.

OK

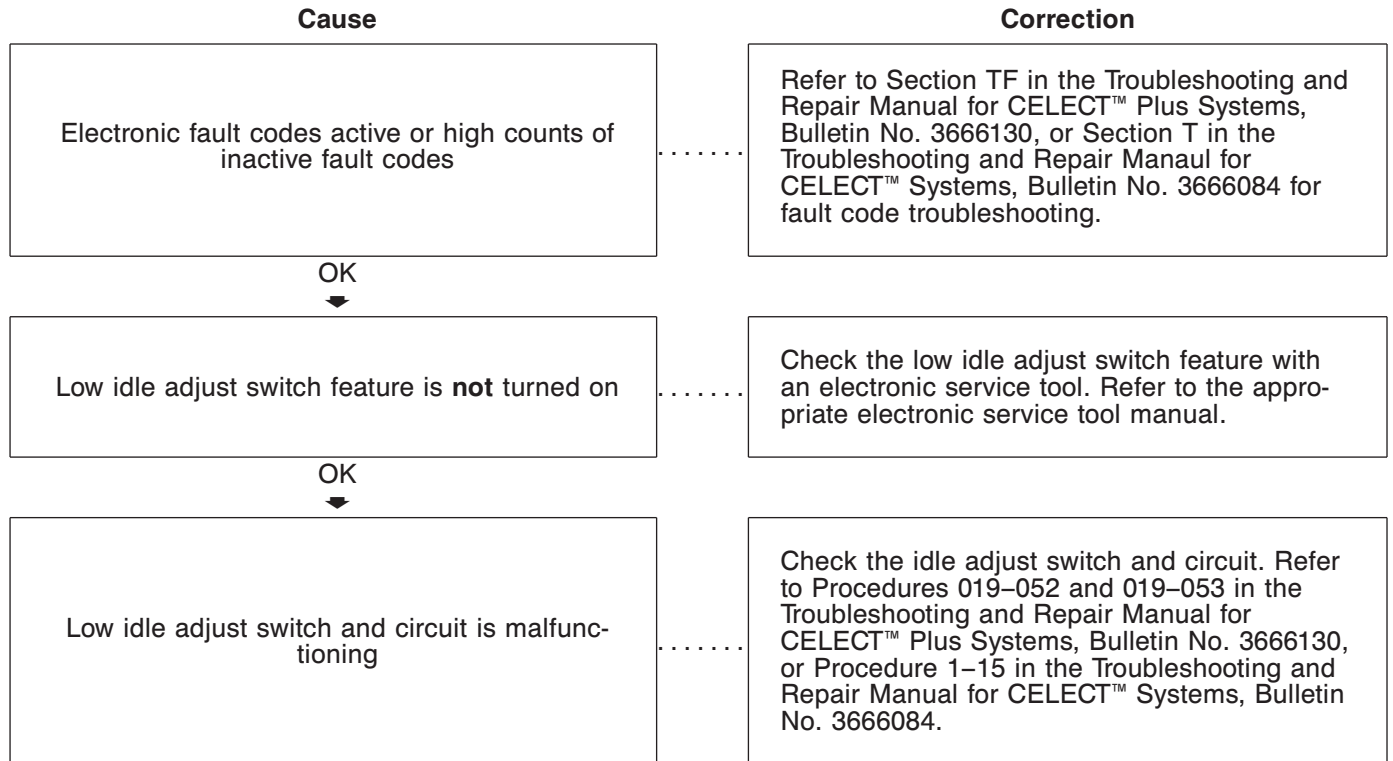


Engine power output is low

Refer to the Engine Power Output Low symptom tree.

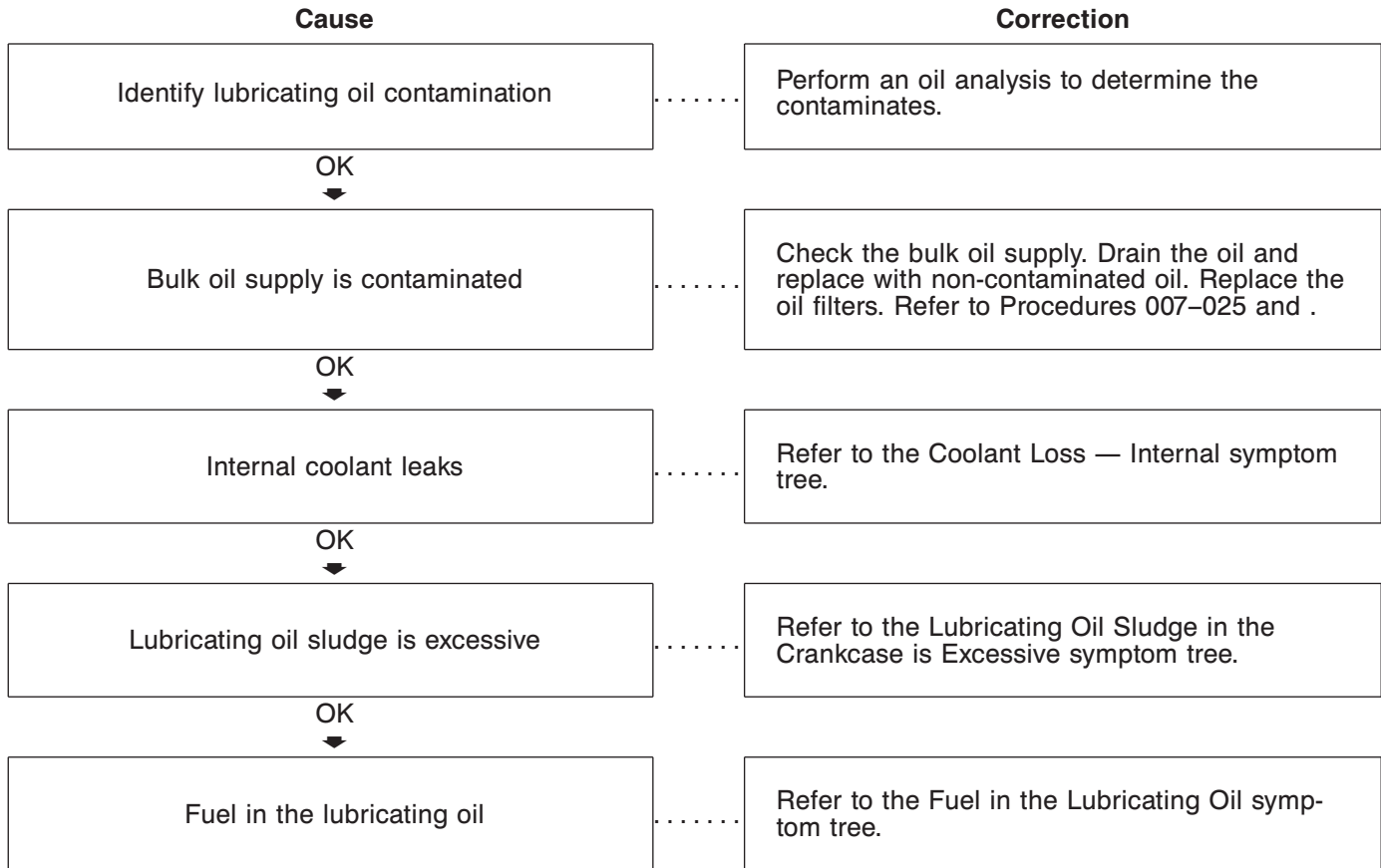
Low Idle Adjust Switch Does Not Work

This is symptom tree T099.



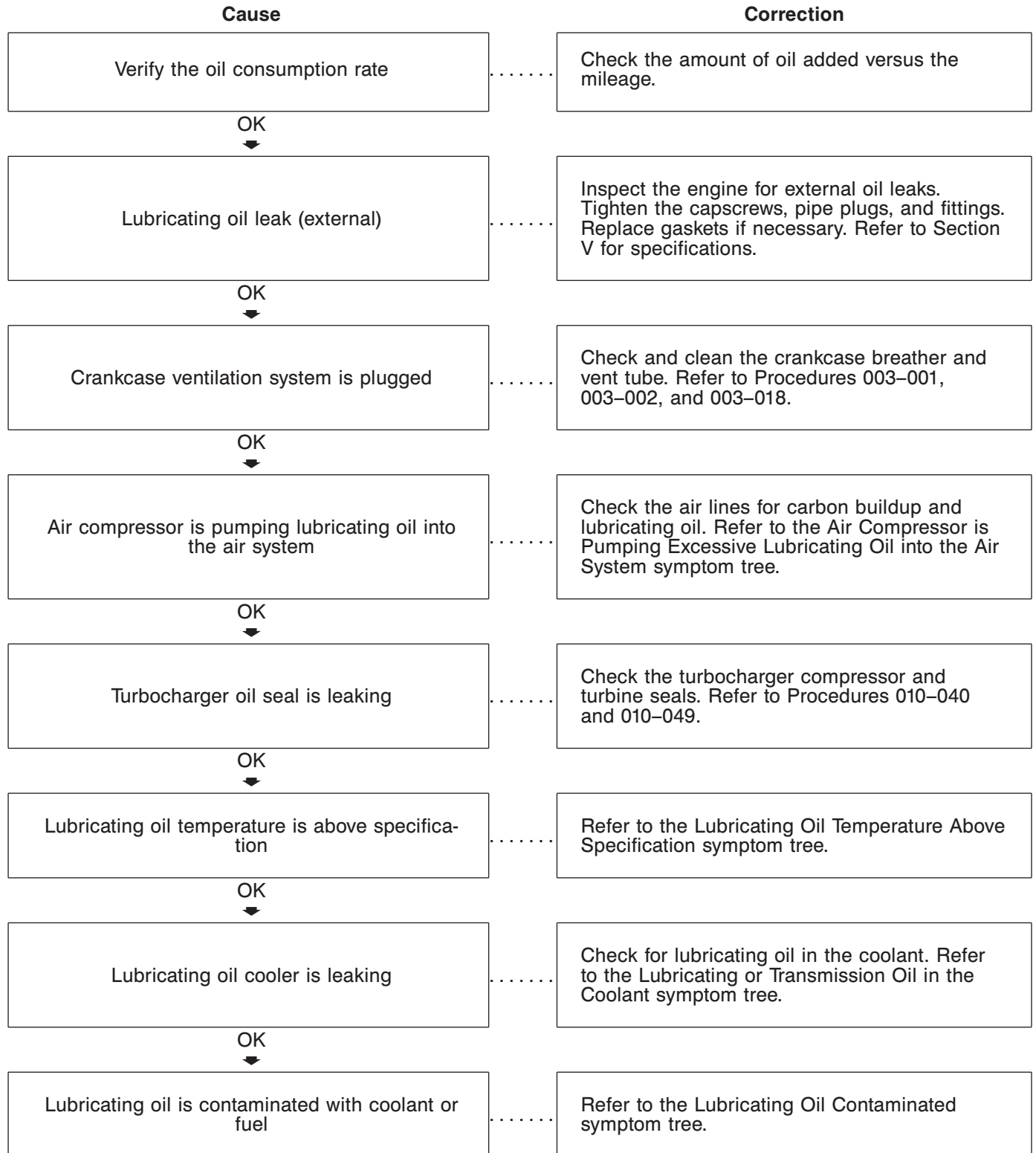
Lubricating Oil Contaminated

This is symptom tree T103.



Lubricating Oil Consumption Excessive

This is symptom tree T102.



(Continued)

Lubricating Oil Consumption Excessive (Continued)

Cause	Correction
Lubricating oil dipstick calibration is not correct	Check the dipstick calibration. Refer to Procedure 007-009.
OK ↓	
Lubricating oil does not meet specifications for operating conditions	Change the oil and filters. Refer to Procedures 007-025 and . Use the oil type recommended in Section V of the Engine Operation and Maintenance Manual.
OK ↓	
Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to Section V of the Operation and Maintenance manual for your engine application.
OK ↓	
Step timing control (STC) oil control valve is damaged	Remove and inspect the STC valve. Refer to Procedure 006-037.
OK ↓	
Piston, piston rings, or cylinder liner is worn or damaged	Check for air intake system leaks. Refer to Procedure 010-024. Check the pistons, piston rings, and liners for wear or damage. Refer to Procedures 001-043, 001-047, and 001-028.
OK ↓	
Piston rings are not seated correctly (after an engine rebuild or piston installation)	Check blowby. Refer to Section 14. If blowby is excessive, check the piston rings for correct seating. Refer to Procedures 001-043 and 001-047.

Lubricating Oil in the Fuel

This is symptom tree T101.

Cause

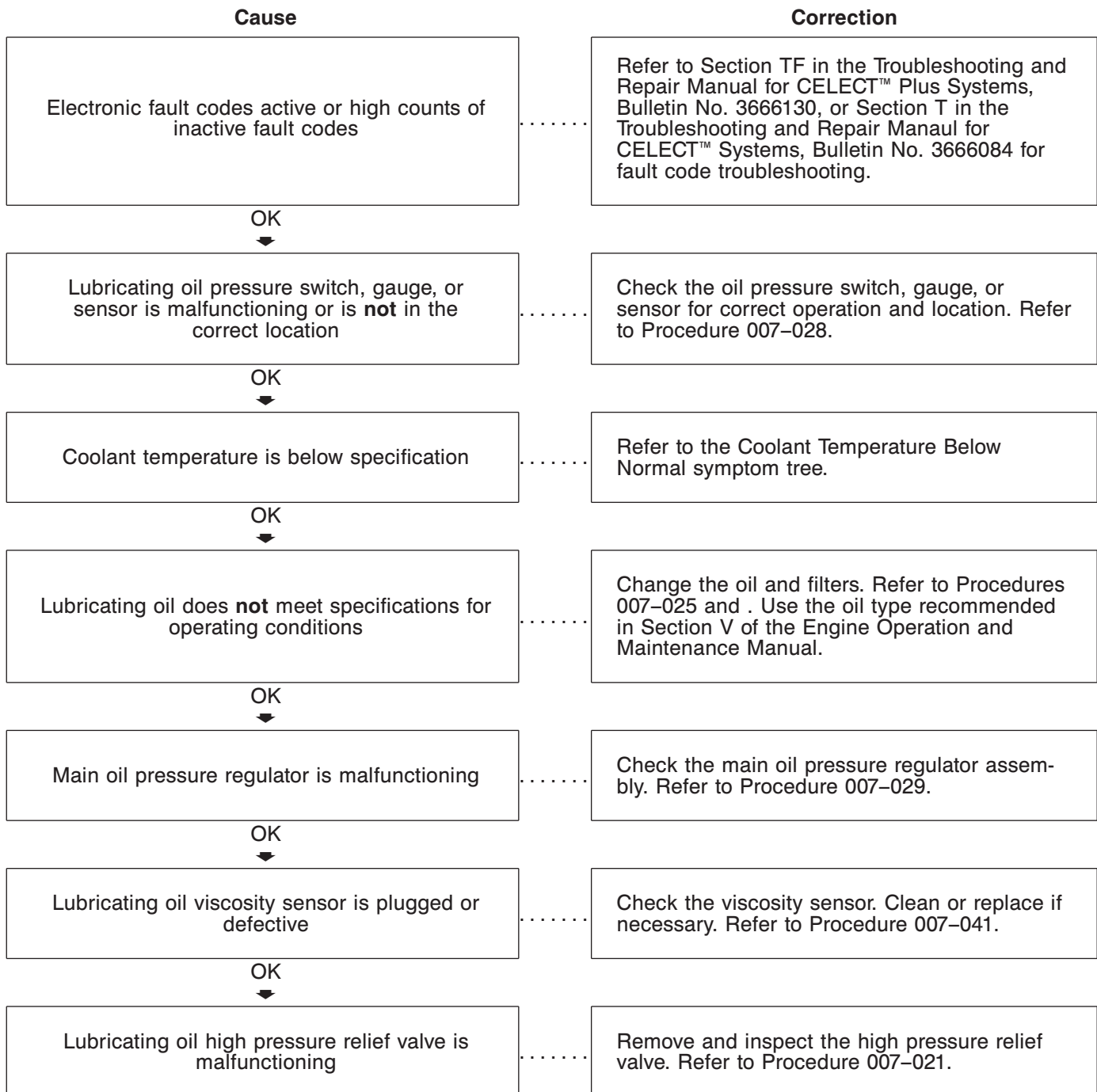
Step timing control (STC) oil control valve
barrel o-rings are missing, hardened, or cut;
retaining ring is missing; barrel and plunger
class fit is excessive

Correction

Remove the STC valve and inspect the barrel
o-rings, check for a retaining ring, and inspect
for excessive wear. Refer to Procedure
006-037.

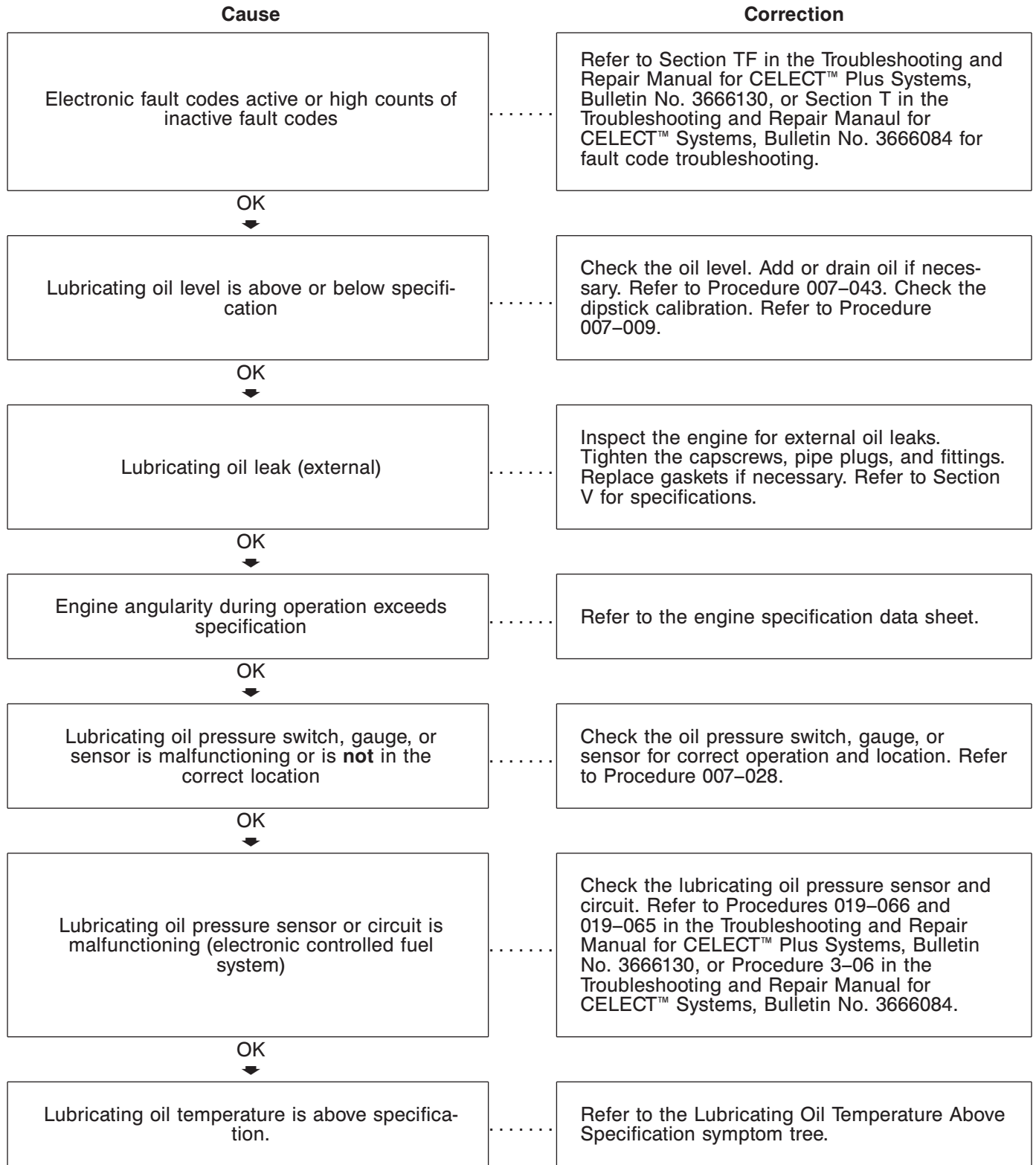
Lubricating Oil Pressure High

This is symptom tree T104.



Lubricating Oil Pressure Low

This is symptom tree T105.



OK
↓

(Continued)

Lubricating Oil Pressure Low (Continued)

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

(Continued)

Lubricating Oil Pressure Low (Continued)

Cause

Internal engine damage or internal lubricating oil leak

Correction

Analyze the lubricating oil. Inspect the oil filter. Refer to Procedure 007-051. Check the main bearings, rod bearings, cam bushings, and rocker lever bushings for excessive wear. Refer to Section 1.

Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree T106.

Cause

Correction

Bulk oil supply is contaminated

Check the bulk oil supply. Drain the oil and replace with non-contaminated oil. Replace the oil filters. Refer to Procedures 007–025 and .

OK



Lubricating oil does **not** meet specifications for operating conditions

Change the oil and filters. Refer to Procedures 007–025 and . Use the oil type recommended in Section V of the Engine Operation and Maintenance Manual.

OK



Lubricating oil drain interval is excessive

Verify the correct lubricating oil drain interval. Refer to Section V of the Operation and Maintenance Manual for your engine application.

OK



Fuel grade is **not** correct for the application or the fuel quality is poor

Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual for your engine applicaiton.

OK



Coolant temperature is below specification

Refer to the Coolant Temperature Below Normal symptom tree.

OK



Lubricating oil is contaminated with coolant or fuel

Refer to the Lubricating Oil Contaminated symptom tree.

OK



Crankcase pressure is excessive

Check for excessive blowby. Refer to Section 14. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.

OK



Crankcase ventilation system is plugged

Check and clean the crankcase breather and vent tube. Refer to Procedures 003–001, 003–002, and 003–018.

OK



(Continued)

Lubricating Oil Sludge in the Crankcase Excessive (Continued)

Cause	Correction
Step timing control (STC) oil control valve is damaged	Remove and inspect the STC valve. Refer to Procedure 006-037.
OK ↓	
Injector cup is damaged or is not correct	Check the injector cups for damage and for correct part numbers. Refer to Procedure 006-026.
OK ↓	
Static injection timing is not correct	Check the static injection timing. Refer to Procedure 006-025.

Lubricating Oil Temperature Above Specification

This is symptom tree T107.

Cause

Correction

Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.

OK



Lubricating oil level is above or below specification

Check the oil level. Add or drain oil if necessary. Refer to Procedure 007-043. Check the dipstick calibration. Refer to Procedure 007-009.

OK



Coolant temperature is above specification

Refer to the Coolant Temperature is Above Normal — Sudden Overheat or the Coolant Temperature is Above Normal — Gradual Overheat symptom tree.

OK



Lubricating oil 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.

OK



Lubricating oil temperature sensor or circuit is malfunctioning (electronic controlled fuel system)

Check the lubricating oil temperature sensor and circuit. Refer to Procedures 019-067 and 019-068 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3-06 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Lubricating oil thermostat is malfunctioning

Check the oil thermostat. Refer to Procedure 007-039.

OK

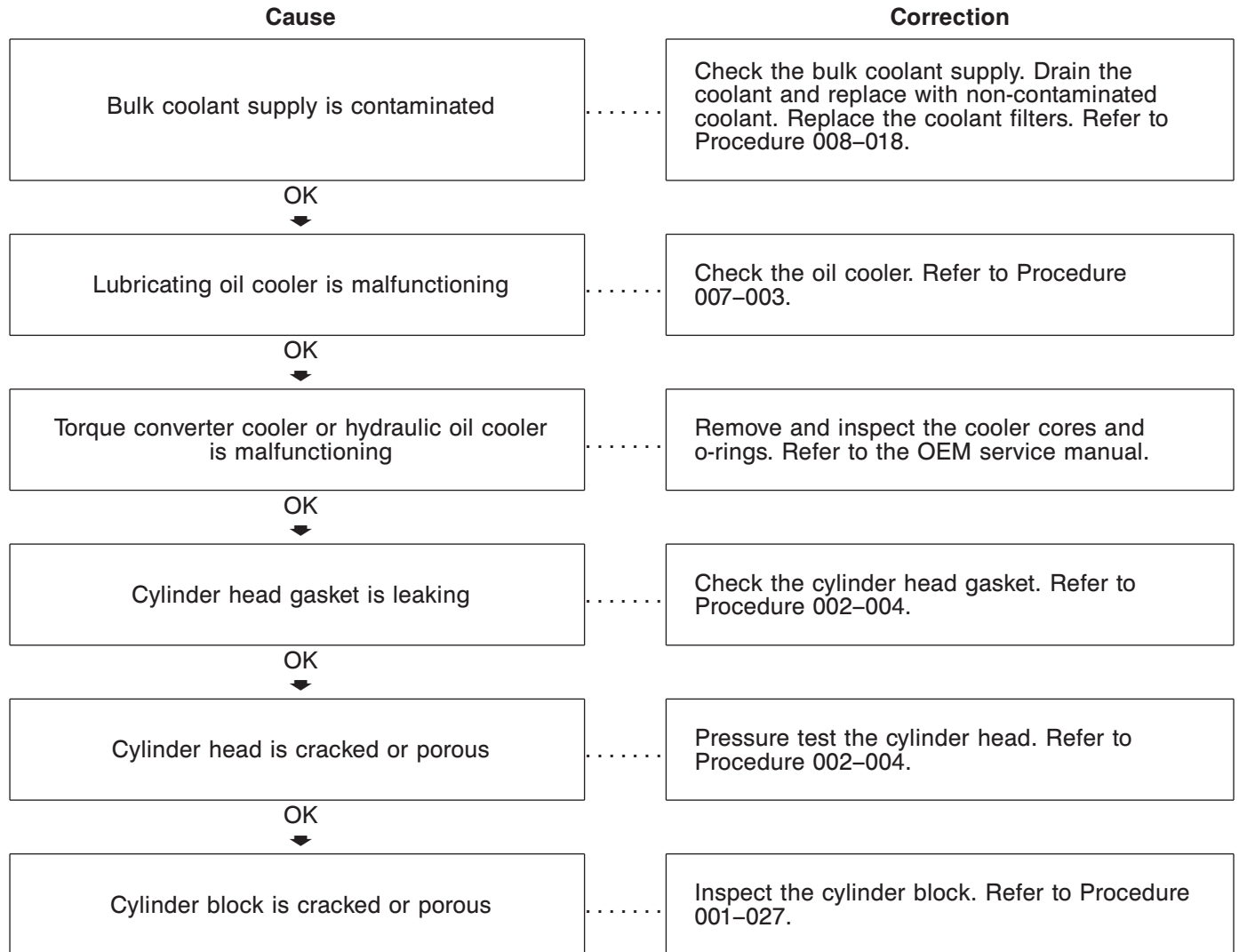


Lubricating oil cooler is malfunctioning

Check the oil cooler. Refer to Procedure 007-003.

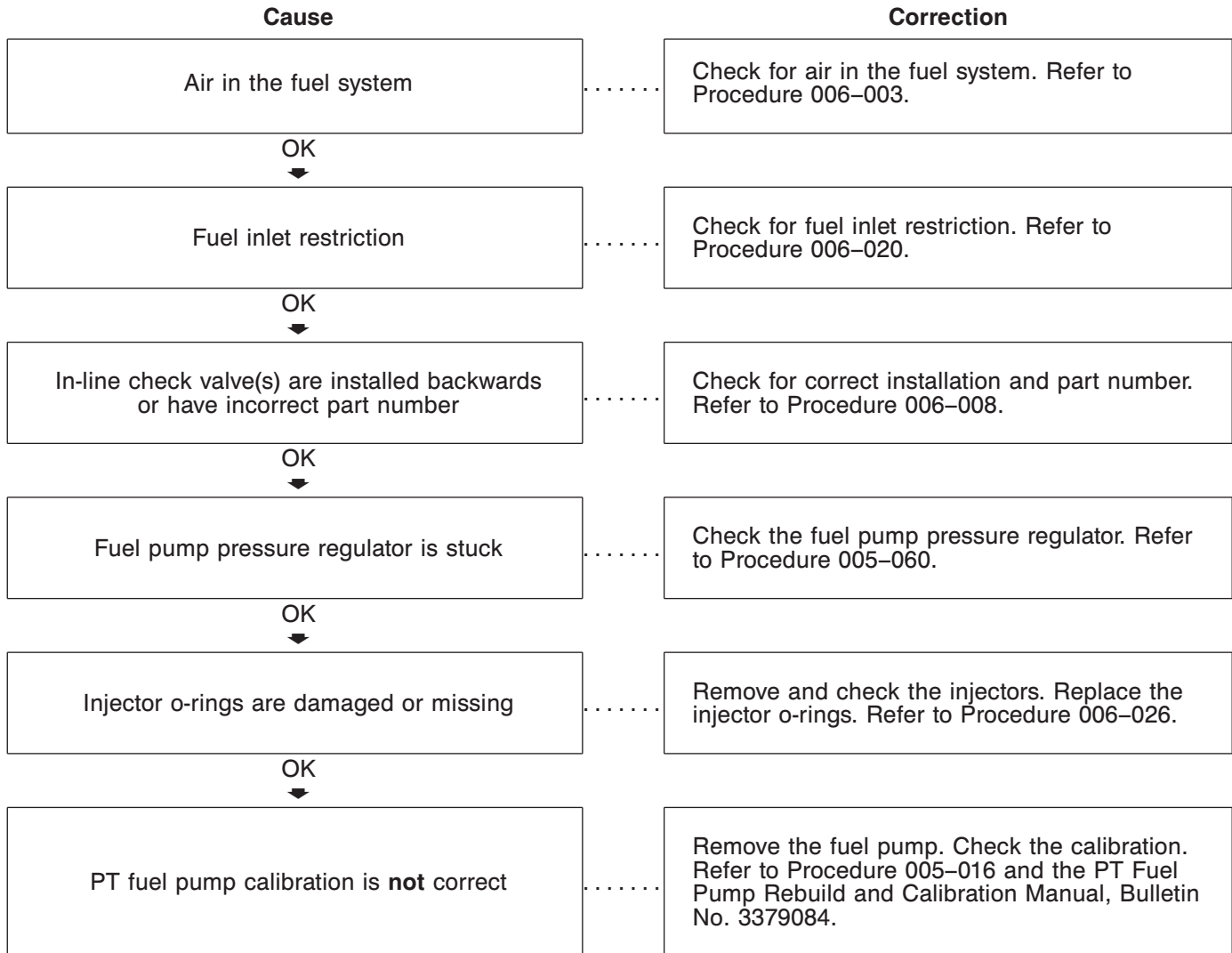
Lubricating or Transmission Oil in the Coolant

This is symptom tree T108.



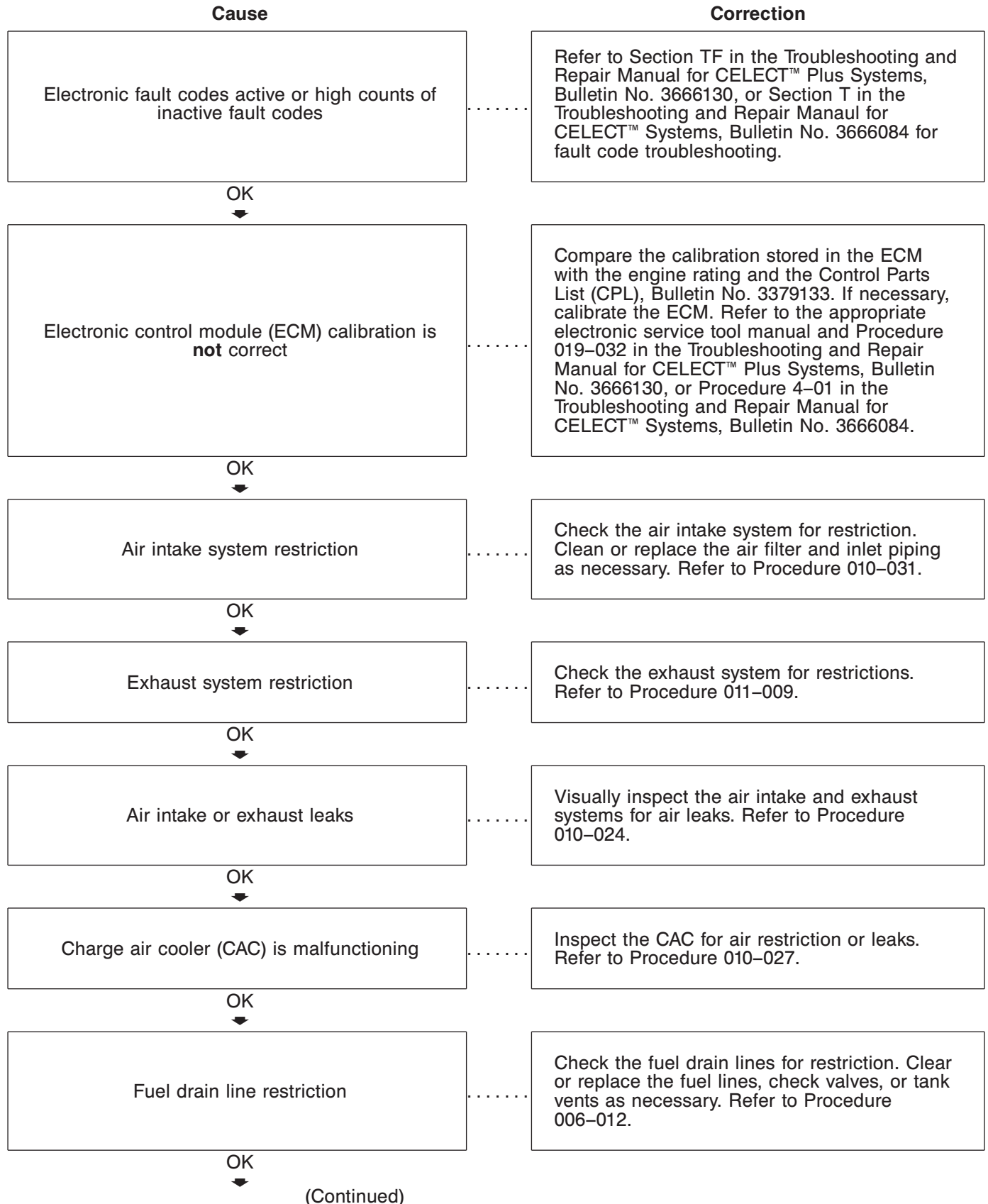
Operating Fuel Pressure is Low

This is symptom tree T109.



Smoke, Black — Excessive (CELECT™ and CELECT™ Plus)

This is symptom tree T116-155.



(Continued)

Smoke, Black — Excessive (CELECT™ and CELECT™ Plus) (Continued)

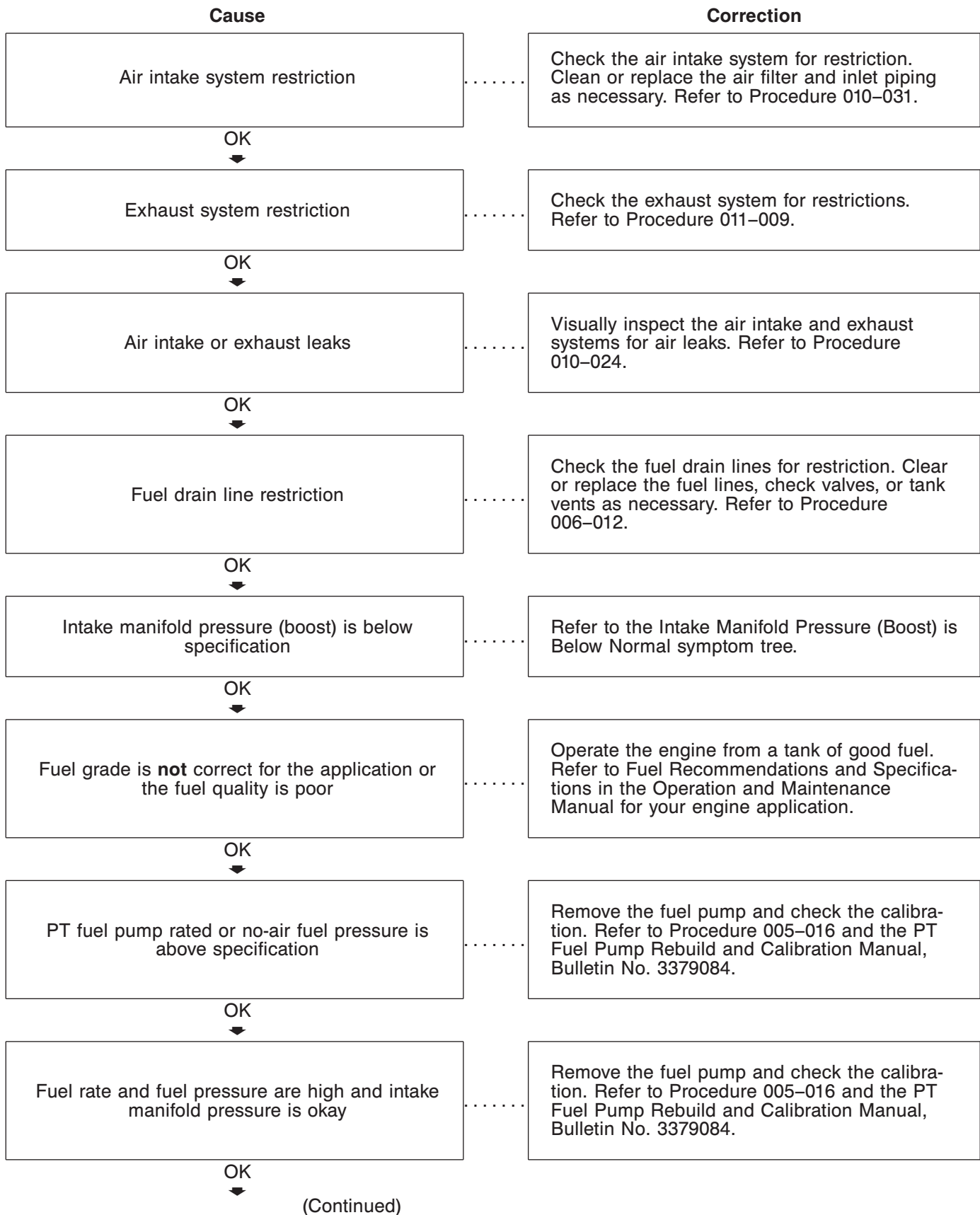
Cause	Correction
Intake manifold pressure (boost) is below specification	Refer to the Intake Manifold Pressure (Boost) is Below Normal symptom tree.
OK ↓	
Overhead adjustments are not correct	Adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	
Injector is malfunctioning (CELECT™ and CELECT™ Plus)	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-005 and 006-026.
OK ↓	
Fuel grade is not correct for the application or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual for your engine application.
OK ↓	
Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedures 003-001, 003-002, and 003-018.
OK ↓	
Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedures 010-040 and 010-049.
OK ↓	
Turbocharger wheel clearance is out of specification	Check the radial bearing clearance and axial clearance. Inspect the turbocharger. Repair or replace the turbocharger if necessary. Refer to Procedures 010-038 and 010-047.
OK ↓	
Fuel rate is low, fuel pressure is okay, intake manifold pressure is high, and ambient air temperature is between 0° and 38°C [32° and 100°F]	Check the turbocharger, injectors, cylinder head, and pistons for correct part numbers. Refer to the Control Parts List (CPL), Bulletin No. 3379133.
OK ↓ (Continued)	

Smoke, Black — Excessive (CELECT™ and CELECT™ Plus) (Continued)

Cause	Correction
Static injection timing is not correct	Check the static injection timing. Refer to Procedure 006-025.
OK ↓	
Crankcase pressure is excessive	Check for excessive blowby. Refer to Section 14. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.

Smoke, Black — Excessive (PT)

This is symptom tree T116-011.



(Continued)

Smoke, Black — Excessive (PT) (Continued)

Cause	Correction
Fuel rate is high, fuel pressure is okay or low, and intake manifold pressure is okay OK ↓	Remove the injectors and check the calibration. Refer to Procedure 006-026.
Turbocharger oil seal is leaking OK ↓	Check the turbocharger compressor and turbine seals. Refer to Procedures 010-040 and 010-049.
Turbocharger wheel clearance is out of specification OK ↓	Check the radial bearing clearance and axial clearance. Inspect the turbocharger. Repair or replace the turbocharger if necessary. Refer to Procedures 010-038 and 010-047.
Overhead adjustments are not correct OK ↓	Adjust the overhead settings. Refer to Procedure 003-004.
Injector cup is damaged or is not correct OK ↓	Check the injector cups for damage and for correct part numbers. Refer to Procedure 006-026.
Fuel rate is low, fuel pressure is okay, intake manifold pressure is high, and ambient air temperature is between 0° and 38°C [32° and 100°F]	Check the turbocharger, injectors, cylinder head, and pistons for correct part numbers. Refer to the Control Parts List (CPL), Bulletin No. 3379133.

Smoke, White — Excessive (CELECT™ and CELECT™ Plus)

This is symptom tree T118-155.

Cause

Correction

Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Section T in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084 for fault code troubleshooting.

OK



Engine block heater is malfunctioning

Check the electrical sources and wiring to the cylinder block heater. Replace the block heater if necessary. Refer to the OEM service manuals.

OK



Coolant temperature is below specification

Refer to the Coolant Temperature Below Normal symptom tree.

OK



Coolant temperature sensor is malfunctioning

Check the coolant temperature sensor. Refer to Procedure 019–019 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3–09 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



Engine is operating at low ambient temperature

Check the winterfront, shutters, and under hood air. Refer to Cold Weather Operation, Bulletin No. 3387266, and the Operation and Maintenance Manual. Use intake air from under the hood in cold weather.

OK



Intake manifold temperature sensor is malfunctioning

Check the intake manifold temperature sensor. Refer to Procedure 019–059 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 3–10 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.

OK



(Continued)

Smoke, White — Excessive (CELECT™ and CELECT™ Plus) (Continued)

Cause	Correction
Electronic control module (ECM) calibration is not correct	Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin No. 3379133. If necessary, calibrate the ECM. Refer to the appropriate electronic service tool manual and Procedure 019-032 in the Troubleshooting and Repair Manual for CELECT™ Plus Systems, Bulletin No. 3666130, or Procedure 4-01 in the Troubleshooting and Repair Manual for CELECT™ Systems, Bulletin No. 3666084.
OK ↓	
Fuel grade is not correct for the application or the fuel quality is poor	Operate the engine from a tank of good fuel. Refer to Fuel Recommendations and Specifications in the Operation and Maintenance Manual for your engine application.
OK ↓	
Overhead adjustments are not correct	Adjust the overhead settings. Refer to Procedure 003-004.
OK ↓	
Injector is malfunctioning	Perform the single cylinder cut out test. Replace the injectors as necessary. Refer to Procedures 006-005 and 006-026.
OK ↓	
Static injection timing is not correct	Check the static injection timing. Refer to Procedure 006-025.
OK ↓	
Coolant is leaking into the combustion chamber	Refer to the Coolant Loss — Internal symptom tree.
OK ↓	
Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-021.
OK ↓	
Valve protrusion is below specification	Check the valve protrusion. Replace the valve seat inserts or the cylinder head. Refer to Procedures 002-019 and 002-004.
OK ↓	

(Continued)

Smoke, White — Excessive (CELECT™ and CELECT™ Plus) (Continued)

Cause

Correction

Injector protrusion is **not** correct

Check the injector protrusion. Refer to Procedure 006-028.

OK

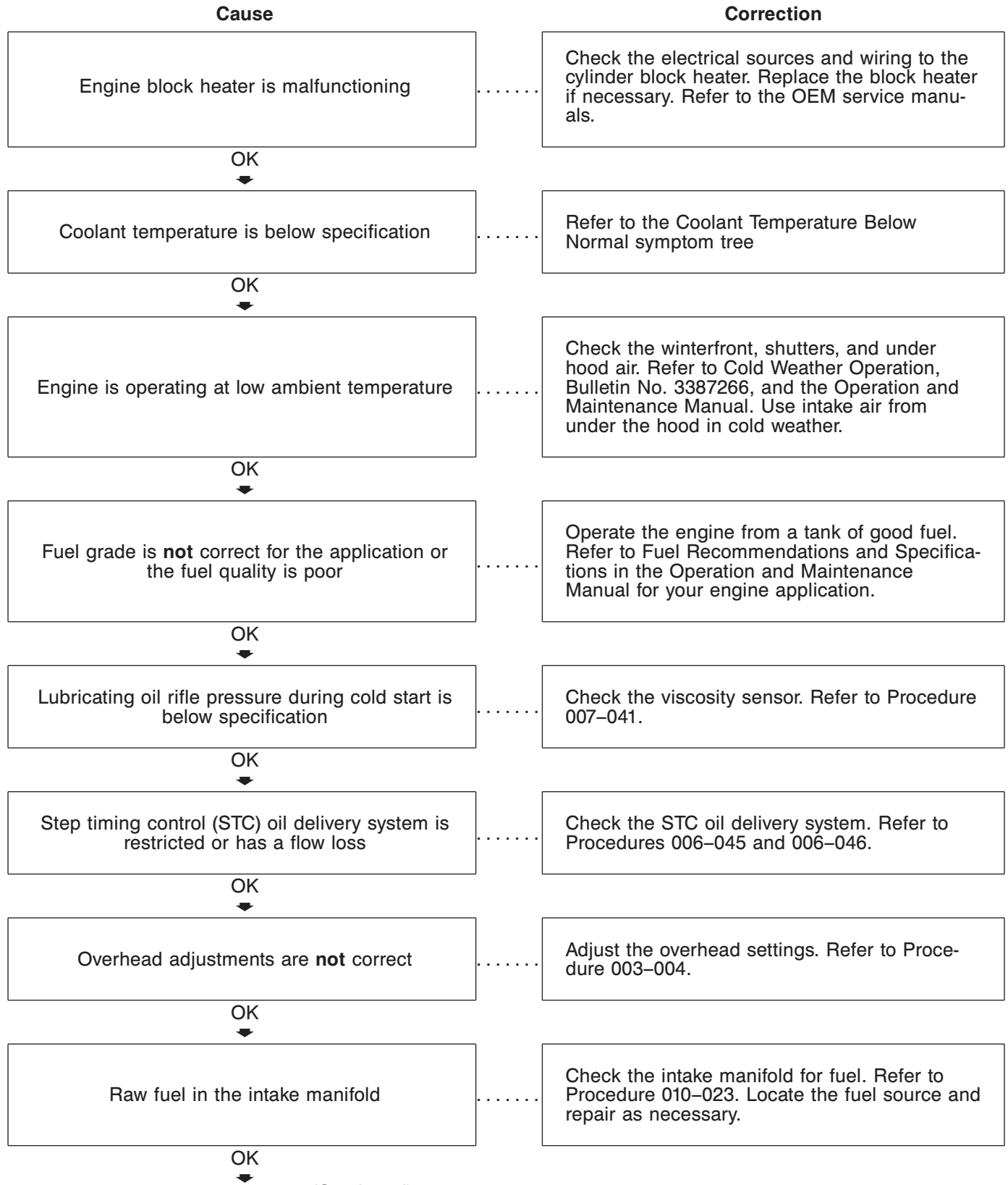


Pistons or piston rings are worn, damaged, or **not** correct

Check the pistons for correct part numbers. Refer to Control Parts List (CPL), Bulletin No. 3379133. Check the pistons and rings for wear and damage. Refer to Procedures 001-043 and 001-047.

Smoke, White — Excessive (PT)

This is symptom tree T118-011.



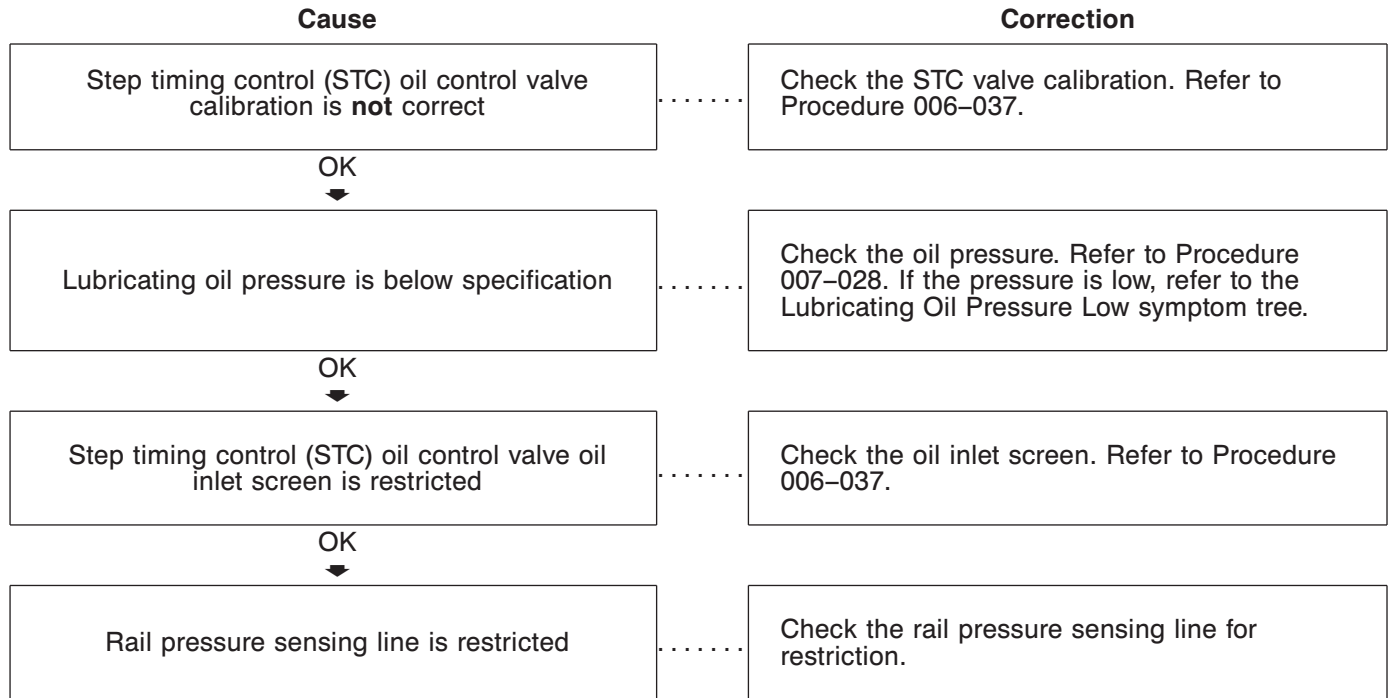
(Continued)

Smoke, White — Excessive (PT) (Continued)

Cause	Correction
Injector cup is damaged or is not correct	Check the injector cups for damage and for correct part numbers. Refer to Procedure 006-026.
OK ↓	
Injector is malfunctioning	Perform the single cylinder cut out test. Replace the injectors as necessary. Refer to Procedures 006-005 and 006-026.
OK ↓	
Static injection timing is not correct	Check the static injection timing. Refer to Procedure 006-025.
OK ↓	
Coolant is leaking into the combustion chamber	Refer to the Coolant Loss — Internal symptom tree.
OK ↓	
Valve protrusion is below specification	Check the valve protrusion. Replace the valve seat inserts or the cylinder head. Refer to Procedures 002-019 and 002-004.
OK ↓	
Injector protrusion is not correct	Check the injector protrusion. Refer to Procedure 006-028.
OK ↓	
Pistons or piston rings are worn, damaged, or not correct	Check the pistons for correct part numbers. Refer to Control Parts List (CPL), Bulletin No. 3379133. Check the pistons and rings for wear and damage. Refer to Procedures 001-043 and 001-047.

Step Timing Control (STC) Valve is Not Shifting Correctly

This is symptom tree T120.

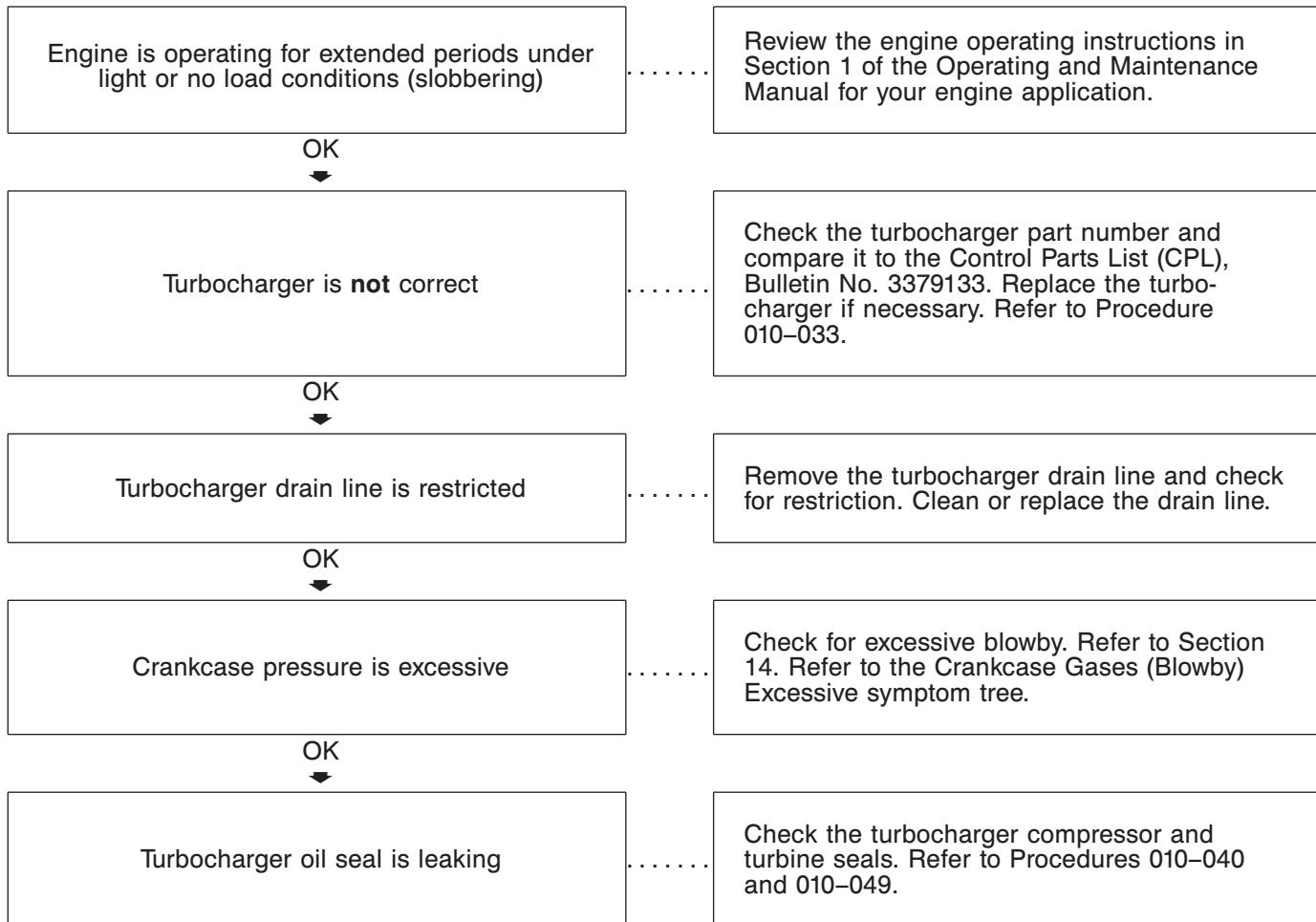


Turbocharger Leaks Engine Oil or Fuel

This is symptom tree T122.

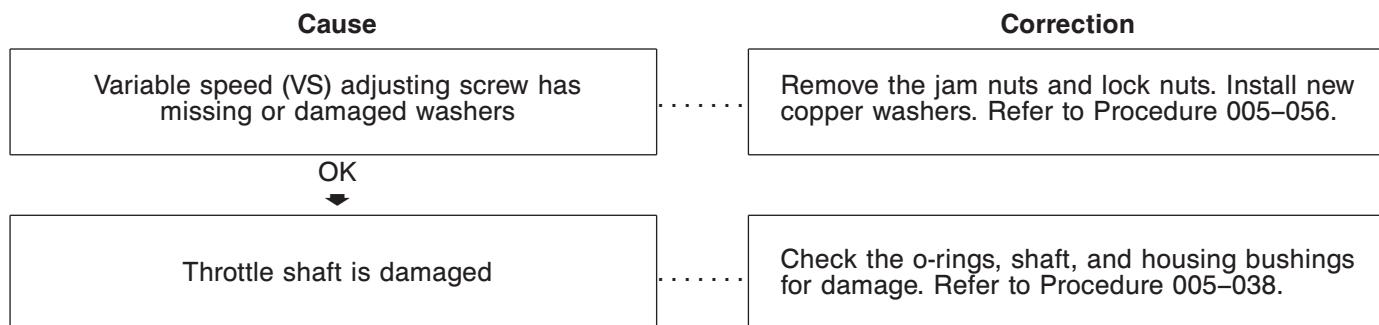
Cause

Correction



Variable Speed (VS) Governor — Fuel Leak at the Throttle Shaft

This is symptom tree T125.



Variable Speed (VS) Governor — Speed is Not Set Correctly

This is symptom tree T126.

Cause

Correction

Lower throttle lever is **not** locked wide open

Make sure the lower throttle lever linkage opens the throttle wide open. Refer to Procedure 005-035.

OK



Variable speed (VS) governor linkage is **not** fully open or is set to idle

Adjust the throttle linkage. Refer to Procedure 005-036.

OK



Low speed screw is **not** adjusted correctly

Loosen the lock nut and adjust the rear screw. Refer to Procedure 005-029.

OK



High speed screw is **not** adjusted correctly

Loosen the lock nut and adjust the high speed (top) screw. Refer to Procedure 005-029.

OK



High speed spring is **not** correct

Remove the fuel pump and change the spring. Refer to Procedure 005-016.

OK

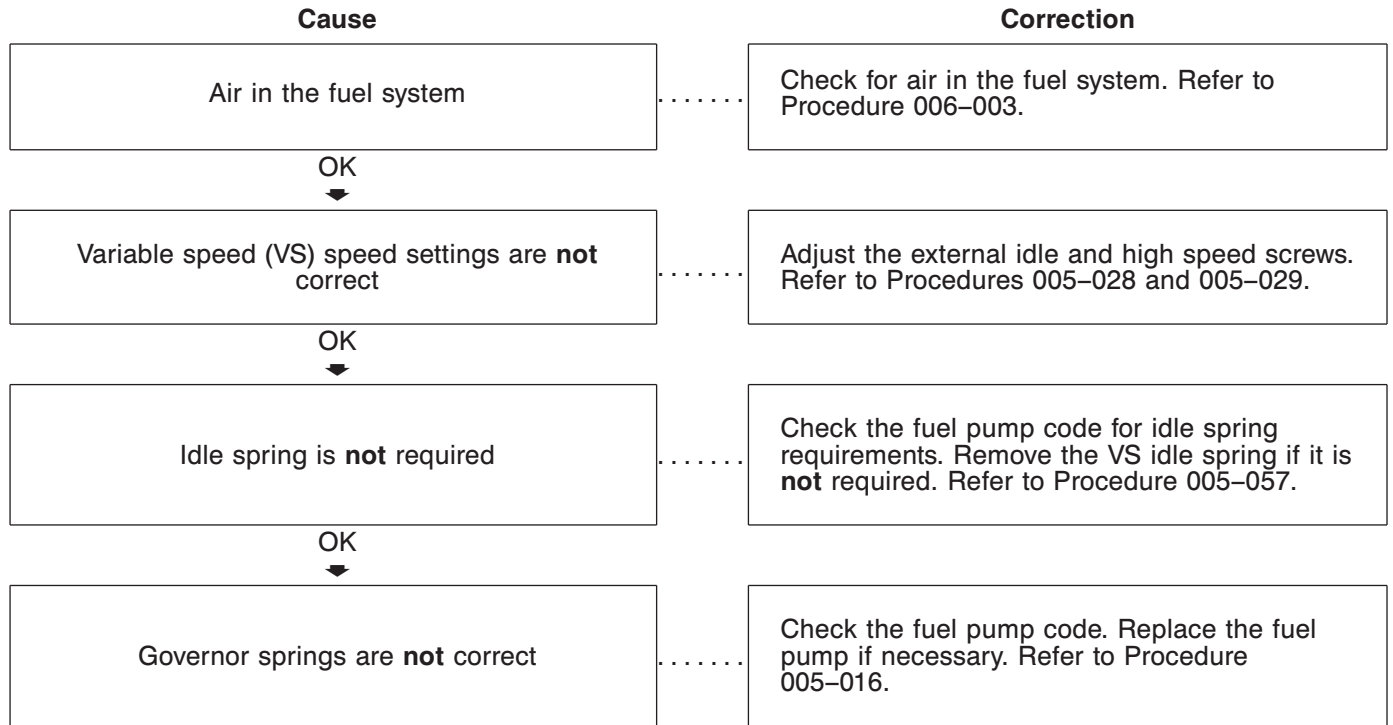


Lever screw does **not** allow the throttle lever plunger to move

Remove the fuel pump. Refer to Procedure 005-016. Check the screw adjustment. Refer to Procedure 005-029.

Variable Speed (VS) Governor — Surge with Engine Under Load

This is symptom tree T127.



Engine Noise Diagnostic Procedures — General Information

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

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

Engine noise can sometimes be isolated by performing a cylinder cutout test. Refer to Procedure 006–005. If the volume of the noise decreases or the noise disappears, it is related to that particular engine cylinder.

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

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

Main Bearing Noise

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

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

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

An irregular noise can indicate worn crankshaft thrust bearings.

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

Connecting Rod Bearing Noise

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

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

Piston Noise

(Refer to Engine Noise Excessive — Piston symptom tree)

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

Driveability — General Information

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

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

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

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

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

Low power is **not** the inability of the vehicle to accelerate satisfactorily from a stop or the bottom of a grade. Refer to the symptom tree Engine Power Output Low for the proper procedures to locate and correct a low power problem. The chart starts off with basic items which can cause lower power. Note that there are separate charts for the STC and CELECT™/CELECT™ Plus systems.

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

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

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

- Failed boost sensor
- Excessive drainline restriction
- Throttle deadband

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

Response Test — CELECT™ and CELECT™ Plus

This procedure can be used for testing response on heavy duty CELECT™ and CELECT™ Plus engines.

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

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

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

Driveability/Low Power — Customer Complaint Form

Customer Name/Company _____ Date _____

1. How did the problem occur? Suddenly _____ Gradually _____
2. At what hour/mileage did the problem begin? Hours _____ Miles _____ Since New _____
 - After engine repair? Yes _____ No _____
 - After equipment repair? Yes _____ No _____
 - After change in equipment use? Yes _____ No _____
 - After change in selectable programmable parameters? Yes _____ No _____
 - If so, what was repaired and when? _____
3. Does the vehicle also experience poor fuel economy? Yes _____ No _____

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

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

4. **A B C D E F**
 Can the vehicle obtain the expected road speed? Yes _____ No _____
 What is desired speed? rpm/mpg _____
 What is achieved speed? rpm/mpg _____
 GVW _____

5. **A B C D**
 Is the vehicle able to pull the load? Yes _____ No _____
 When?
 _____ In the hills
 _____ With a loaded trailer
 _____ On the flat
 _____ Other _____

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

6. **A B C D E F**
 Is the vehicle slow to accelerate or respond? Yes _____ No _____
 From a stop? Yes _____ No _____
 After a shift? Yes _____ No _____ rpm _____
 Before a shift? Yes _____ No _____ rpm _____
 No shift? Yes _____ No _____ rpm _____

7. **A B C D**
 Does the vehicle hesitate after periods of long deceleration or coasting? . Yes _____ No _____ rpm _____

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

8. **A B C D E F**
 Additional Comments: _____

Driveability/Low Power/Excessive Fuel Consumption — Checklist

Vehicle/Equipment Specifications

Year, Type and Model: _____

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

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

Typical GVW: _____, Engine Rating: _____

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

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

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

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

Power Steering: Yes _____ No _____

Air Conditioner: Yes _____ No _____

Air Shield: Yes _____ No _____

Freon Compressor: Yes _____ No _____

General Information:					
DO No.:			SC No.:		
Fuel Pump Code:			Fuel Pump Serial No.:		
Mileage:			Engine Serial No.:		
Date in Service:			Engine Model and Rating:		
Cruise Speed and rpm:			Rated Speed and rpm:		
PT PACER Equipped:	Yes	No	PCU Part No.:		
Road Speed Governor:	Yes	No	Type:		
STC Equipped:	Yes	No	STC Valve Part No.:		
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 Alginment:	OK	Not OK
Altitude:			Ambient Temperature:		
Fuel Heater:					
Fuel Type:	No. 1D	No. 2D	Other		
Typical Terrain:	Flat	Hilly	%Asphalt	%Concrete	

Additional Comments:

Recommended Literature:

Troubleshooting Driveability Complaints, Bulletin No. 3387137

Guide to Troubleshooting, Bulletin No. 3379090

Professional Driver Techniques, Bulletin No. 3804818

Guide to LCPM, Bulletin No. 3382021

Troubleshooting Excessive Fuel Consumption, Bulletin No. 3387245

Fuel Consumption — General Information

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

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

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

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

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

Fuel Consumption — Customer Complaint Form

Customer Name/Company _____ Date _____

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

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

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

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

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

This Page Can Be Copied For Your Convenience.

Oil Consumption

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

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

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



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

15200020

Engine Lubricating Oil Consumption Report

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

Lubricating Oil Added

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

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

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

Equals _____ Usage Rate _____

Customer Signature	Cummins Dealer	Cummins Distributor
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Cummins
Engine Company, Inc.
Box 3005
Columbus, IN, U.S.A.
47202-3005
15200020

OIL CONSUMPTION REPORT

Customer Name:	Dist/Dir:
Engine Model:	Mi/Km/Hr:
Engine Serial No.:	CPL No.:
Vehicle Make/Model:	Date:
<p>1. Review of maintenance history:</p> <p>List any previous failures that could have had a detrimental effect on cylinder component life. Failures could include fuel, coolant, and/or foreign abrasives in the oil, second ring groove beat-out, filter plugging, etc.</p>	
<ul style="list-style-type: none"> ● Lube Oil Used: <ul style="list-style-type: none"> - Brand - Viscosity - Change Interval (mi/km/hr) 	
<ul style="list-style-type: none"> ● Combination Oil Filter: <ul style="list-style-type: none"> - Model - Element - Change Interval (mi/km/hr) 	
<ul style="list-style-type: none"> ● Bypass Oil Filter: <ul style="list-style-type: none"> - Model - Element - Change Interval (mi/km/hr) 	
<ul style="list-style-type: none"> ● Full Flow Oil Filter: <ul style="list-style-type: none"> - Model - Element - Change Interval (mi/km/hr) 	
<ul style="list-style-type: none"> ● Air Cleaner: <ul style="list-style-type: none"> - Make and Model - Change Interval 	
<p>2. List any external engine leaks.</p>	
<p>3. Visually check for any internal leaks and list. Check turbocharger seals, valve guides, air compressor, etc.</p>	
<p>4. Had the fuel pump been tampered with? _____ What is maximum rail pressure readings? _____ If yes, the pump must be reset to factory specifications and the customer sent out to re-evaluate his oil consumption rate and the eligibility requirements must be met again.</p>	
<p>5. Drain and refill oil pan to check dipstick markings and notes findings. Warning: Governmental agencies have determined that used engine oil is toxic and carcinogenic. Avoid breathing, injection, and excessive contact.</p>	
<p>6. Only after above checks are completed, leaks corrected and proper documentation is completed, disassemble engine to determine cause for the failure and repair as required.</p>	
<p>7. State reason for oil consumption.</p>	
<p>Signed: _____</p>	

Section 0 - Complete Engine - Group 00

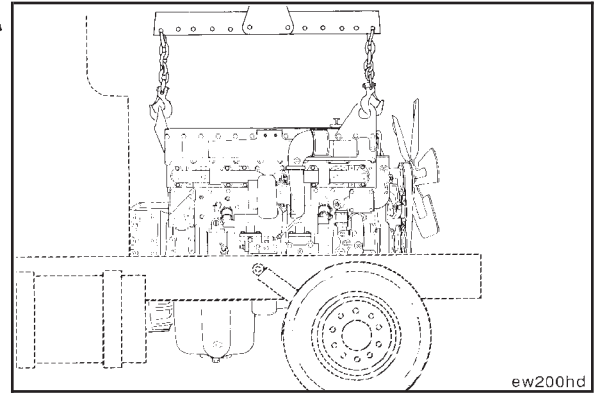
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Install	0-6
Engine Removal	0-3
Remove.....	0-3
Service Tools	0-2
Engine Removal and Installation	0-2

Complete Engine - 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.

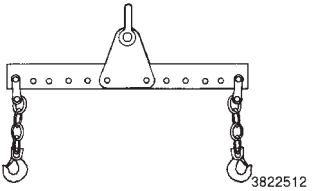
All replacement steps will **not** apply to all types of equipment. Complete only the steps which apply to the equipment involved. Use the equipment manufacturer's recommendations and precautions for removal of chassis parts to gain access to the engine.



Service Tools

Engine Removal and Installation

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

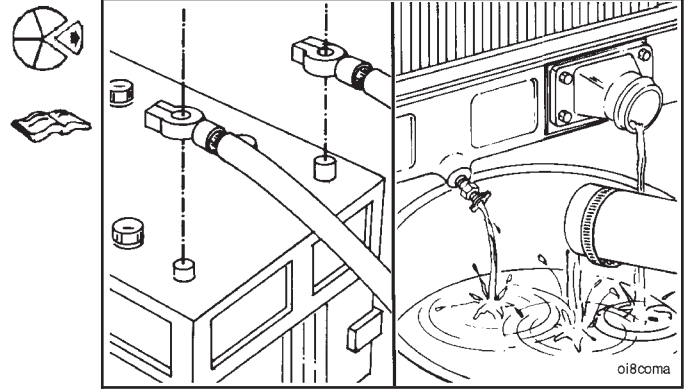
Tool No.	Tool Description	Tool Illustration
3822512	Engine Lifting Fixture Used to remove and install the engine.	

Engine Removal (000-001)

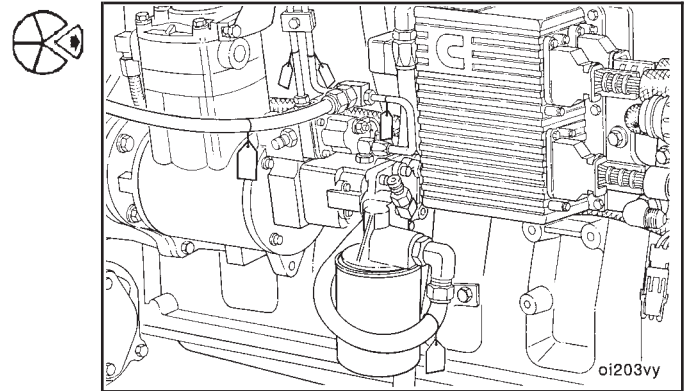
Remove (000-001-002)

Disconnect the battery cables.

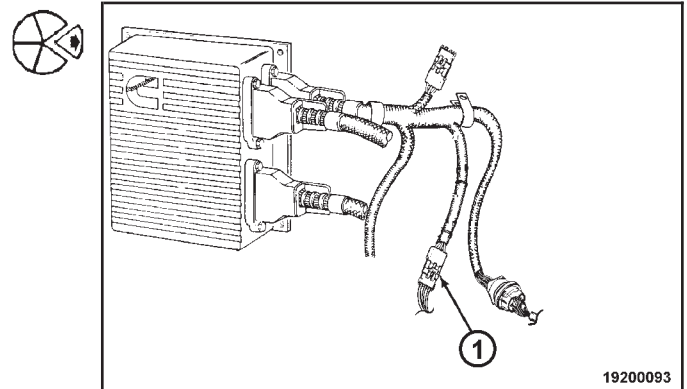
Drain the engine coolant. Refer to Procedure 008-018-005.



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



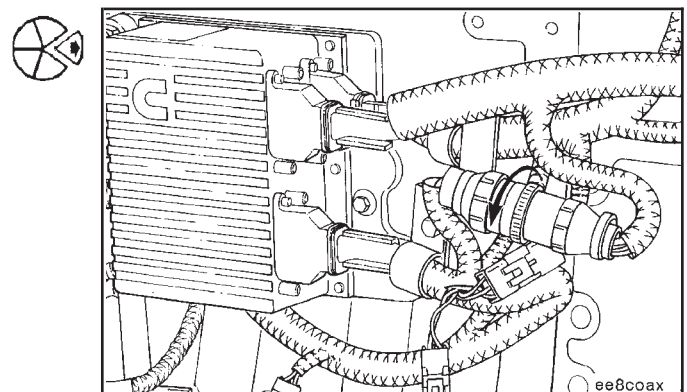
Disconnect the 12 VDC power in connector (1) from the engine harness on CELECT™ or CELECT™ Plus engines.

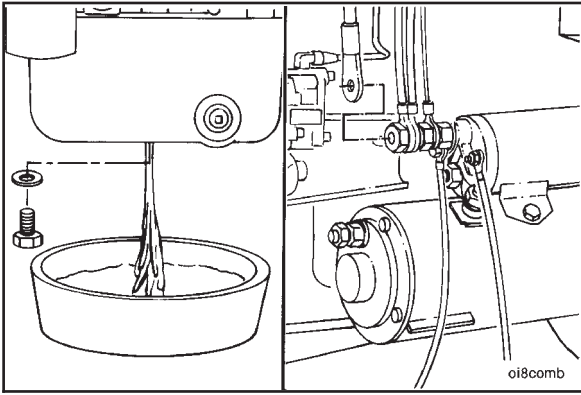


Remove the OEM harness from the ECM on CELECT™ or CELECT™ Plus engines.

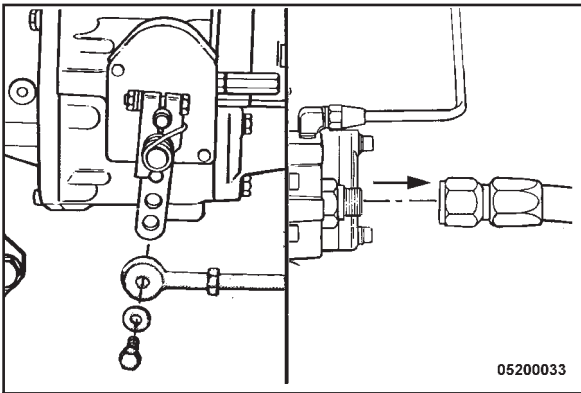
On CELECT™ engines, disconnect the 9-pin connector from the engine harness to the OEM harness.

On CELECT™ Plus engines, disconnect the 21-pin Deutsch connector from the engine harness to the OEM harness.

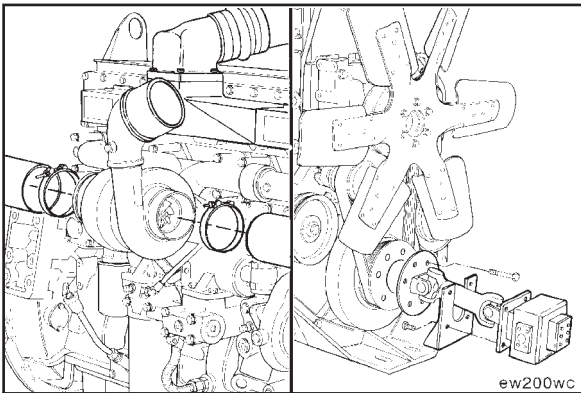




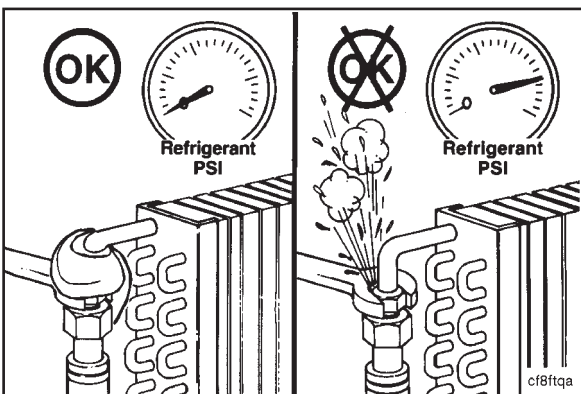
Drain the lubricating oil. Refer to Procedure 007-025-005.
Disconnect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires and hydraulic lines.



Disconnect the throttle linkage from the fuel pump on STC engines.
Remove the fuel pump supply hose.



Disconnect the intake and exhaust air pipes.
Disconnect all chassis mounted engine driven accessories.

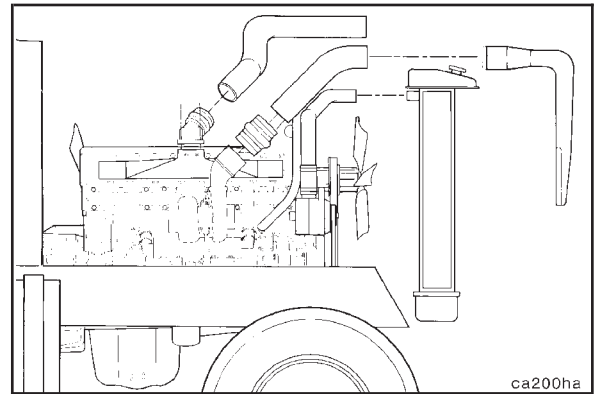


▲ WARNING ▲

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

For environmental protection, federal regulations require that Freon be recycled, and **not** vented into the atmosphere.

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

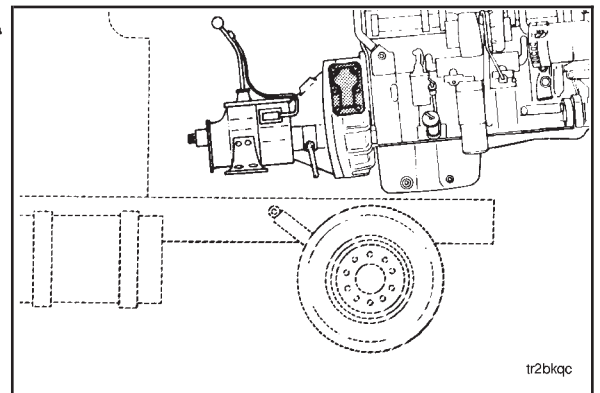


WARNING

The engine lifting equipment must be designed to safely lift the engine and transmission as an assembly.

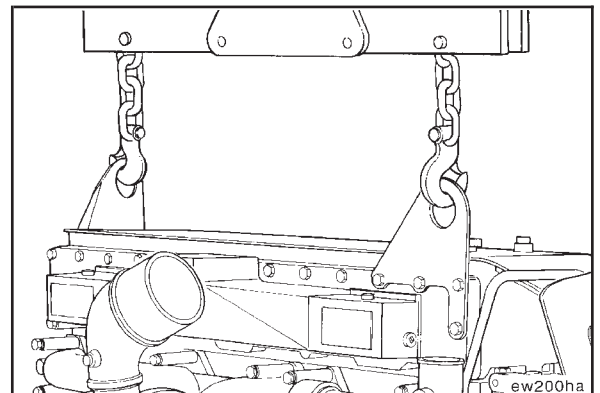
The dry weight of a CELECT™ or CELECT™ Plus engine is approximately 940 Kg [2070 lb]. The dry weight of a STC engine is approximately 929 Kg [2045 lb]. Refer to the equipment manufacturer's specifications for the transmission weight.

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



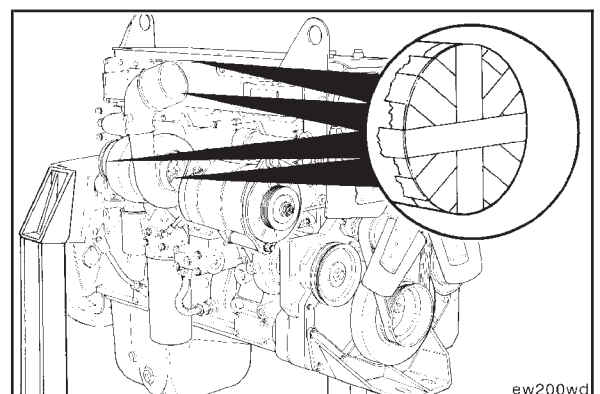
Use a properly rated hoist and engine lifting fixture, Part No. 3822512, attached to the engine mounted lifting brackets to remove the engine.

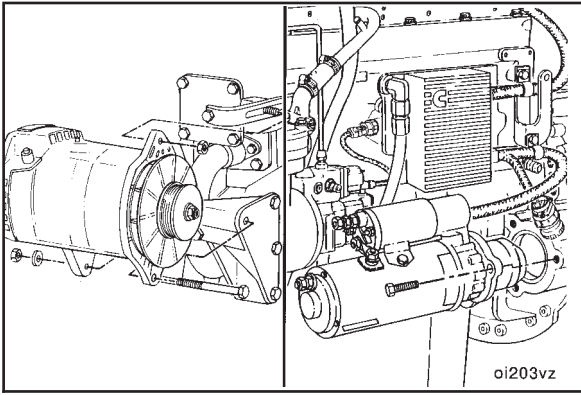
NOTE: If the transmission is **not** removed, place a support under the transmission to prevent it from falling.



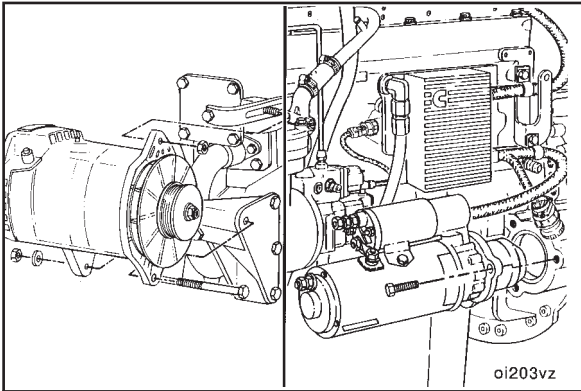
Cover all engine openings to prevent dirt and debris from entering the engine.

Place the engine on suitable engine support stands.



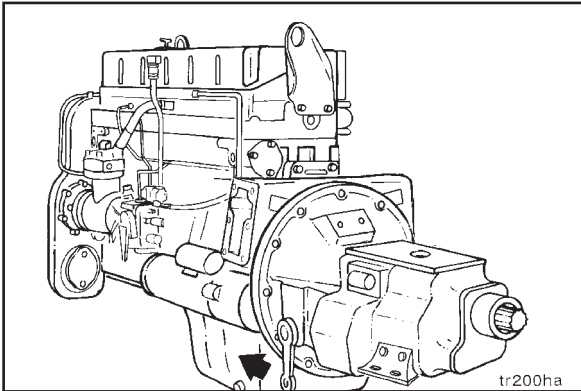


Remove all remaining accessories and brackets to use with the replacement engine.



Engine Installation (000-002) Install (000-002-026)

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

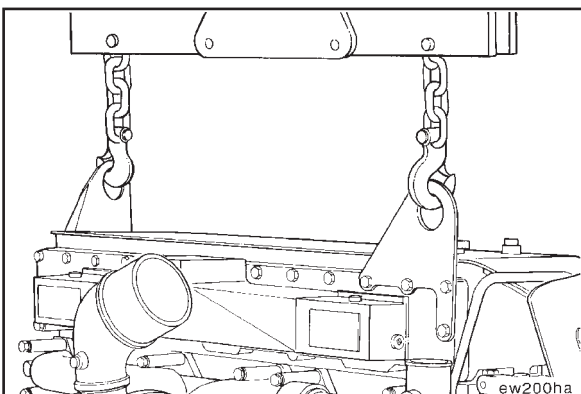


⚠ WARNING ⚠

The engine lifting equipment must be designed to safely lift the engine and transmission as an assembly.

The dry weight of a CELECT™ or CELECT™ Plus engine is approximately 940 Kg [2070 lb]. The dry weight of a STC engine is approximately 929 Kg [2045 lb]. Refer to the equipment manufacturer's specifications for the transmission weight.

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



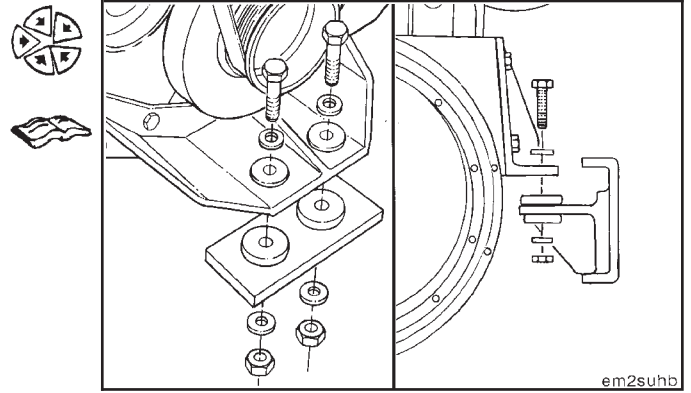
Use a properly rated hoist and engine lifting bracket, Part No. 3822512, attached to the engine mounted lifting brackets to install the engine.

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

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

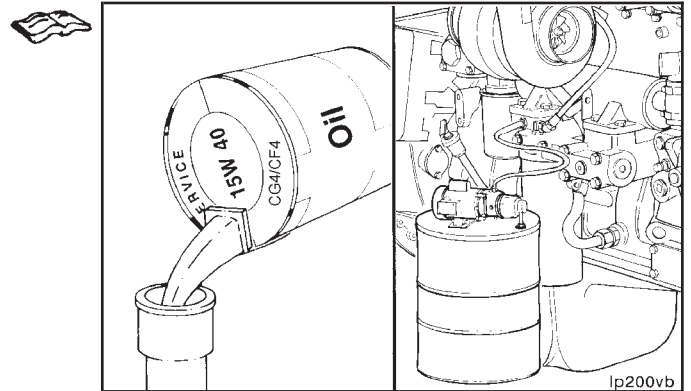
Connect all engine and chassis mounted accessories which were removed.

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



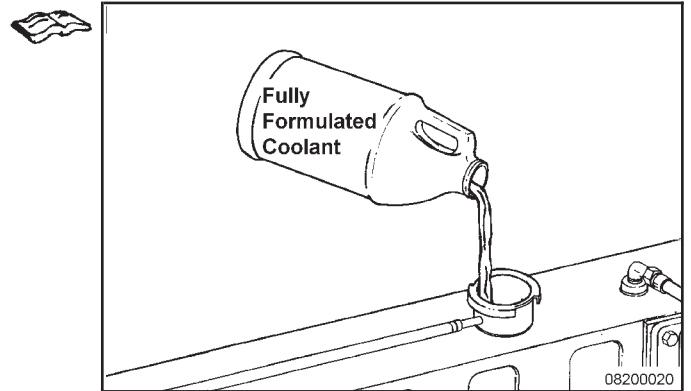
Fill the engine with clean 15W-40 lubricating oil. Refer to Procedure 007-025-028. Refer to Section E for the correct oil capacity.

NOTE: The engine lubricating oil system **must** be pressurized before the engine is operated. Refer to Procedure 007-037-050.



Fill the cooling system with fully formulated coolant or a 50/50 mixture of fully formulated antifreeze and good quality water. Refer to Procedure 008-018-028.

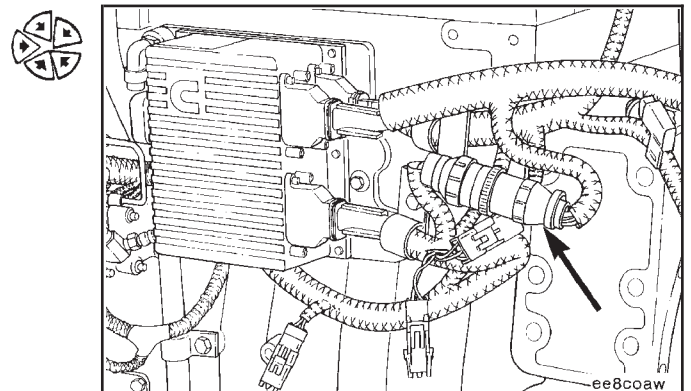
Refer to the equipment manufacturer's specifications for radiator and system capacity.

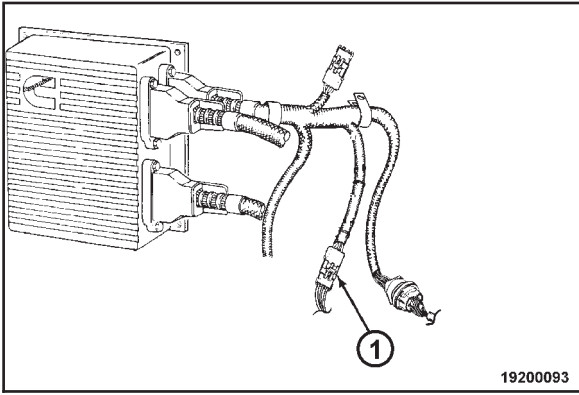


Connect the OEM harness to the ECM on CELECT™ and CELECT™ Plus engines.

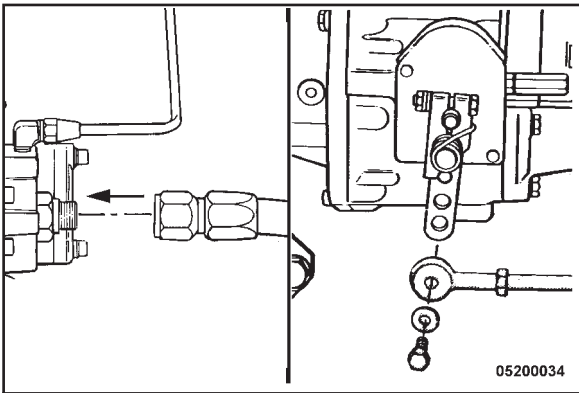
On CELECT™ engines, connect the 9-pin connector from the engine harness to the OEM harness.

On CELECT™ Plus engines, connect the 21-pin connector from the engine harness to the OEM harness.

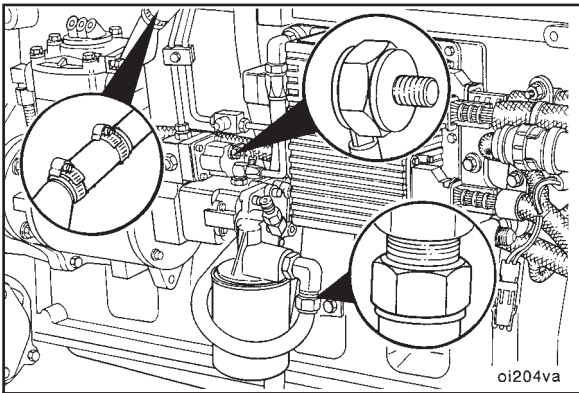




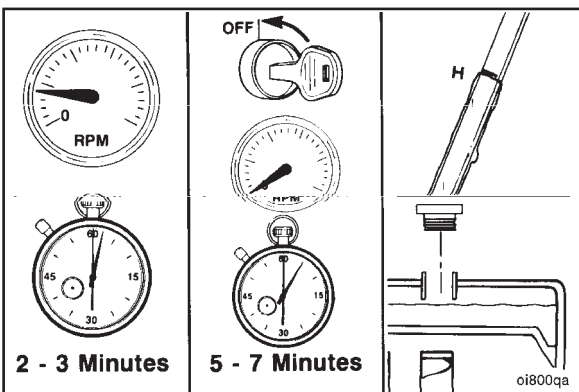
Connect the 12 VDC power in connector from the engine harness.



Connect the fuel pump suction line to the fuel pump.
On STC engines, attach the throttle linkage to the fuel pump.



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



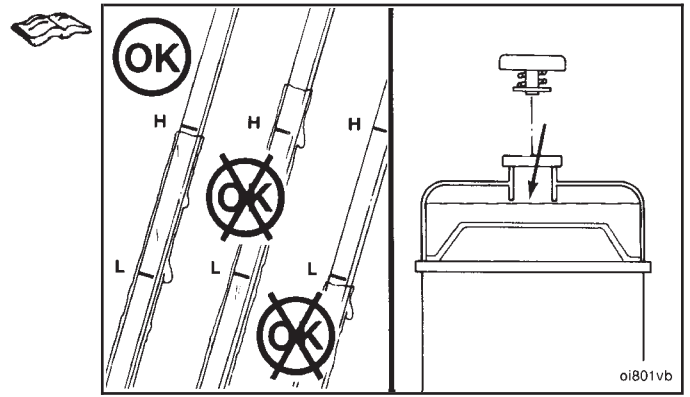
▲ WARNING ▲

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

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

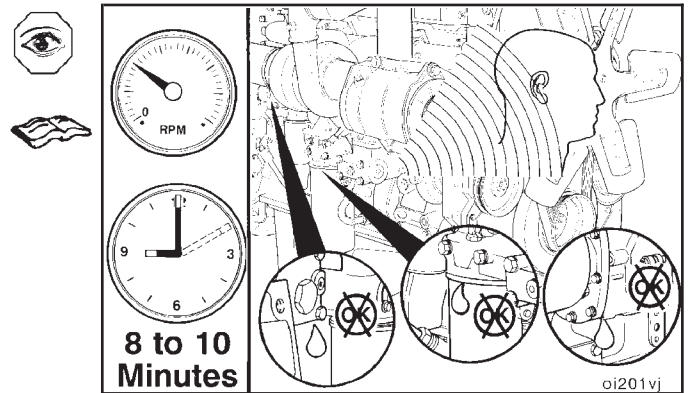
Stop the engine and wait 5 to 7 minutes for the oil to drain to the oil pan, and check the oil and coolant levels again.

Fill the engine to the correct coolant and oil levels if necessary. Refer to Procedures 008-018-028 and 007-025-028.



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

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



Section 1 - Cylinder Block - Group 01

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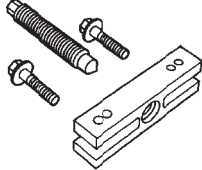
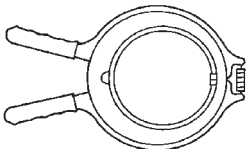
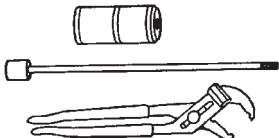
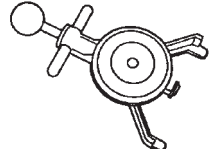
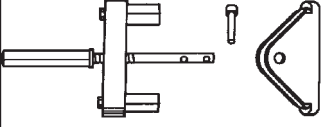
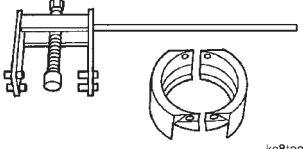
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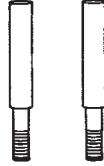
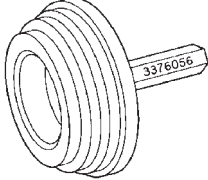

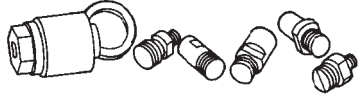
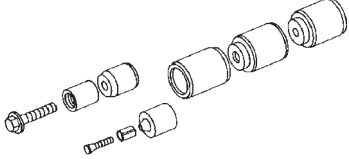
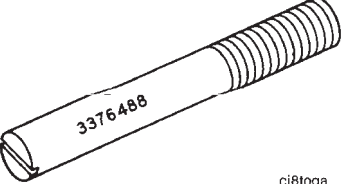

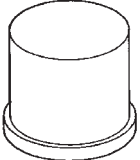
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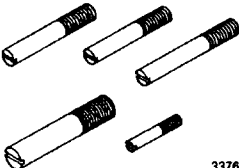
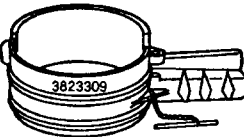
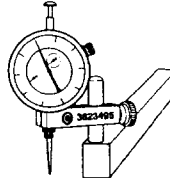
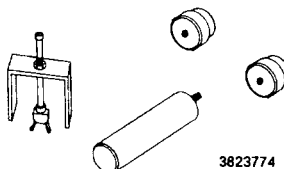
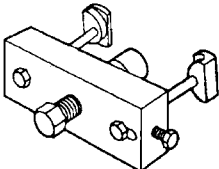
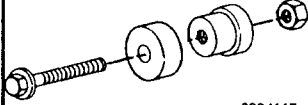
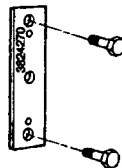
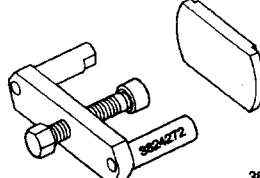
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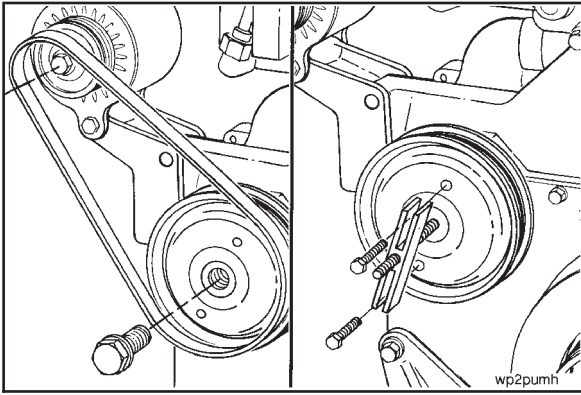
Service Tools Cylinder Block

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

Tool No.	Tool Description	Tool Illustration
ST-647	Standard Puller Remove alternator drive pulley. Use with two 5/16 x 18 x 2 inch capscrews.	 ad8toga
ST-821	Piston Ring Expander Remove and install piston rings on pistons.	 pi8togd
ST-1178	Main Bearing Cap Puller Remove main bearing caps.	 mb8toga
ST-1293	Belt Tension Gauge Measure drive v-ribbed belt tension.	 fa8togc
3375629	Universal Cylinder Liner Puller Remove cylinder liners from cylinder block. Requires cylinder liner puller plate, Part No. 3376049.	 ck8togq
3375840	Crankshaft Gear Puller Kit Remove the crankshaft gear. Requires puller, Part No. 3375834, and jaw, Part No. 3375839, to be used.	 ks8togd

Tool No.	Tool Description	Tool Illustration
3376038	<p>Connecting Rod Guide Pins Guide connecting rods over crankshaft during removal or installation of connecting rods.</p>	 <p style="text-align: right;">cx8togg</p>
3376056	<p>Cylinder Liner Driver Install cylinder liner in cylinder block.</p>	
3376069	<p>Guide Used with camshaft bushing driver, Part No. 3376636, to replace cylinder block camshaft bushings.</p>	 <p style="text-align: right;">ck8togj</p>
3376326	<p>Pulley Installation Tool Install drive pulleys. Use pulley pusher adapter, Part No. 3377401, to install the alternator drive pulley.</p>	 <p style="text-align: right;">ad8togb</p>
3376388	<p>Camshaft Guide Pilot Aid in removal and installation of the camshaft in cylinder block.</p>	 <p style="text-align: right;">3376388</p>
3376488	<p>Guide Pin Two guide pins are used to install the water header plate.</p>	 <p style="text-align: right;">ci8toga</p>
3376636	<p>Camshaft Bushing Driver Replace cylinder block camshaft bushings.</p>	 <p style="text-align: right;">ck8togg</p>
3376637	<p>Bushing Driver Used with camshaft bushing driver, Part No. 3376636, to replace cylinder block camshaft bushings.</p>	 <p style="text-align: right;">ck8togk</p>

Tool No.	Tool Description	Tool Illustration
3376695	<p>Guide Pin Kit</p> <p>Aid during installation of vibration damper. The kit consists of two each of guide pins, Part No's. 3376488, 3376638, 3376696, 3376697 and 3376698.</p>	 <p>3376695</p>
3823309	<p>Piston Ring Compressor</p> <p>Compress piston rings on pistons during installation of pistons in the cylinder block.</p>	 <p>3823309</p>
3823495	<p>Gauge Block</p> <p>Measure cylinder liner protrusion on the cylinder block and gear housing protrusion below the cylinder block.</p>	 <p>3823495</p>
3823774	<p>Needle Bearing Kit</p> <p>Used to remove and install needle bearings in the gear housing and hydraulic pump adapter. Use mandrel, Part No. 3823776, to install hydraulic pump needle bearings.</p>	 <p>3823774</p>
3824106	<p>Cam Gear Puller Kit</p> <p>Used to remove the camshaft gear from the camshaft without removing the camshaft from the engine.</p>	 <p>3824106</p>
3824117	<p>Needle Bearing Installation Tool</p> <p>Used to remove and install the water pump drive needle bearing in the gear housing.</p>	 <p>3824117</p>
3824270	<p>Engine Barring Tool</p> <p>Used to bar the engine by hand.</p>	 <p>3824270</p>
3824272	<p>Liner Clamping Tool</p> <p>Used to seat and hold the liner while liner protrusion is measured.</p>	 <p>3824272</p>



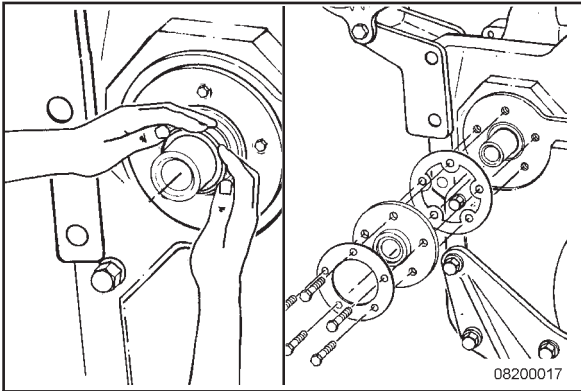
Alternator Drive Seal (001-001)

Remove (001-001-002)



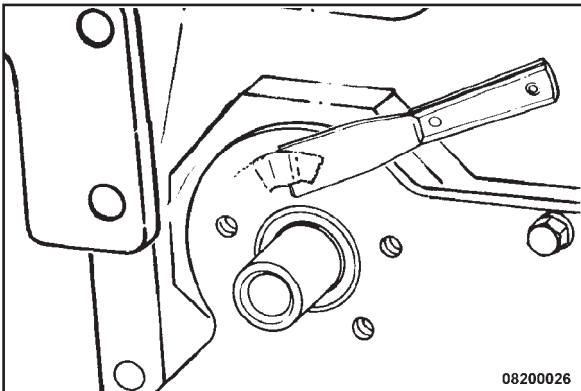
Remove the alternator drive belt. Refer to Procedure 013-005-002.

Remove the alternator drive pulley. Refer to Procedure 009-010-002.



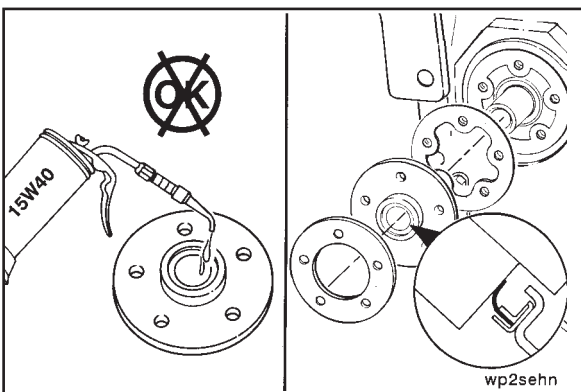
Remove the five capscrews, clamping ring.

Remove the dust seal and oil seal together.



Clean (001-001-006)

Clean the gasket surface of the gear cover.



Install (001-001-026)

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



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

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

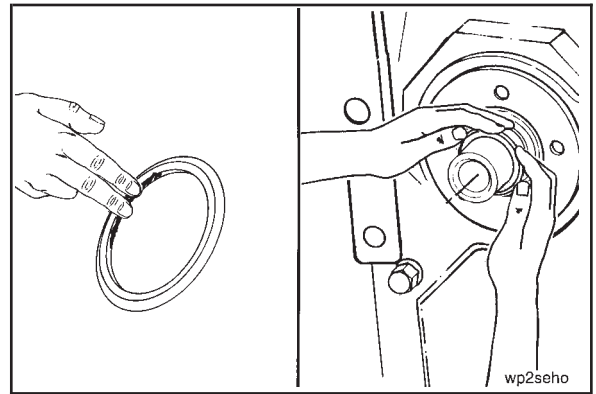
Install the clamping ring with five (M8-1.25 x 20) capscrews. Tighten the capscrews in a star pattern.

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

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

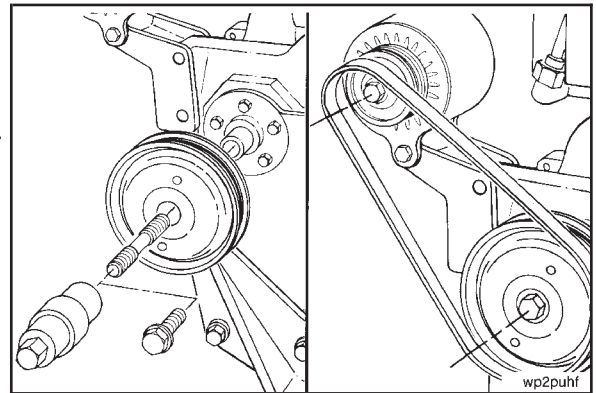
Install the dust seal onto the shaft with the larger outside diameter facing towards the engine.

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



Install the alternator drive pulley. Refer to Procedure 009-010-026.

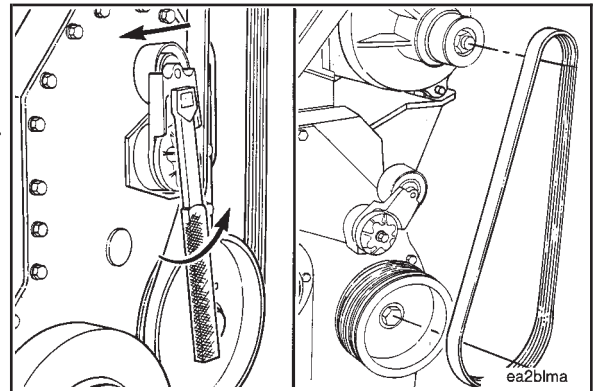
Install and adjust the alternator drive belt. Refer to Procedure 013-005-026.



Accessory Drive Seal (001-003)

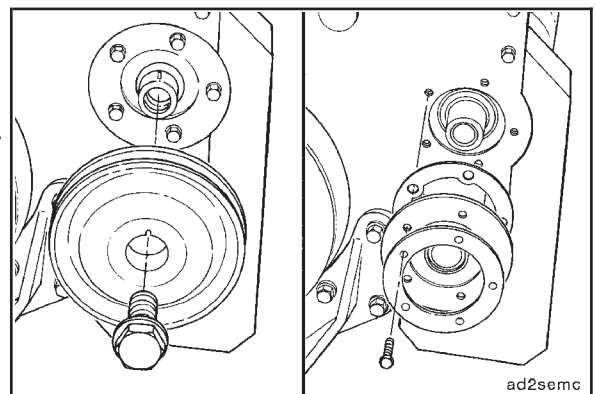
Remove (001-003-002)

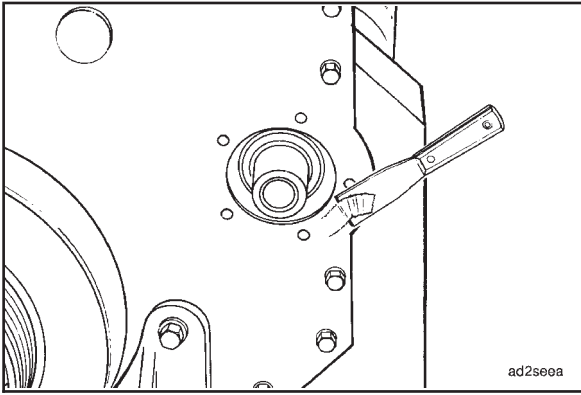
If equipped with an automatic belt tensioner, remove the alternator drive belt. Refer to Procedure 013-021-002.



Remove the accessory drive pulley. Refer to Procedure 009-004-002.

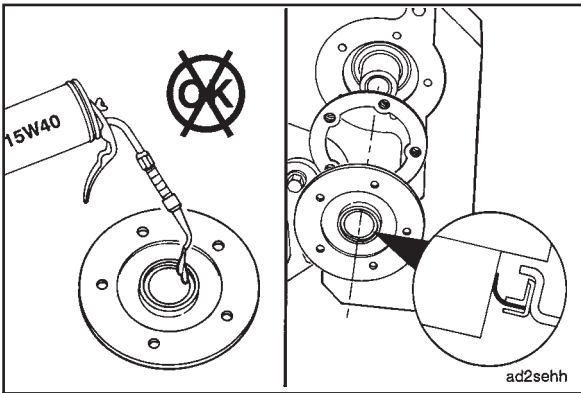
Remove the five capscrews, clamping ring, seal and gasket.





Clean (001-003-006)

Clean the gasket surface of the gear cover.

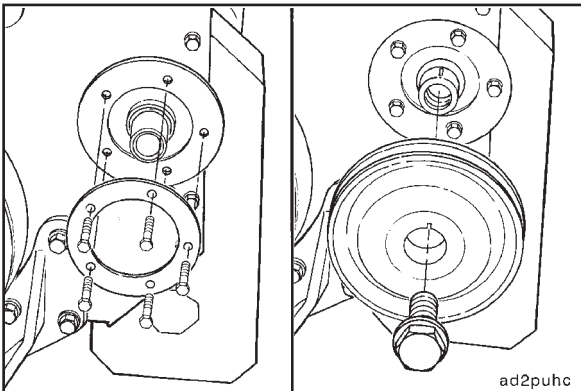


Install (001-003-026)

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

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

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



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

Install the clamping ring and five capscrews.



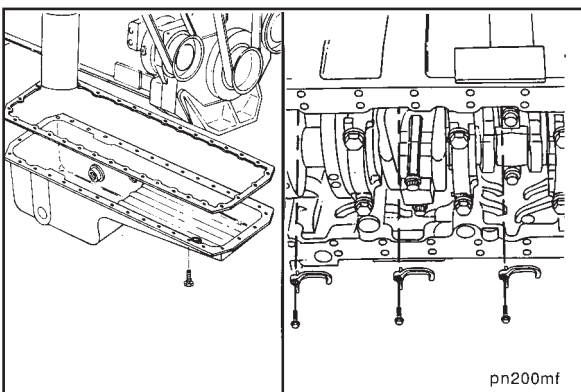
Tighten the capscrews in a star pattern in two steps.

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



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

Install the accessory drive pulley. Refer to Procedure 009-004-026.



Bearings, Connecting Rod (001-005)

Remove (001-005-002)

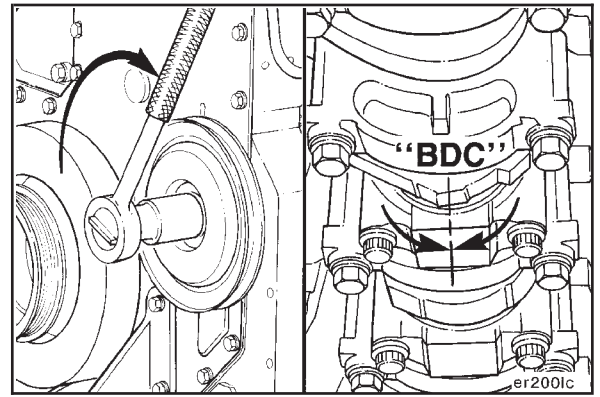


Drain the lubricating oil. Refer to Procedure 007-025-005.

Remove the lubricating oil pan. Refer to Procedure 007-025-002.

Remove the piston cooling nozzles. Refer to Procedure 001-046-002.

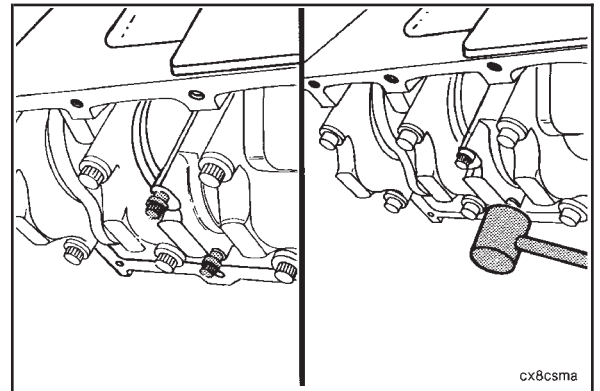
Use the accessory drive pulley to rotate the crankshaft so the connecting rod to be removed is at "BDC" (bottom dead center).



Loosen the connecting rod capscrews.

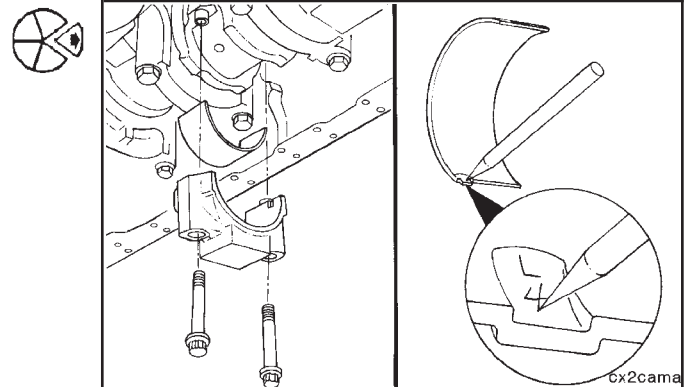
NOTE: Do **not** remove the capscrews.

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



Remove the capscrews and rod caps.

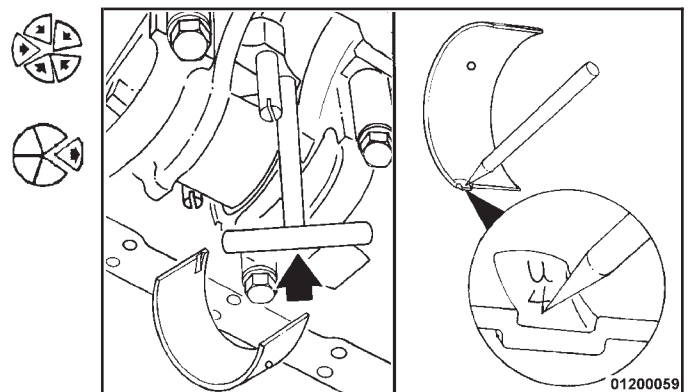
Remove the lower bearing shell from the rod cap. Mark it with the letter "L" (for lower) and the cylinder number it was removed from.

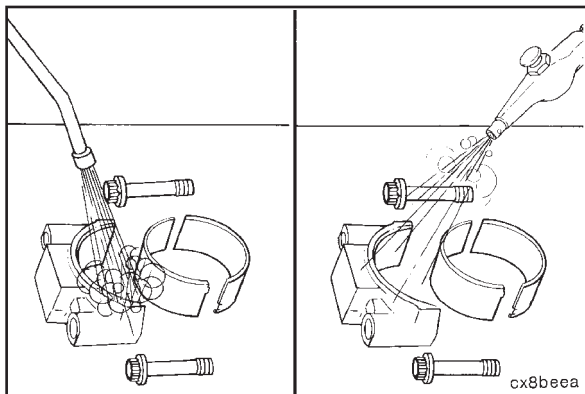


Install two connecting rod guide pins, Part No. 3376038.

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

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





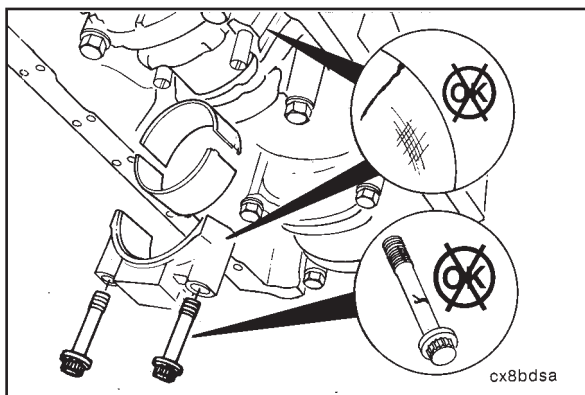
Clean (001-005-006)



WARNING

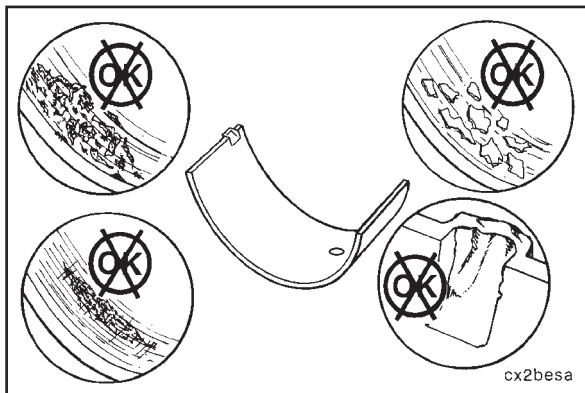
When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

Steam clean the parts and dry with compressed air.



Inspect for Reuse (001-005-007)

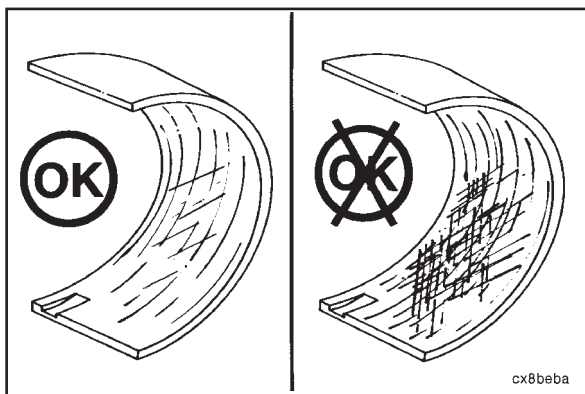
Visually inspect the rod caps, connecting rod bearing saddles and capscrews for nicks, cracks, burrs, scratches or fretting.



Visually inspect the bearings for damage.

Replace any bearings with the following damage:

- Pitting
- Flaking
- Corrosion
- Lock tang damage
- Scratches (deep enough to be felt with a fingernail)



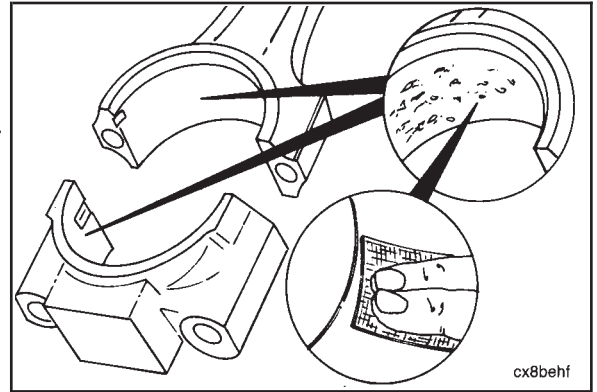
Normal bearing wear produces a smooth finish which will wear into the copper lining. Exposed copper does **not** always indicate worn bearings. Refer to the Parts Reuse Guidelines, Bulletin No. 3810303.

If large areas of copper lining are visible in the bearings before the engine has accumulated 241,000 kilometers [150,000 miles] or 3,750 hours, inspect the engine for contamination from fine dirt particles and correct the problem.

Visually inspect the bearing shell seating surface for nicks or burrs.

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

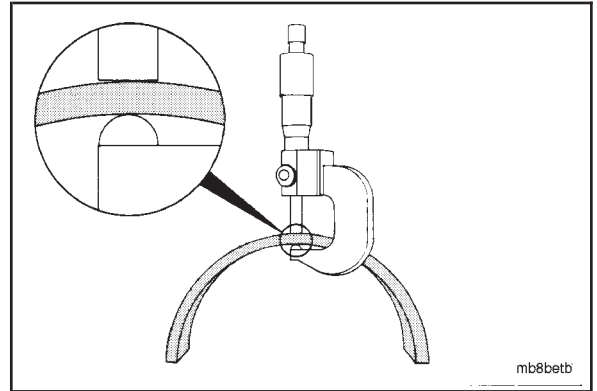
For more detailed information of bearing damage, refer to the Analysis and Prevention of Bearing Failures Manual, Bulletin No. 3810387.



cx8behf

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

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



mb8betb

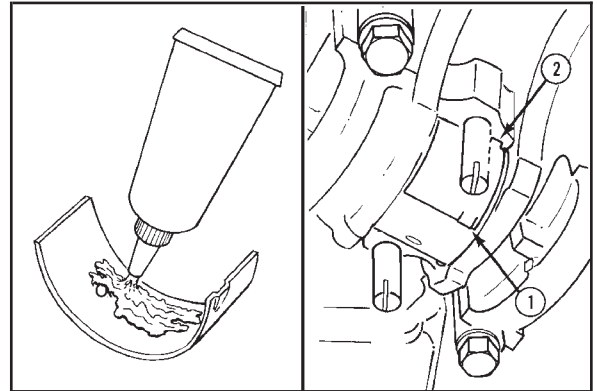
Install (001-005-026)

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

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

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

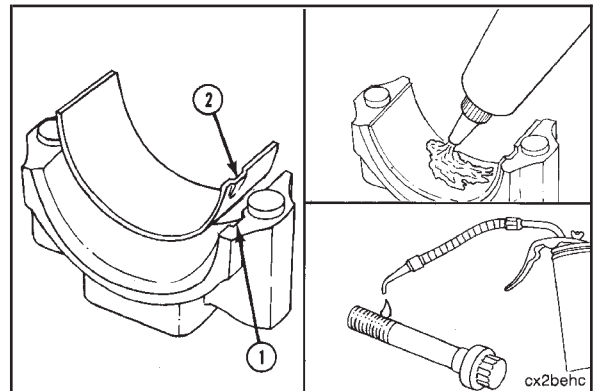
Remove the two connecting rod guide pins, Part No. 3376038.



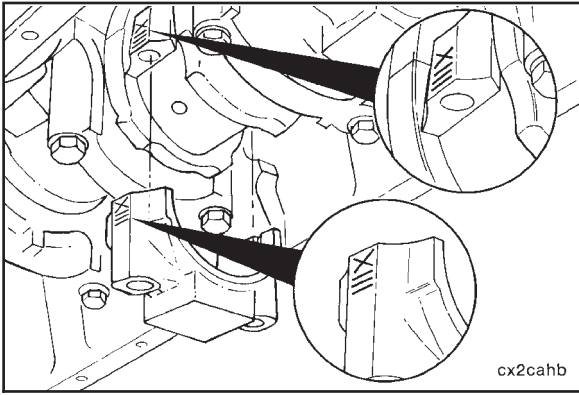
Install the bearing shell in the connecting rod cap with the tang (2) of the bearing in the slot (1) of the cap.

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

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

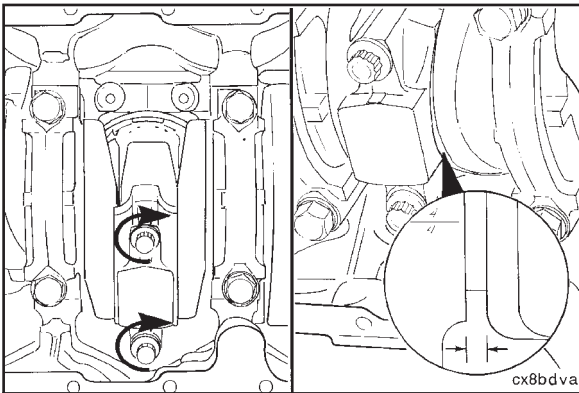


cx2behc



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

Install the connecting rod caps and capscrews.

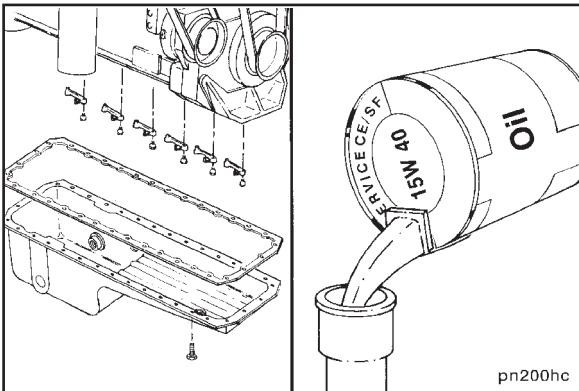


Tighten the capscrews in alternating sequence to the following torque values:

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



Measure the connecting rod side clearance. Refer to Procedure 001-014-026.

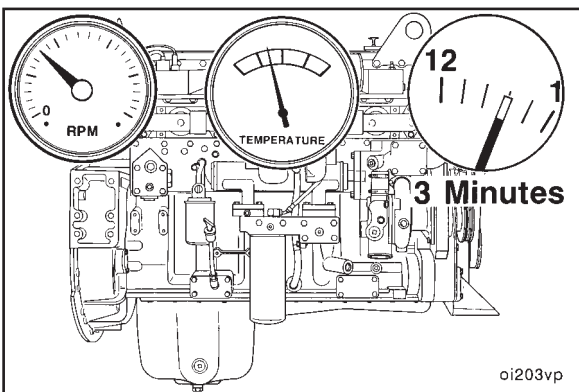


Install the piston cooling nozzles. Refer to Procedure 001-046-026.

Install the lubricating oil pan. Refer to Procedure 007-025-026.



Fill the lubricating oil pan. Refer to Procedure 007-025-028.



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

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

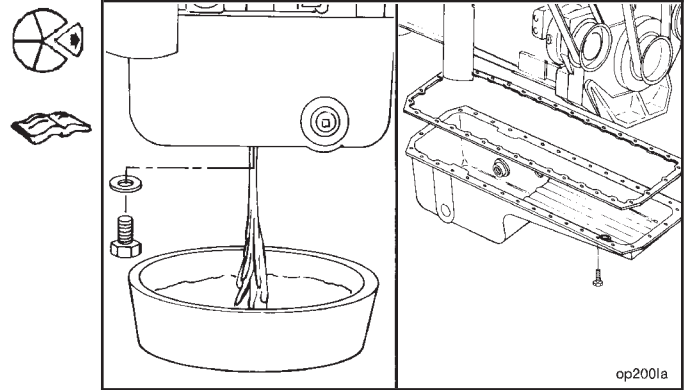
Bearings, Main (001-006)

Remove (001-006-002)

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

Drain the lubricating oil. Refer to Procedure 007-025-005.

Remove the lubricating oil pan. Refer to Procedure 007-025-002.

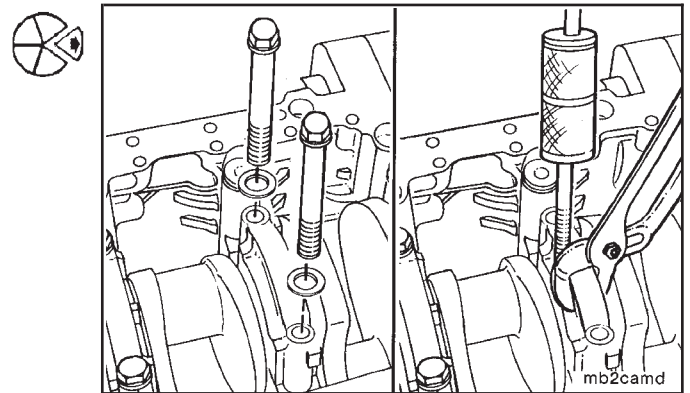


Replace the main bearings one at a time.

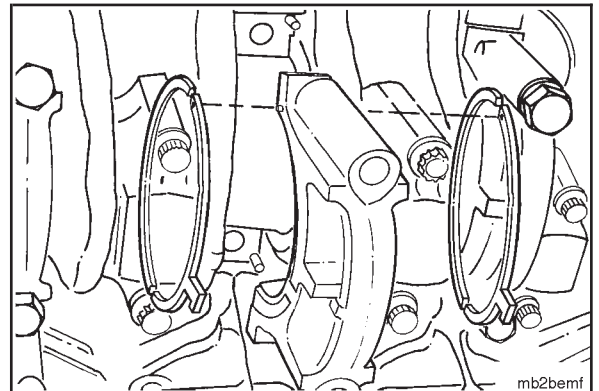
Remove the main bearing capscrews.

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

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

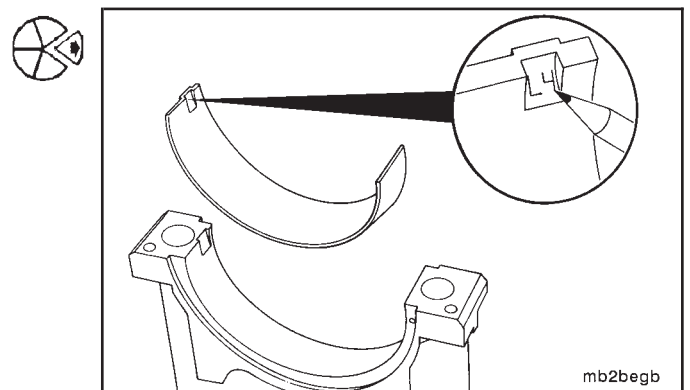


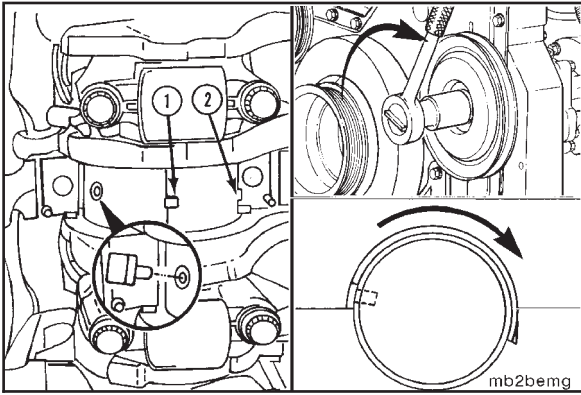
The number four main bearing cap has thrust bearings. The cap is located with two dowel pins.



Remove the lower main bearing shell from the cap.

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

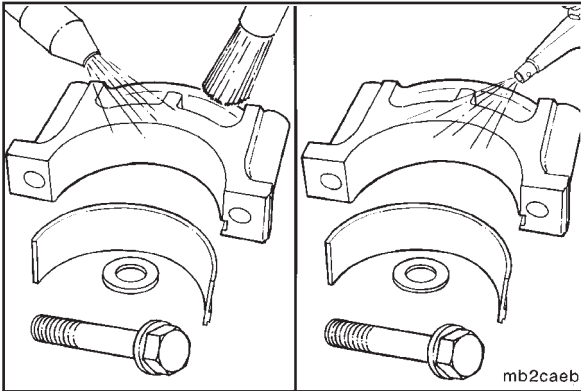




To remove the upper main bearing shell, install bearing rollout tool, Part No. 3823818, in the oil hole of the main bearing journal.

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

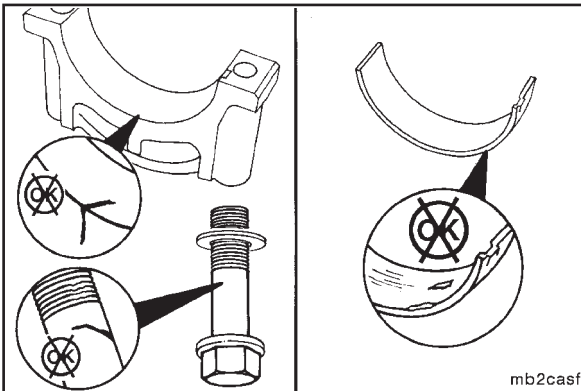
Rotate the crankshaft with the accessory drive pulley to remove the main bearing shell.



Clean (001-006-006)

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

Dry the parts with compressed air.



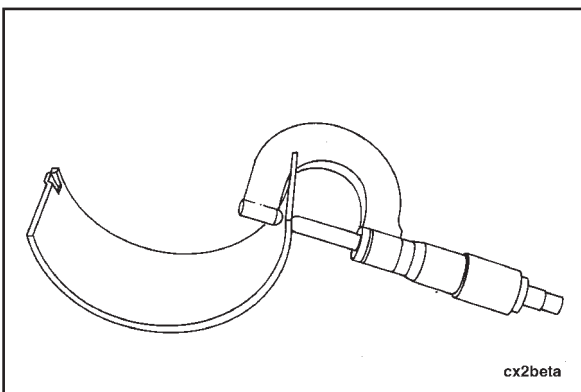
Inspect for Reuse (001-006-007)

Visually inspect the main cap, capscrews, and washers for damage.



Visually inspect the bearing shells for nicks, scratches or damage.

If the main bearings are damaged, refer to the M11 Shop Manual, Bulletin No. 3666075, to inspect the crankshaft main bearing journals. If the crankshaft is damaged, the engine **must** be removed for repair. Refer to Procedure 000-001-002.



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

Standard Main Bearing Shell Thickness

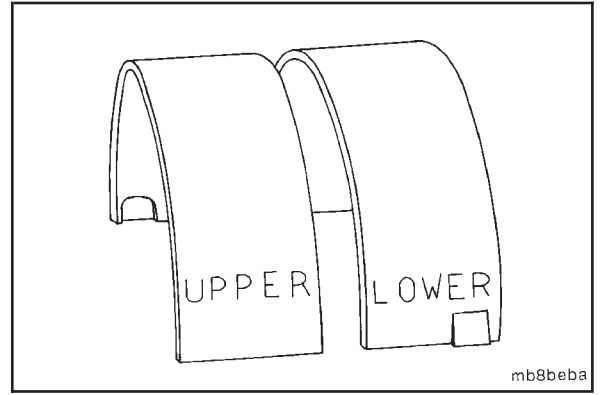
mm		in
3.894	MIN	0.1533
3.945	MAX	0.1553

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

Install (001-006-026)

⚠ CAUTION ⚠

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



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

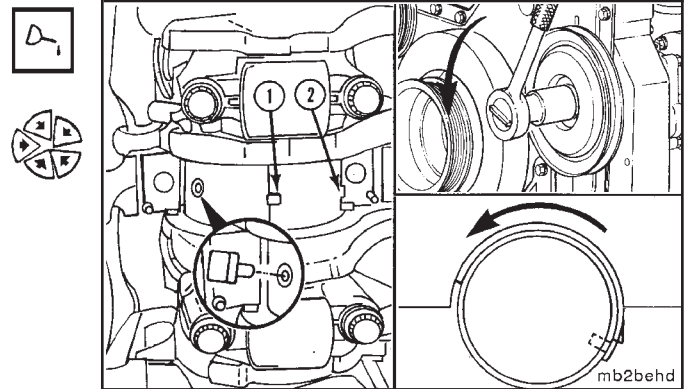
Use Lubriplate® 105, or equivalent, to coat the inside diameter of the upper main bearing shell.

⚠ CAUTION ⚠

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

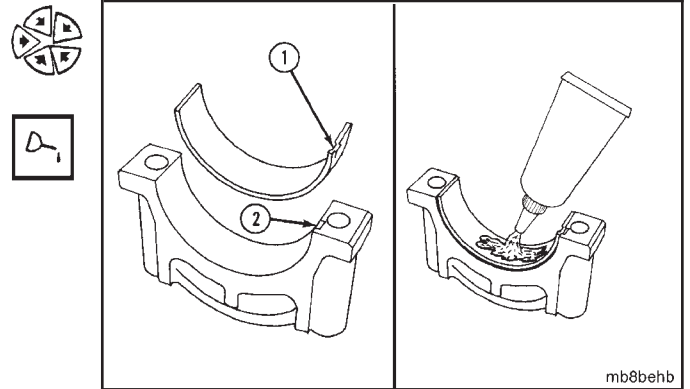
Install the upper main bearing shells using the same method that was used to remove them.

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



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

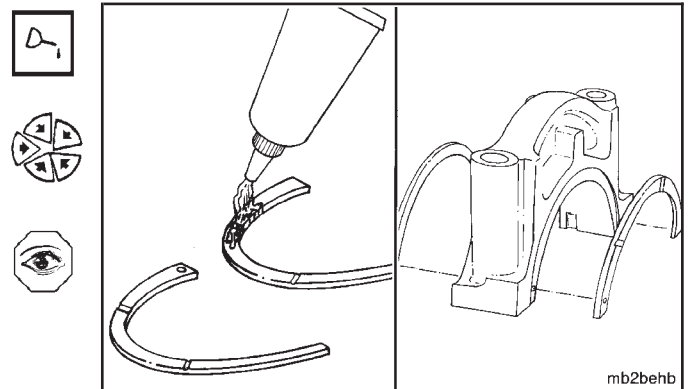
Use Lubriplate® 105, or equivalent, to coat the inside diameter of the bearing shells.

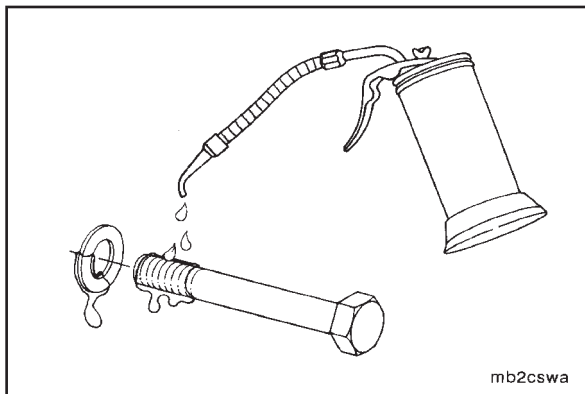


Use Lubriplate® 105, or equivalent, to coat the lower thrust bearings.

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

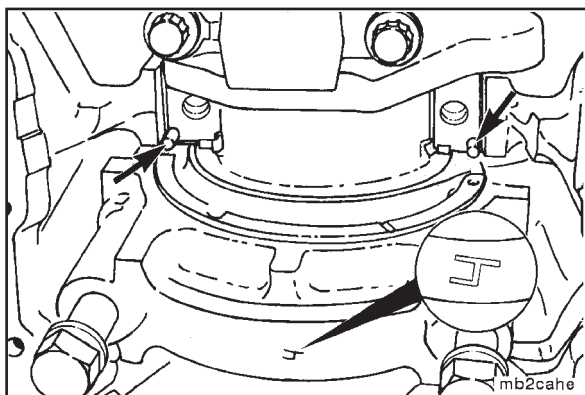
The grooves of the thrust bearing **must** be toward the crankshaft. The locating dowels **must not** protrude above the thrust bearing surface.





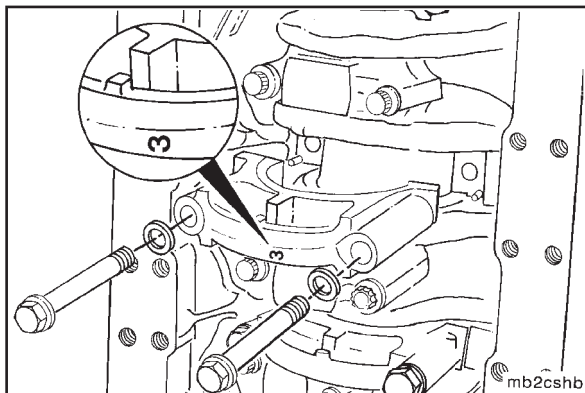
Use clean 15W-40 oil to coat the capscrew threads and on both sides of the washers.

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



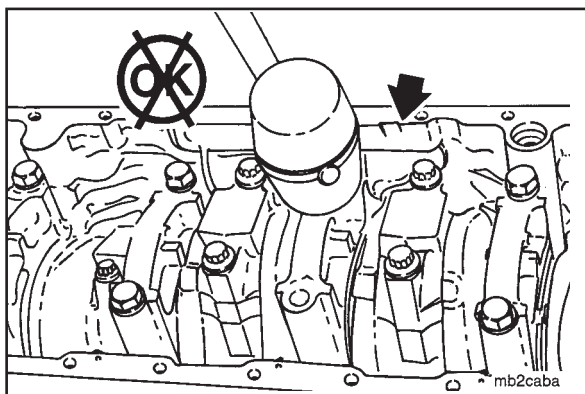
⚠ CAUTION ⚠

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



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

Install the main bearing caps.

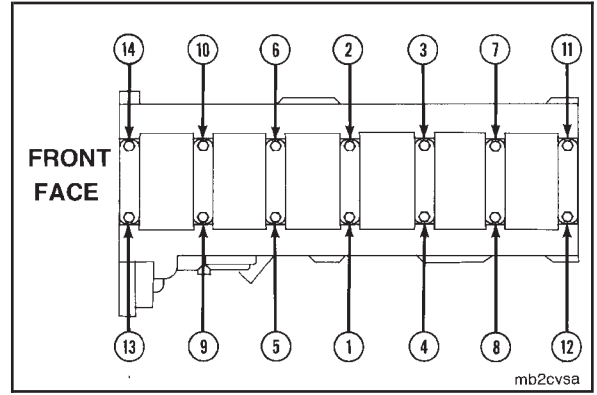


⚠ CAUTION ⚠

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

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

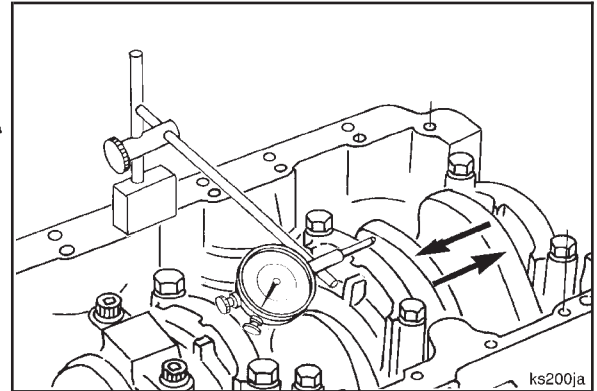
- Torque Value:**
- | | | |
|--------|-----------------------|-------------|
| Step 1 | 68 N•m | [50 ft-lb] |
| 2 | 142 N•m | [105 ft-lb] |
| 3 | 210 N•m | [155 ft-lb] |
| 4 | Loosen completely | |
| 5 | Repeat steps 1 thru 3 | |



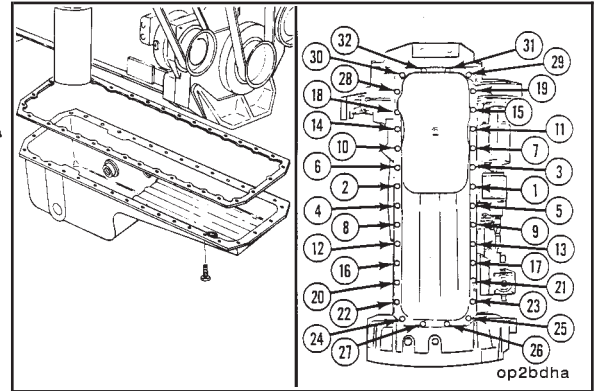
Use a dial indicator to measure the crankshaft end clearance.

Crankshaft End Clearance		
mm		in
0.10	MIN	0.004
0.56	MAX	0.022

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



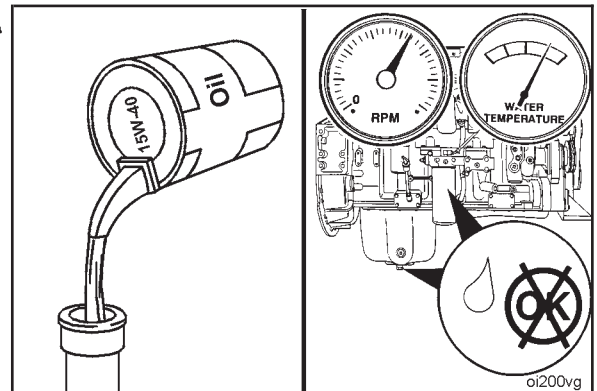
Install the lubricating oil pan. Refer to Procedure 007-025-026.

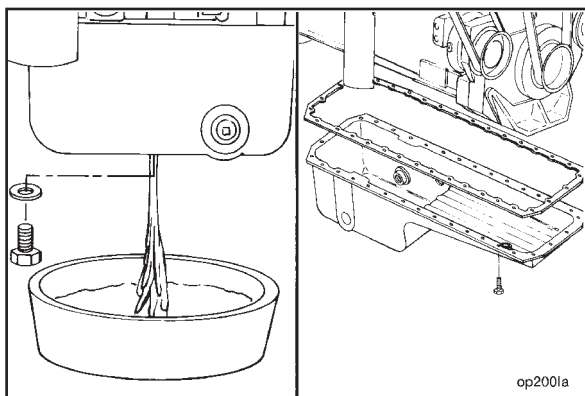


Fill the engine with lubricating oil. Refer to Procedure 007-025-028.

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

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





Bearings, Thrust (001-007)

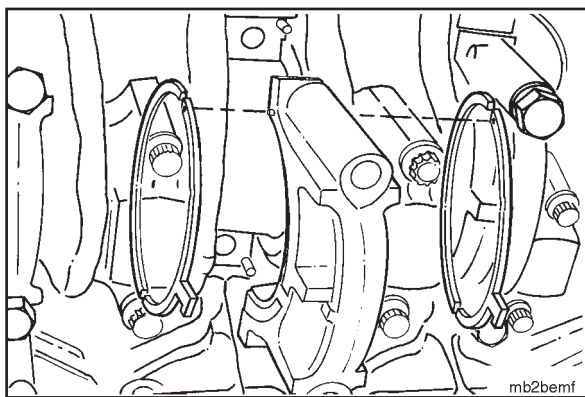
Remove (001-007-002)



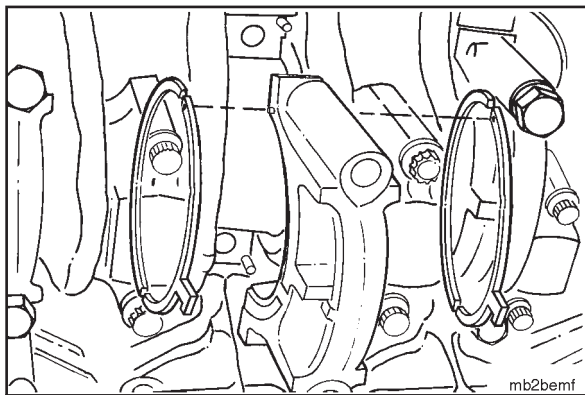
Cummins Engine Company, Inc., recommends replacing the thrust bearings when the main bearings are replaced.

Drain the lubricating oil. Refer to Procedure 007-025-005.

Remove the lubricating oil pan. Refer to Procedure 007-025-002.

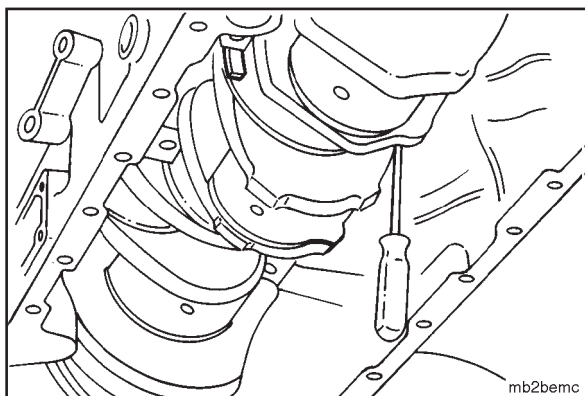


The number four main bearing cap has thrust bearings. The cap is located with two dowel pins.



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

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



⚠ CAUTION ⚠

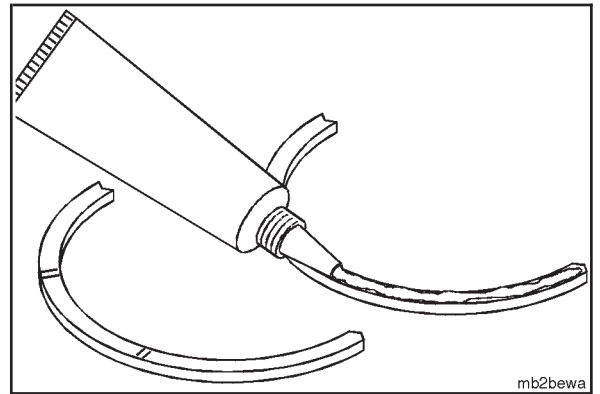
Do not damage the crankshaft when removing the upper thrust bearings.

Use a blunt tool to remove the upper thrust bearings.

Mark these bearings in the oil passage groove as being upper, and front or rear bearings.

Install (001-007-026)

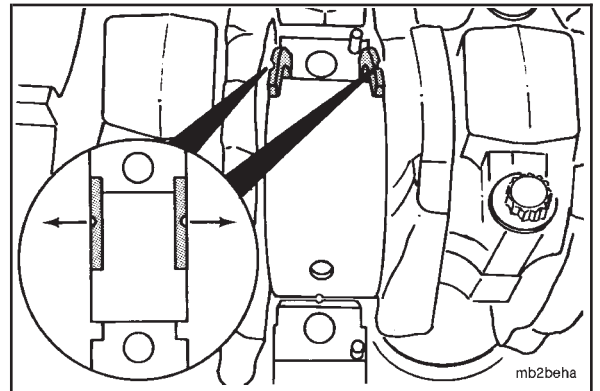
Use Lubriplate® 105, or equivalent, to coat the upper thrust bearings.



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

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

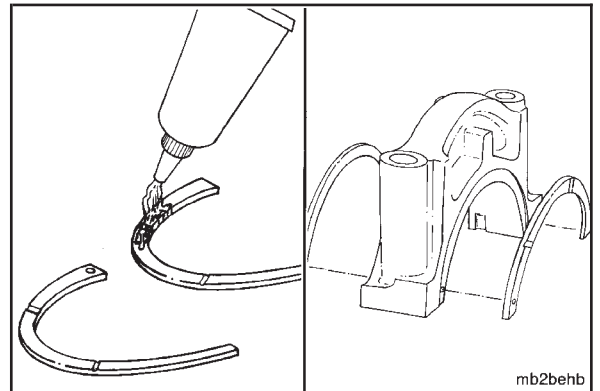
The grooves **must** be toward the crankshaft.



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

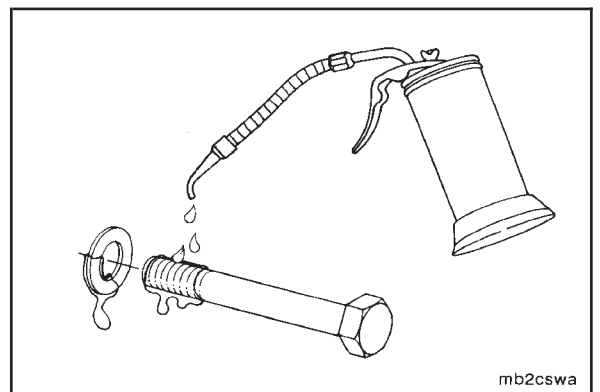
Install the lower thrust bearings in the number four main bearing cap as shown.

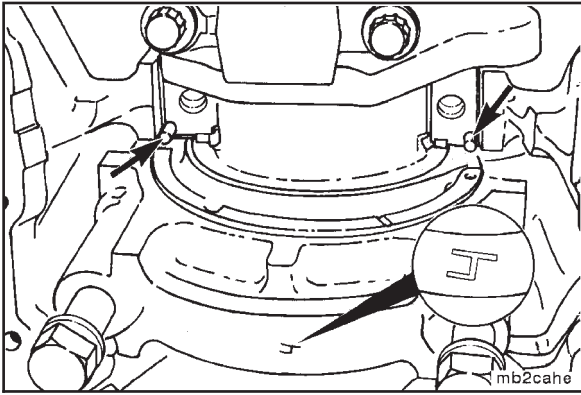
The grooves of the thrust bearing **must** be toward the crankshaft. The locating dowels **must not** protrude above the thrust bearing surface.



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

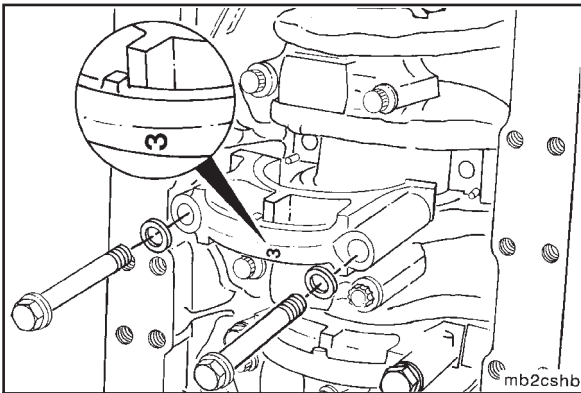
Drain the excess oil from the capscrews before installing them in the cylinder block.





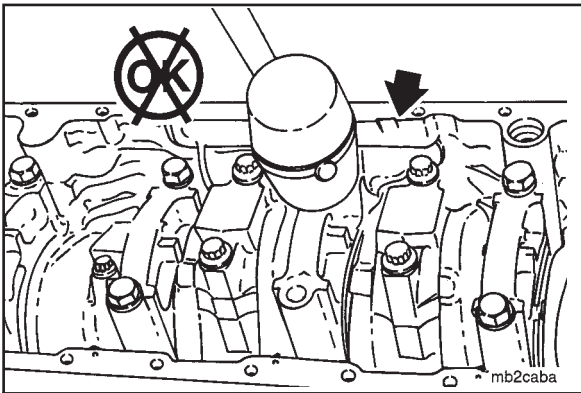
⚠ CAUTION ⚠

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



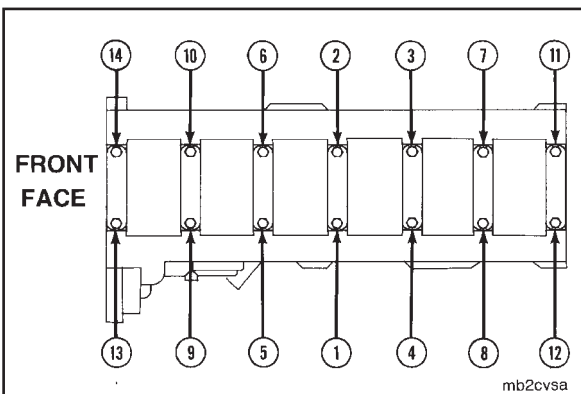
The main bearing caps are numbered one through seven from front to rear in the cylinder block. The caps **must** be installed so the number on the cap matches the bearing saddle in the block. The lock tangs in the main bearing saddle and bearing cap **must** be on the same side.

Install the main bearing caps.



⚠ CAUTION ⚠

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



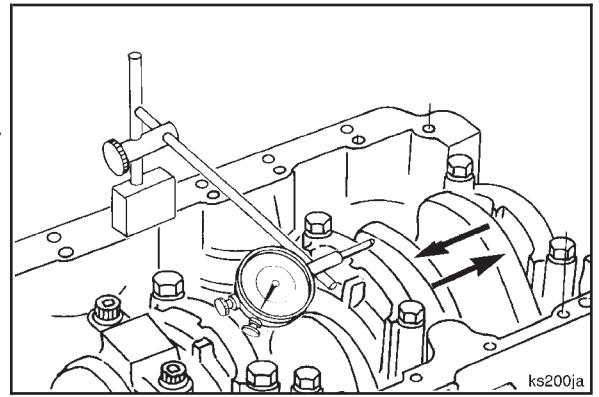
Tighten the main bearing capscrews in alternating sequence to the following torque values:

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

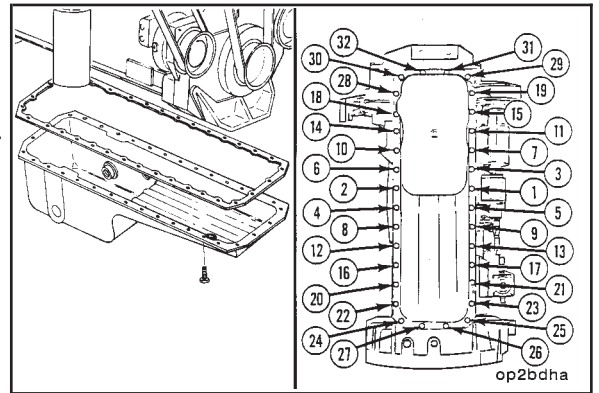
Use a dial indicator to measure the crankshaft end clearance.

Crankshaft End Clearance		
mm		in
0.10	MIN	0.004
0.56	MAX	0.022

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



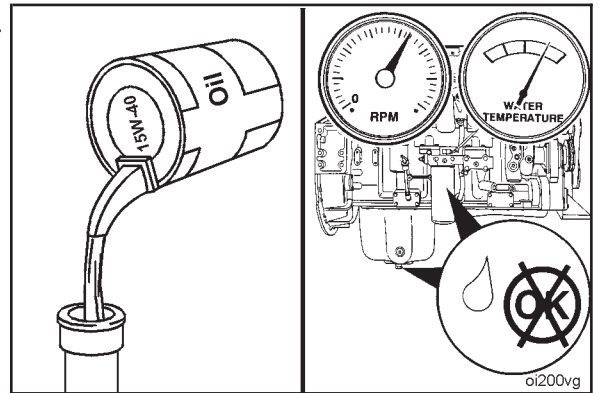
Install the lubricating oil pan. Refer to Procedure 007-025-026.



Fill the engine with lubricating oil. Refer to Procedure 007-025-028.

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

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

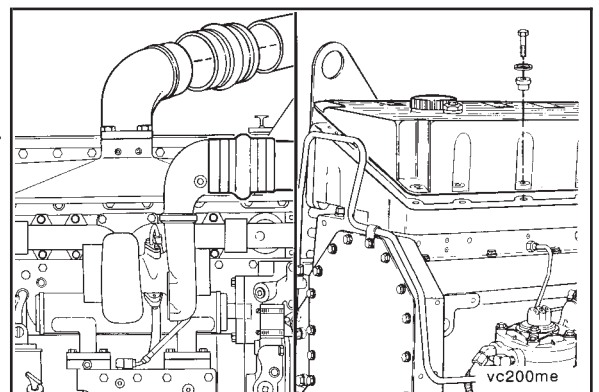


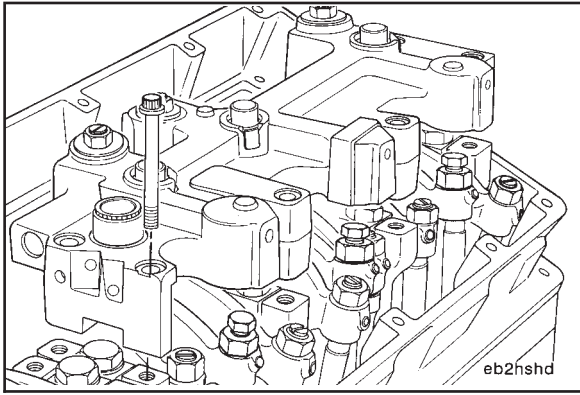
Camshaft (001-008)

Remove (001-008-002)

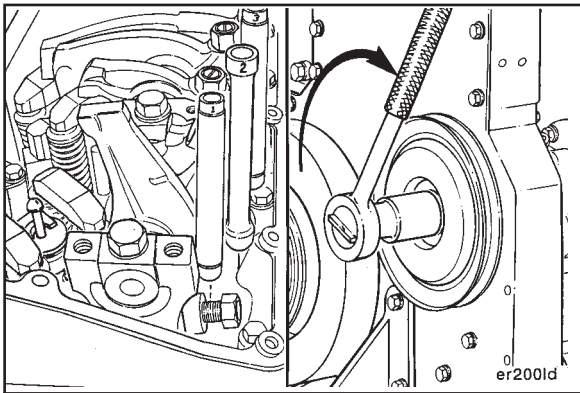
Remove the air piping from the intake manifold.

Remove the rocker lever cover. Refer to Procedure 003-011-002.

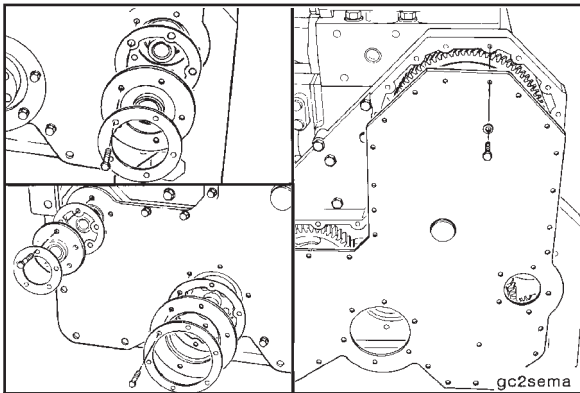




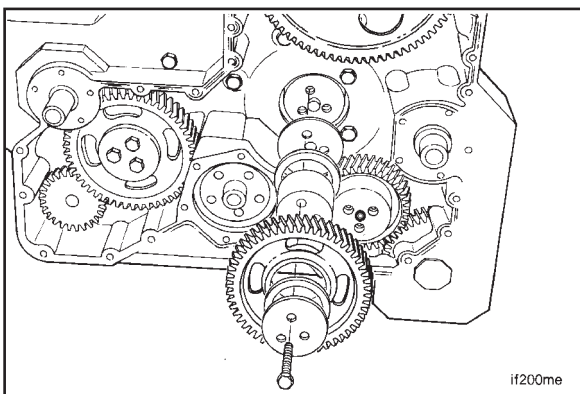
Remove the engine brakes, if equipped. Refer to Procedure 020-001-002.



Remove the push tubes and push rods. Refer to Procedure 004-014-002.



Remove the gear cover. Refer to Procedure 001-031-002.
NOTE: It is possible to remove the camshaft without removing the cylinder head. The cam followers can be tied up and away from the camshaft with wire.

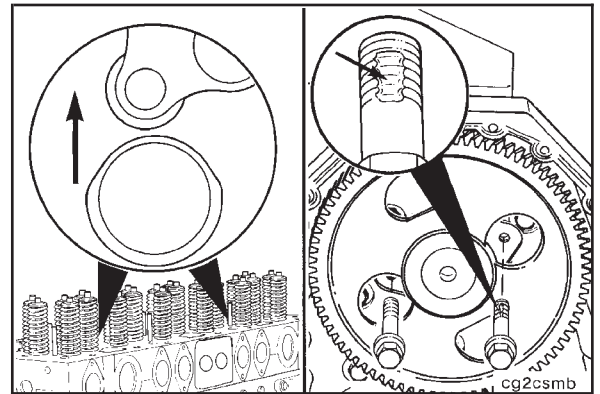


Remove the camshaft idler gear. Refer to Procedure 001-036-002.

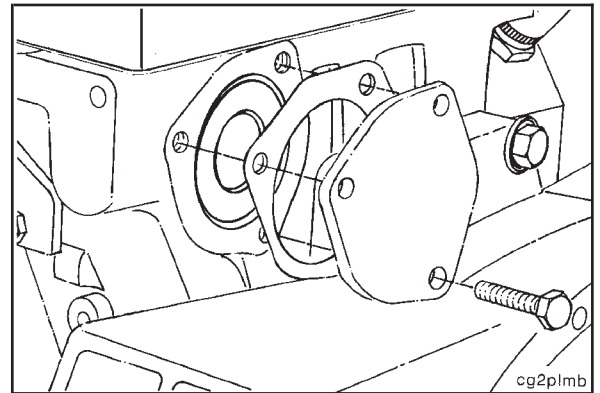
Raise the cam follower assemblies and use a wire to tie the cam followers up away from the camshaft.

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

Remove the thrust plate capscrews.

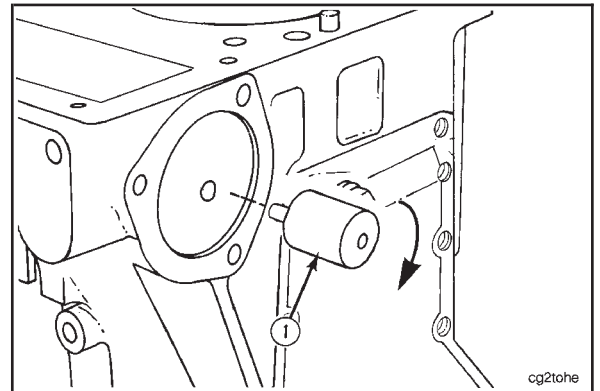


Remove the three capscrews and the camshaft rear cover plate.

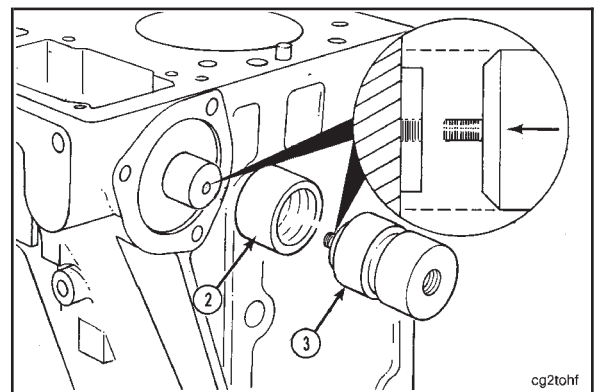


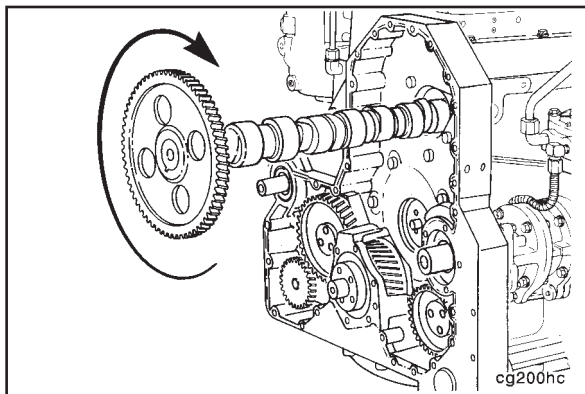
Install camshaft installation pilot, Part No. 3376388, as follows:

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



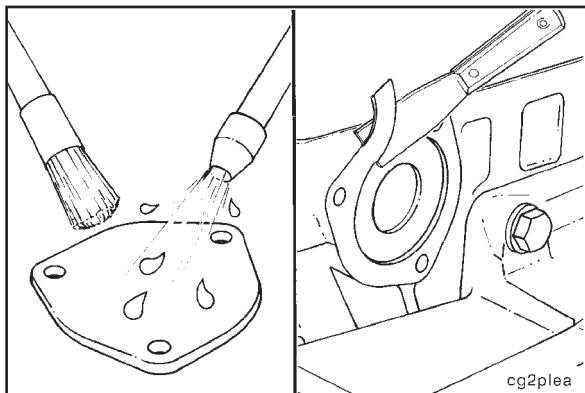
- Install the arbor sleeve (2) over the expander.
- Install the locating pilot extensions (3) to the expander.





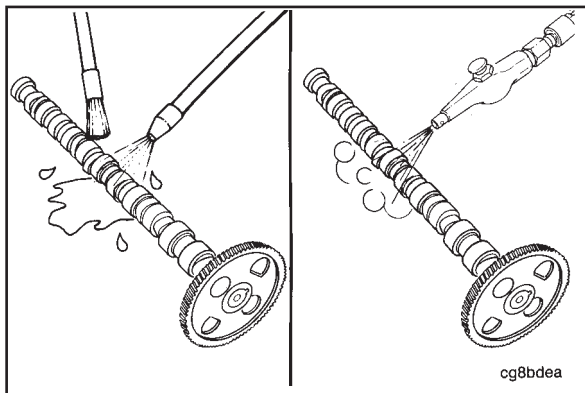
Use one hand to slowly rotate and pull the camshaft from the cylinder block, and the other hand to balance the camshaft as it is removed.

Remove the camshaft pilot tool.



Clean (001-008-006)

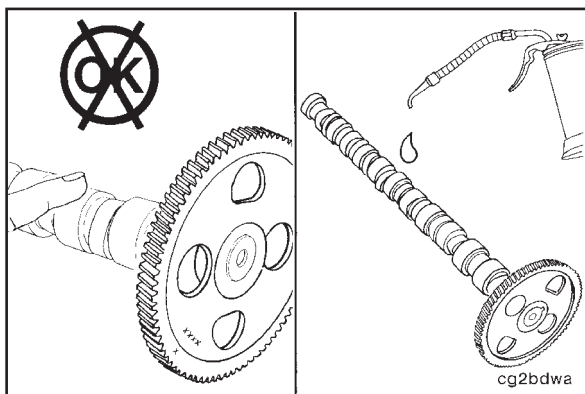
Clean the camshaft rear cover plate and the cylinder block mating surface.



⚠ WARNING ⚠

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

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



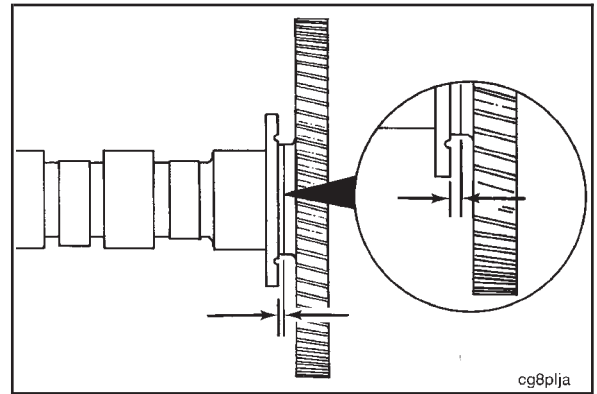
⚠ CAUTION ⚠

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

Inspect for Reuse (001-008-007)

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

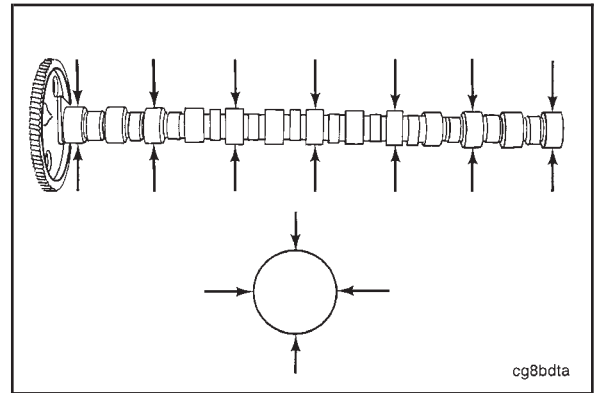
Camshaft Thrust Plate Clearance		
mm		in
0.13	MIN	0.005
0.33	MAX	0.013



cg8plja

Measure the outside diameter of the seven camshaft bushing journals.

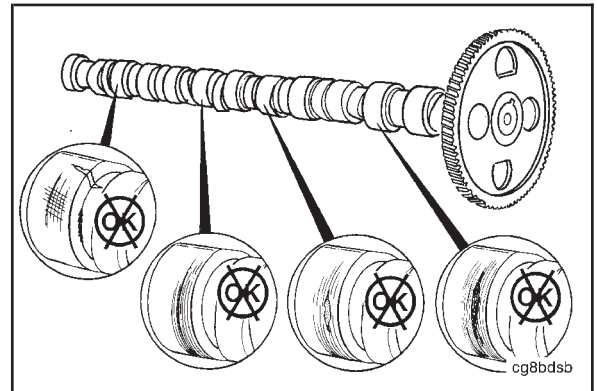
Camshaft Bushing Journal O.D.		
mm		in
71.960	MIN	2.8331
72.013	MAX	2.8352



cg8bdta

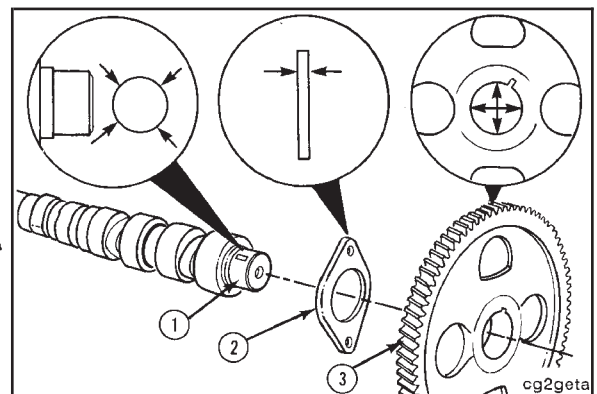
Visually inspect the camshaft lobes for cracks, scratches or other damage.

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

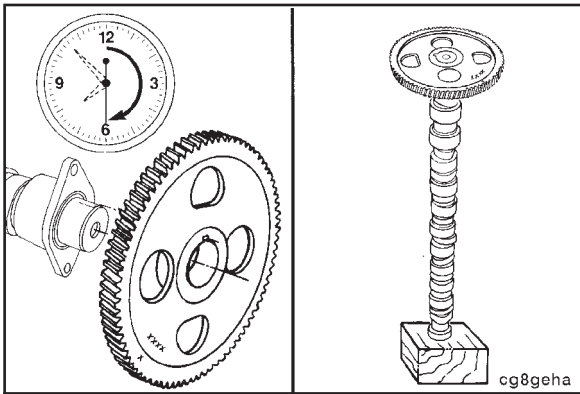


cg8bdsb

Remove the camshaft gear and measure the camshaft nose (1), thrust plate (2) and gear (3). Refer to Procedure 001-013-002.

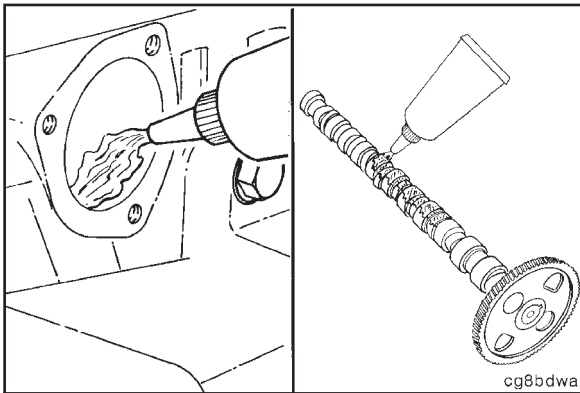


cg2geta

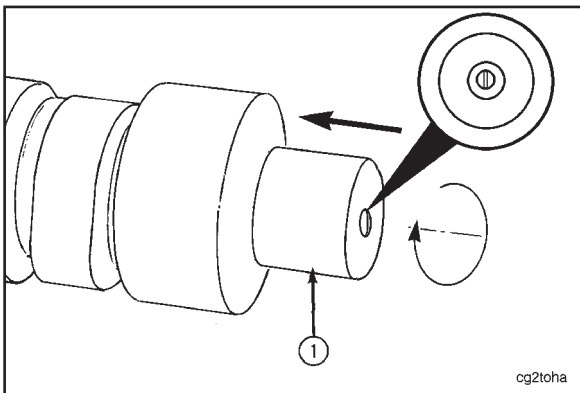


Install (001-008-026)

Install the camshaft gear on the camshaft. Refer to Procedure 001-013-026.

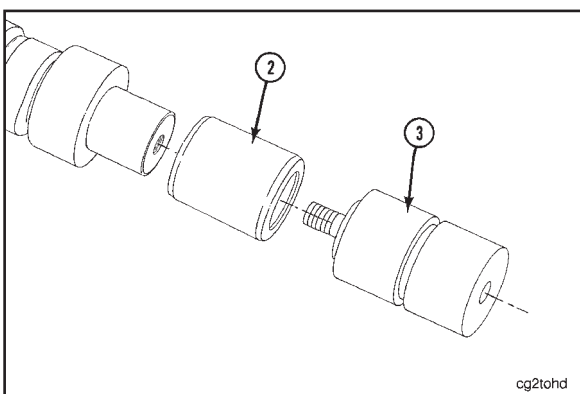


Use Lubriplate® 105, or equivalent, to coat the camshaft bushings and camshaft.



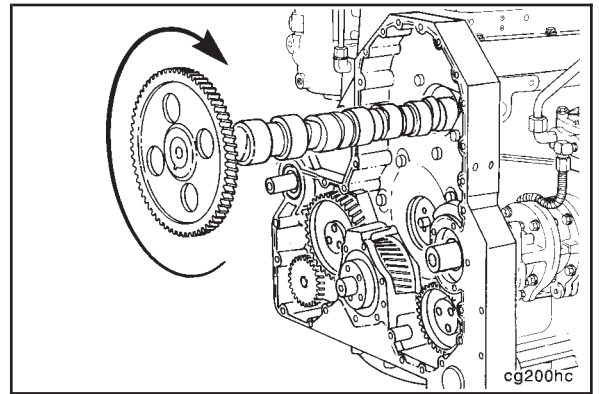
Install camshaft installation pilot, Part No. 3376388, as follows:

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



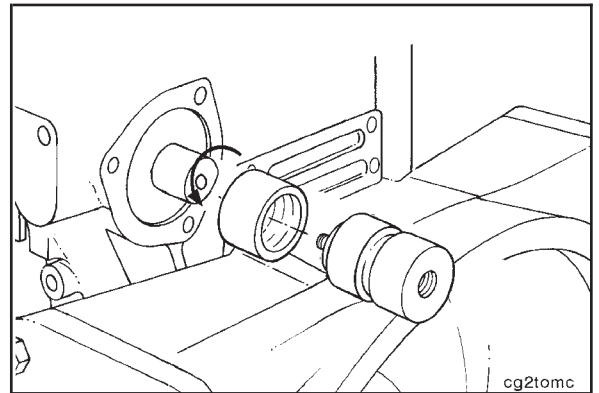
- Install the arbor sleeve (2) over the expander.
- Install the locating pilot extensions (3) to the expander.

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



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

Remove the camshaft pilot.

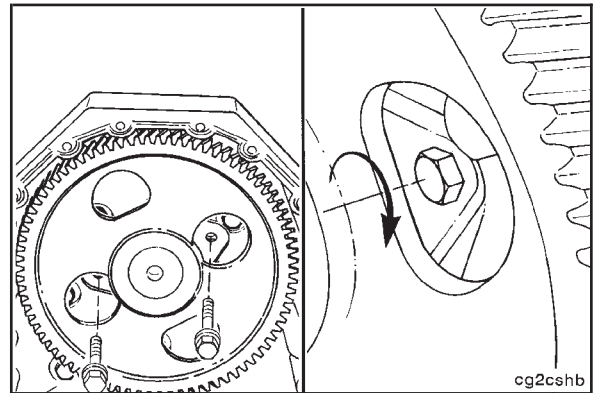


Rotate the camshaft to align the holes in the camshaft gear with the thrust plate capscrew holes in the cylinder block.

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

Install the capscrews.

Torque Value: 47 N•m [35 ft-lb]

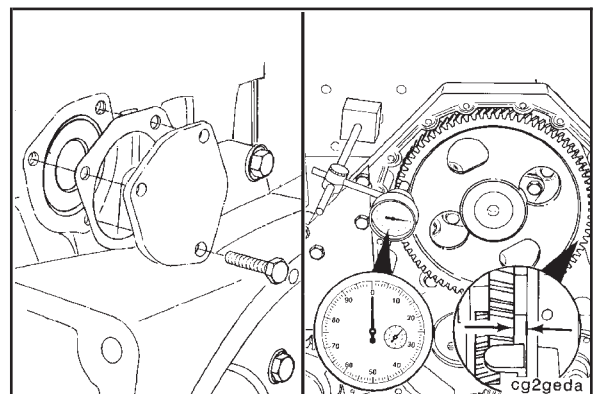


Use a new gasket to install the camshaft rear cover plate.

Tighten the three capscrews.

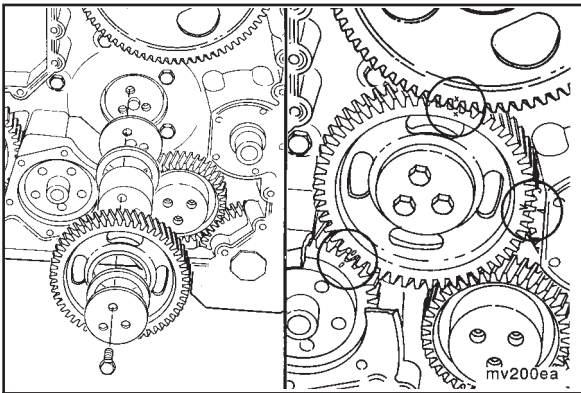
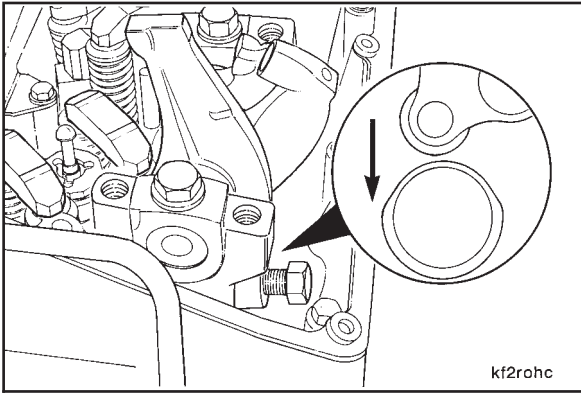
Torque Value: 47 N•m [35 ft-lb]

Measure the camshaft end clearance.

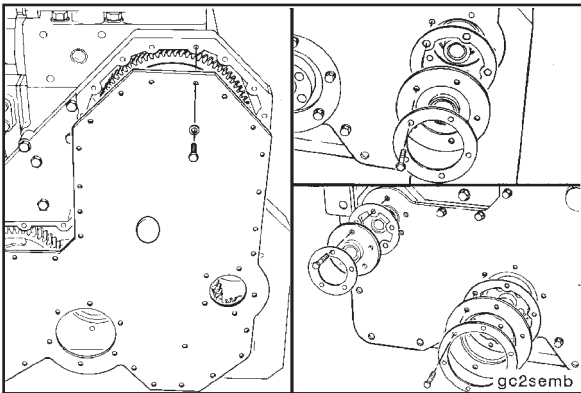


Camshaft End Clearance		
mm		in
0.13	MIN	0.005
0.33	MAX	0.013

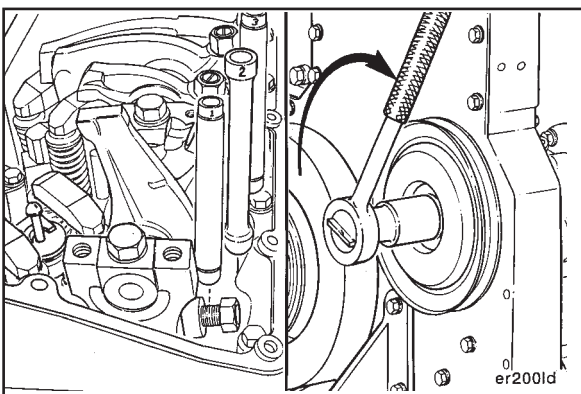
Do **not** drop the cam follower levers on the camshaft lobes.
Carefully lower the cam followers onto the camshaft.



Install the camshaft idler gear. Refer to Procedure 001-036-026.
Check the engine timing. Refer to Procedure 006-025.

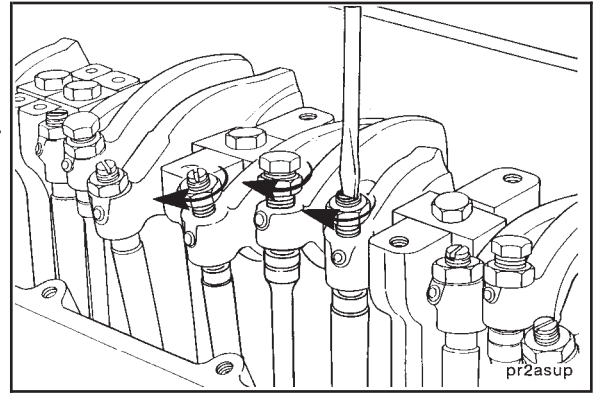


Install the gear cover. Refer to Procedure 001-031-026.

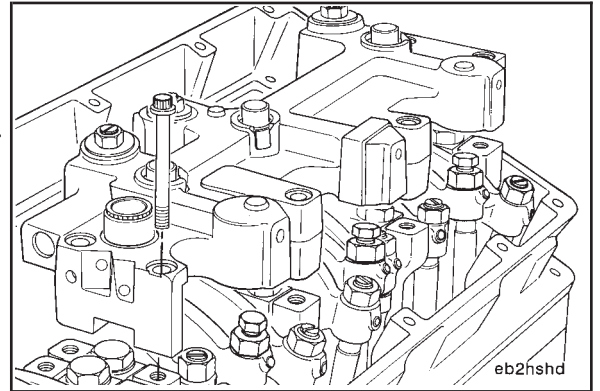


Install the push tubes and push rods. Refer to Procedure 004-014-026.

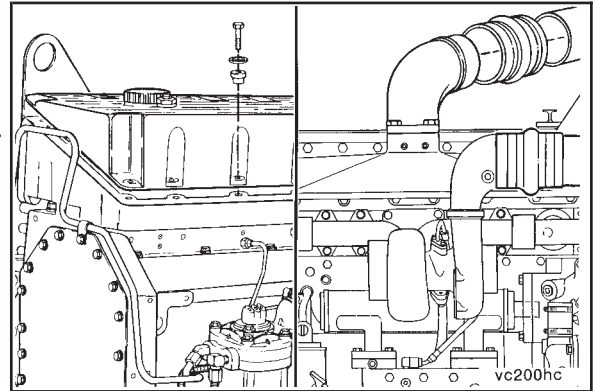
Adjust the valves and injectors. Refer to Procedure 003-004.



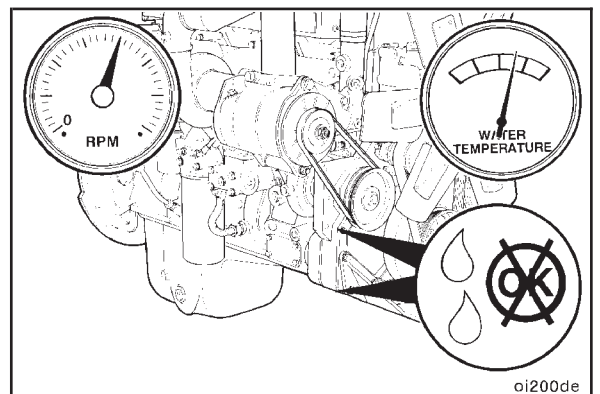
Install the engine brakes, if equipped. Refer to Procedure 020-001-026.

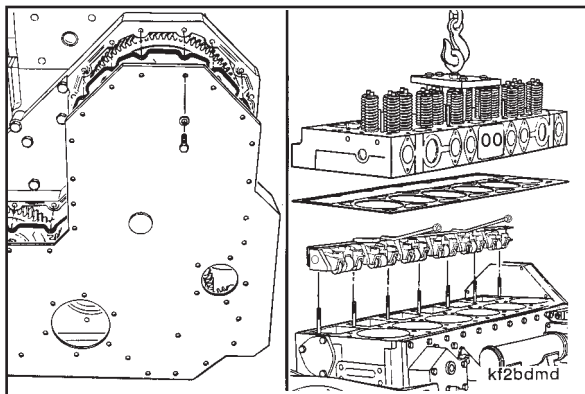


Install the rocker lever cover. Refer to Procedure 003-011-026.



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





Camshaft Bushings (001-010)

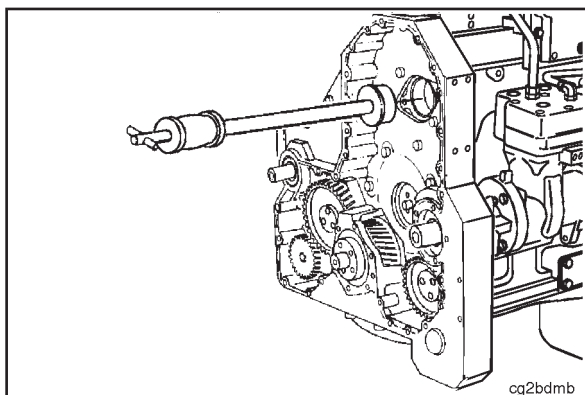
Remove (001-010-002)



Remove the gear cover. Refer to Procedure 001-031-002.

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

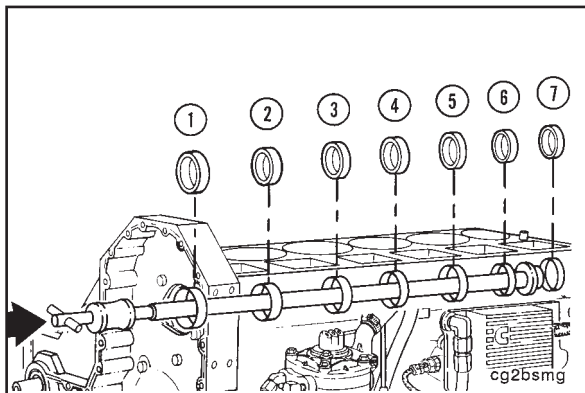
Remove the cam followers. Refer to Procedure 004-001-002.



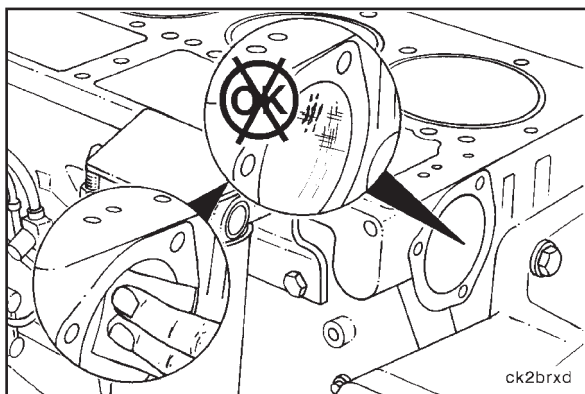
Remove the camshaft. Refer to Procedure 001-008-002.

Use Part No. 3376637 Camshaft Bushing Driver and Part No. 3376070 Driver, or Part No. 3823642 Hydraulic Cam Bushing Tool and Part No. 3823621 Hydraulic Actuator Kit to remove the camshaft bushings.

Remove bushing number one first.



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



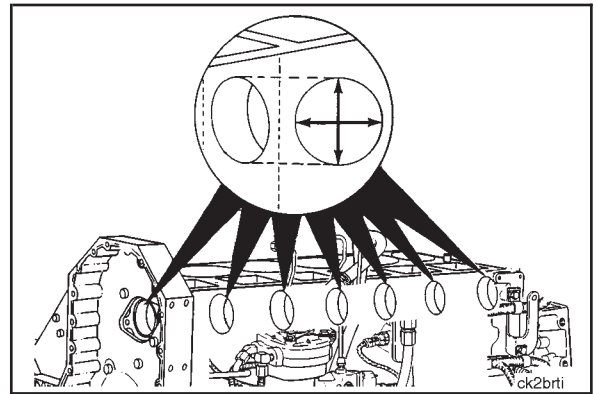
Clean (001-010-006)

Use Scotch-Brite® 7448, or equivalent, to remove burrs and clean the bushing bores.

Inspect for Reuse (001-010-007)

Measure the cylinder block camshaft bore inside diameter.

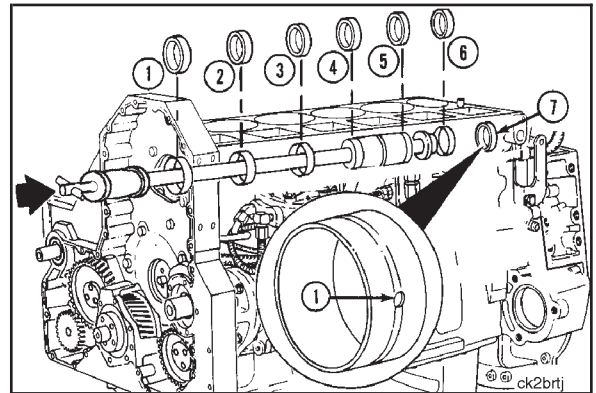
Cylinder Block Camshaft Bore I.D.		
mm		in
76.987	MIN	3.0310
77.040	MAX	3.0331



Install (001-010-026)

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

NOTE: The oil hole (1) in the bushing **must** be at the 3 o'clock location when viewed from the front of the engine.

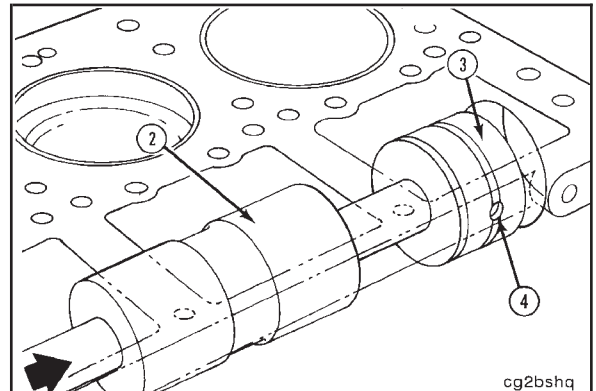


Number Seven Bushing — Installation

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

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

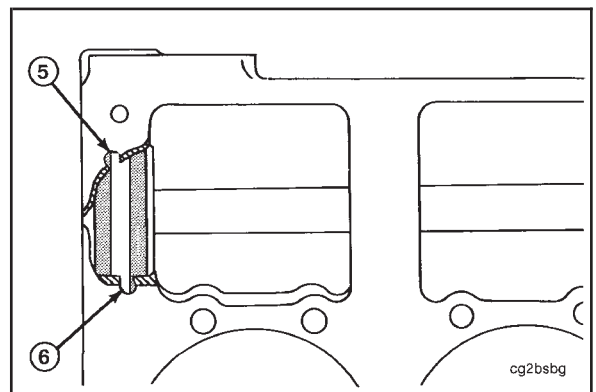
Drive the bushing in the bore.

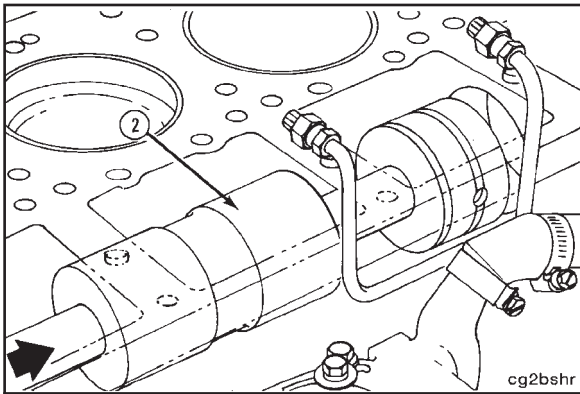


CAUTION

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

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





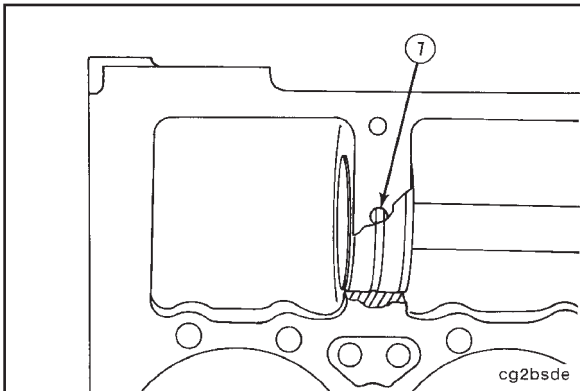
Number Six Through Number Two Bushings — Installation

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

Install the guide (2) in the correct location.

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

Drive in the bushing.



Remove the cam follower studs. Refer to Procedure 004-001-002.

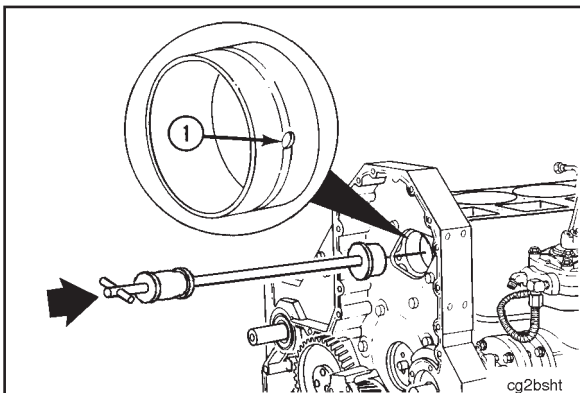
CAUTION



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



Visually inspect the location of the camshaft bushing oil groove.

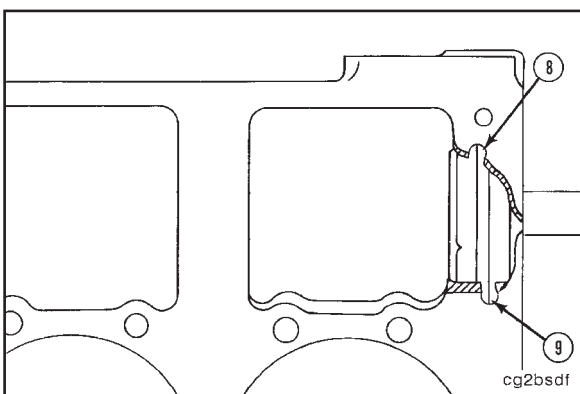


Number One Bushing — Installation

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

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

Drive the bushing in the bore.

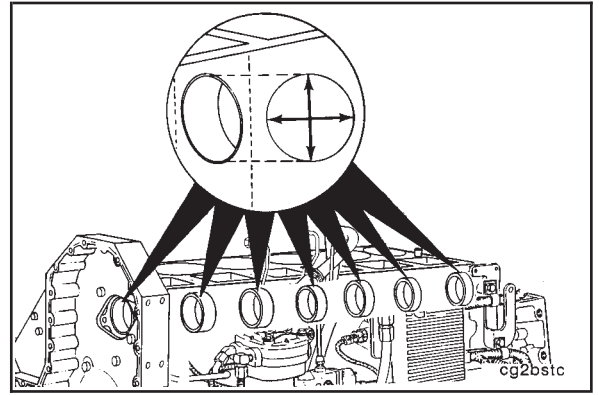


CAUTION

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

Measure the camshaft bushing installed inside diameter.

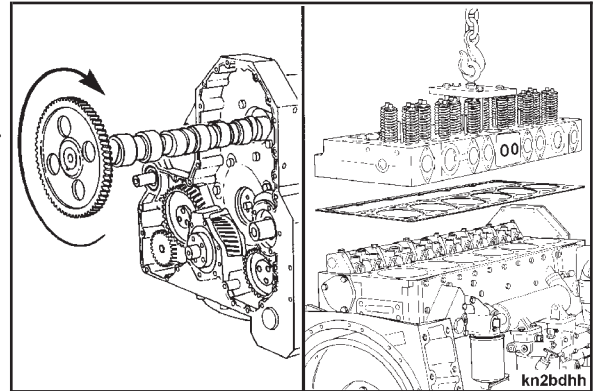
Camshaft Bushing I.D. Installed		
mm		in
72.078	MIN	2.8377
72.142	MAX	2.8402



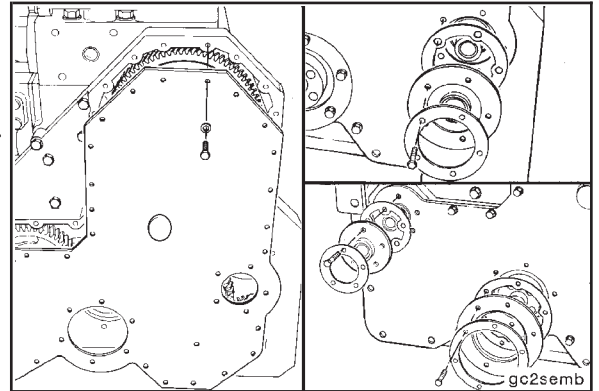
Install the camshaft. Refer to Procedure 001-008-026.

Install the cam follower studs and camfollowers. Refer to Procedure 004-001-026.

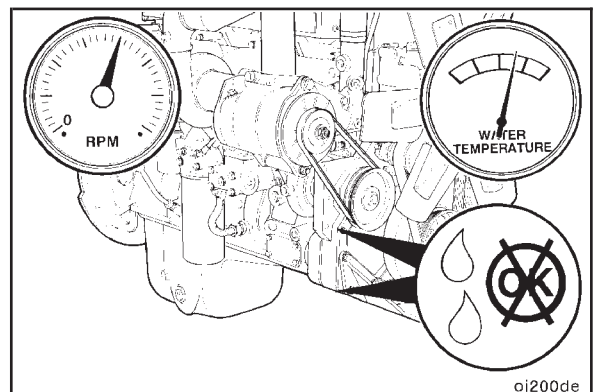
Install the cylinder head. Refer to Procedure 002-004-026.

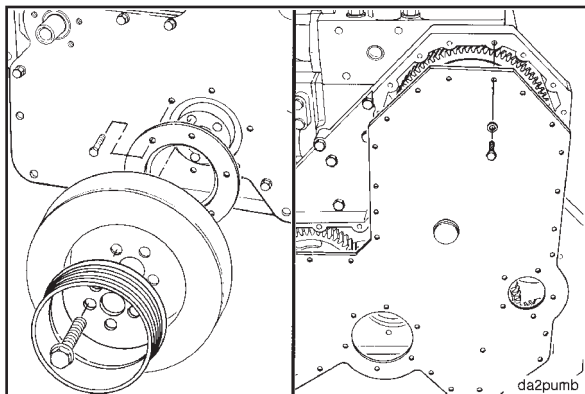


Install the gear cover. Refer to Procedure 001-031-026.



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



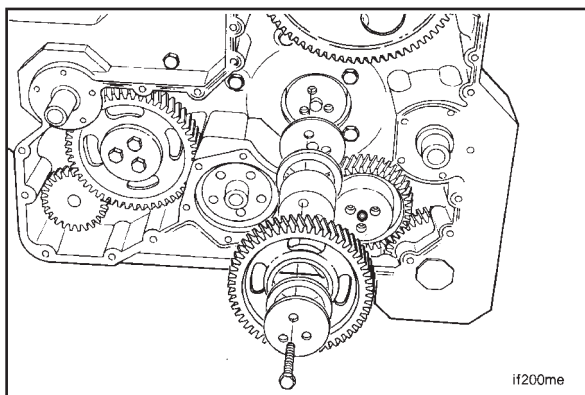


Camshaft Gear (Camshaft Installed) (001-012)

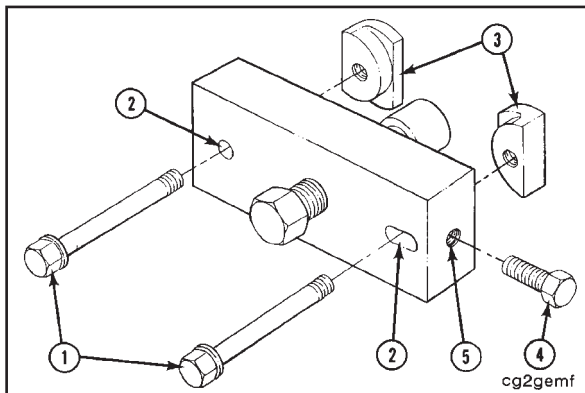


Remove (001-012-002)

Remove the gear cover. Refer to Procedure 001-031-002.



Remove the camshaft idler gear. Refer to Procedure 001-036-002.



The camshaft gear puller kit, Part No. 3824106, **must** be assembled before use.



Insert the two 1/2 x 4 inch cam gear adapter capscrews and two plain flat washers (1) through the cam gear puller plate holes (2).

NOTE: The two 1/2 x 4 inch capscrews **must** be grade 5 or higher.

Attach the two cam gear puller adapters (3) to the two cam gear adapter capscrews.

Start the 1/2 x 1 1/2 inch capscrew (4) into the end hole (5) of the cam gear puller plate. Do **not** thread into the slotted hole of the puller plate at this time.

Install camshaft gear puller, Part No. 3824106, onto the camshaft gear.

Insert the adapter (1) of the non-slotted hole in the puller plate (2) onto the camshaft gear first. The adapter pulling surfaces (3) **must** point toward the center of the camshaft gear.

Slide the capscrew and adapter of the slotted end of the puller plate (4) toward the end of the puller plate and insert the adapter onto the camshaft gear. The adapter pulling surface (3) **must** point toward the center of the camshaft gear.

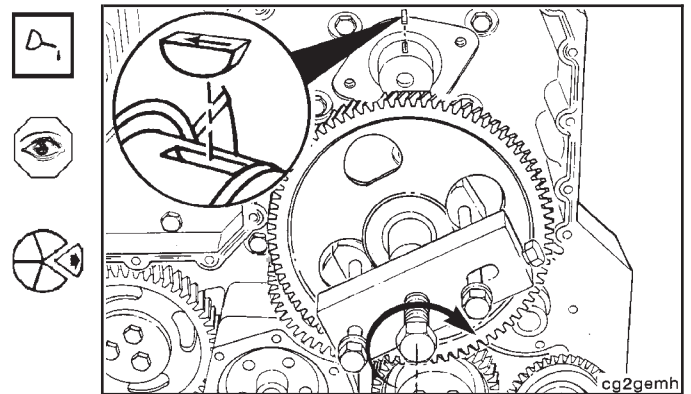
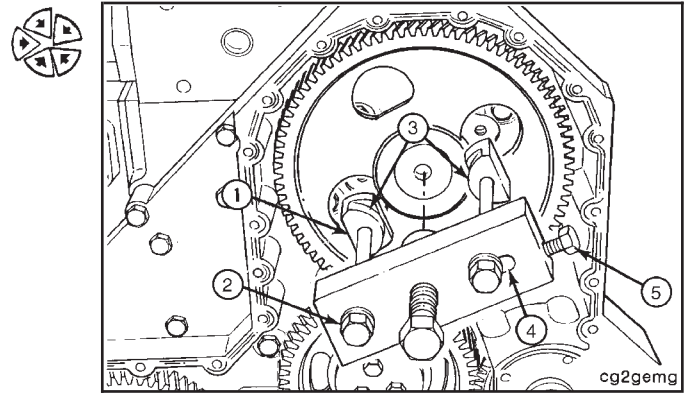
While holding the puller in place with one hand, tighten the capscrew (5) on the end of the puller plate. Make certain the puller adapters are hooked completely over the camshaft gear. Torque the capscrew (5).

Torque Value: 7 N•m [60 in-lb]

Use graphite to lubricate the pressure screw of the puller. Turn the pressure screw **clockwise** to remove the gear.

If the camshaft key is marked with an arrow, record the direction of the arrow.

Remove the camshaft gear key.



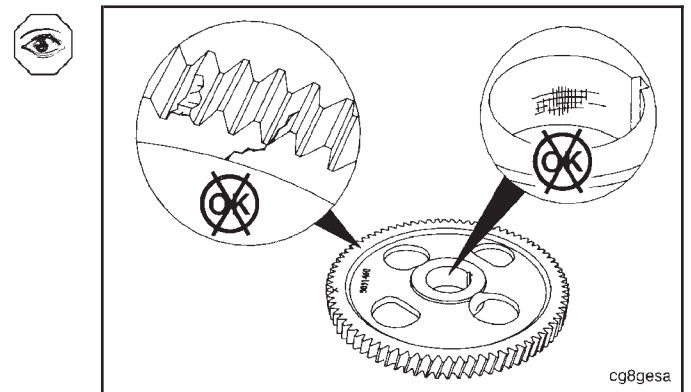
Inspect for Reuse (001-012-007)

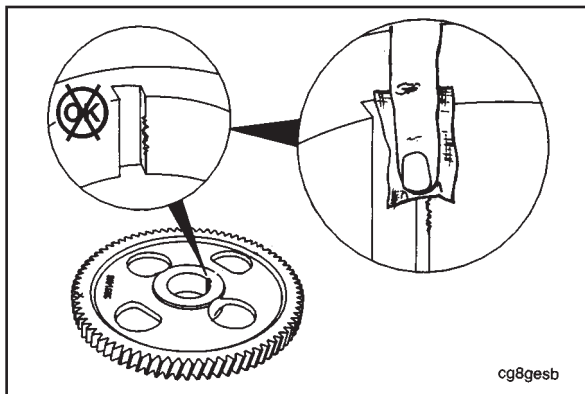
Visually inspect the camshaft gear for cracks, chipped or broken teeth.

Inspect the bore of the gear for fretting or burrs.

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

If the fretting, burrs or raised material **cannot** be removed, replace the gear.

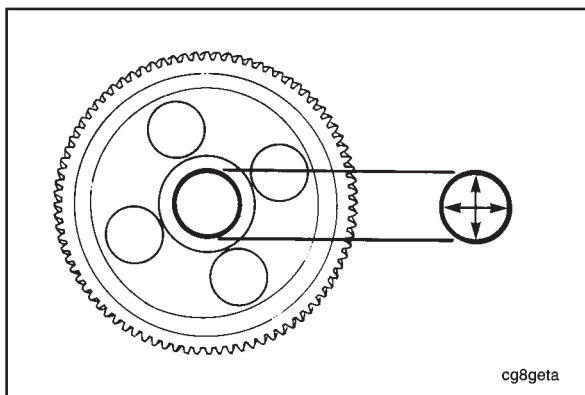




Inspect the gear keyway for burrs.

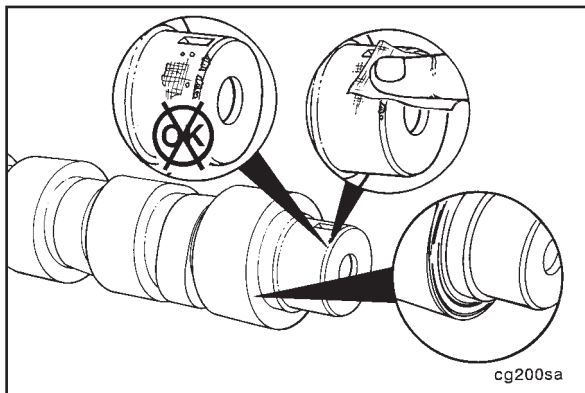
Remove burrs with Scotch-Brite® 7448, Part No. 3823258; a fine honing stone or equivalent.

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



Measure the camshaft gear bore inside diameter.

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

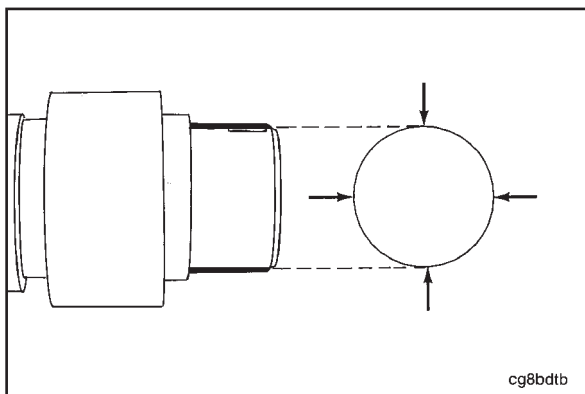


Visually inspect the camshaft nose for fretting or burrs.

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

If fretting or burrs **cannot** be removed, replace the camshaft.

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

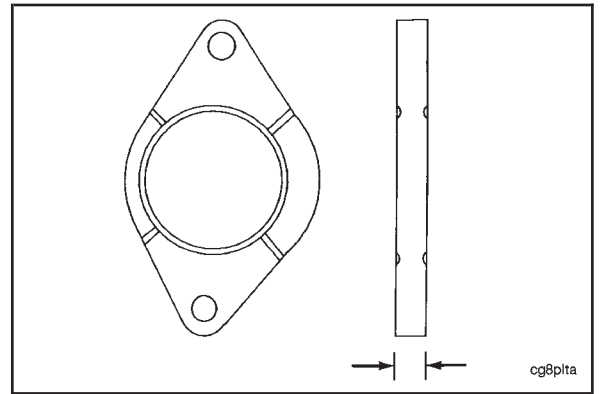


Measure the camshaft gear journal outside diameter.

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

Measure the camshaft thrust plate thickness.

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

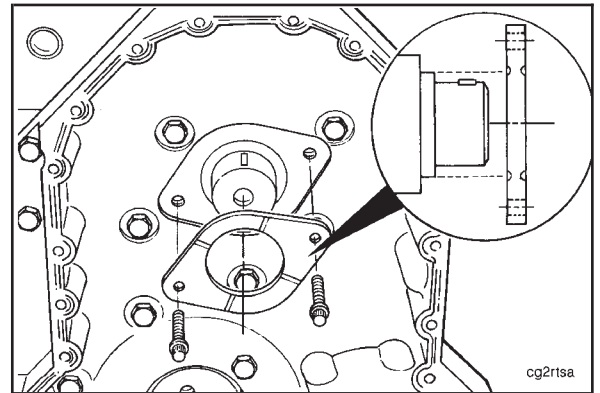


Install (001-012-026)

Install the thrust plate on the camshaft.

Install the capscrews and tighten.

Torque Value: 47 N•m [35 ft-lb]

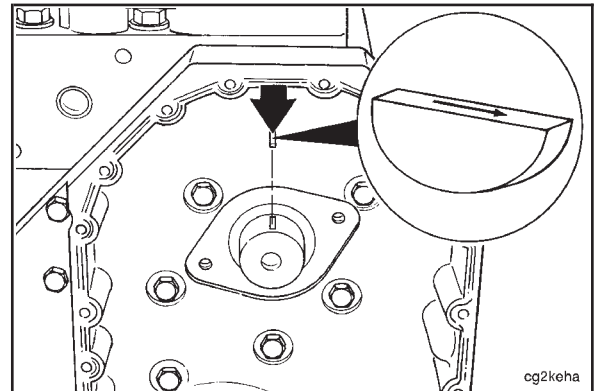


Be sure the gear mounting surface is clean and free of oil, dirt or debris.

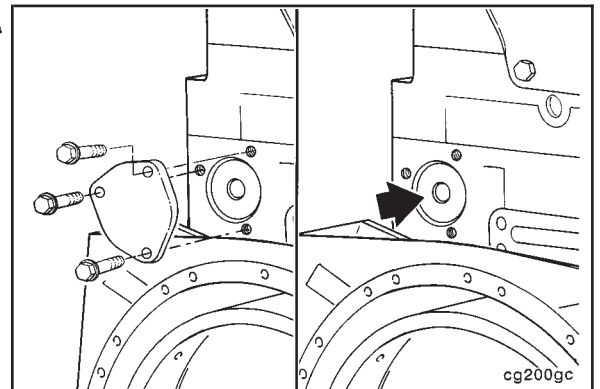
If the same camshaft gear is used again, use the same part number key as the one that was removed. Be sure the arrow on the key is pointing in the same direction as when it was removed.

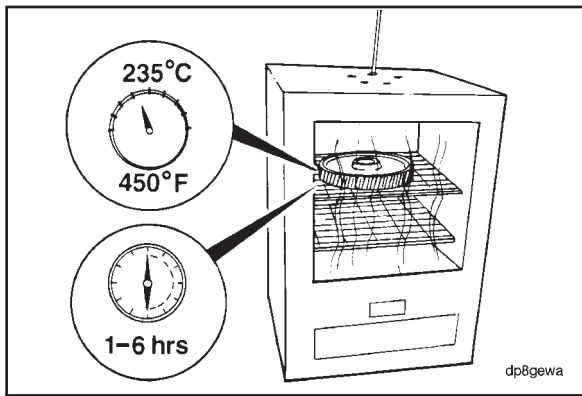
NOTE: Gear housing clearance makes key installation more difficult. Use care in seating the key.

Use a leather hammer to install the camshaft gear key.



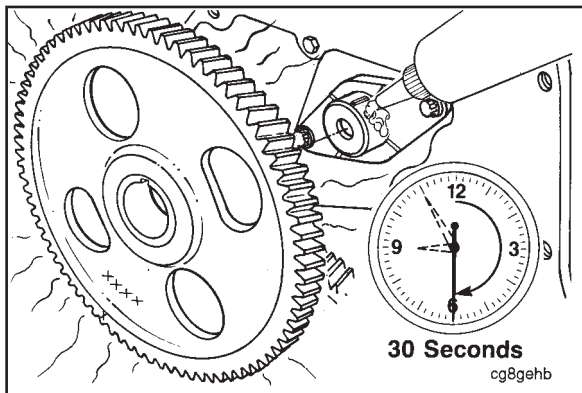
It can be necessary to remove the camshaft rear cover plate and apply pressure to the end of the camshaft to hold it in the forward position while the gear is being installed. Refer to Procedure 001-008-026.





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

Temperature: 235 °C [450 °F]



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

▲ WARNING ▲



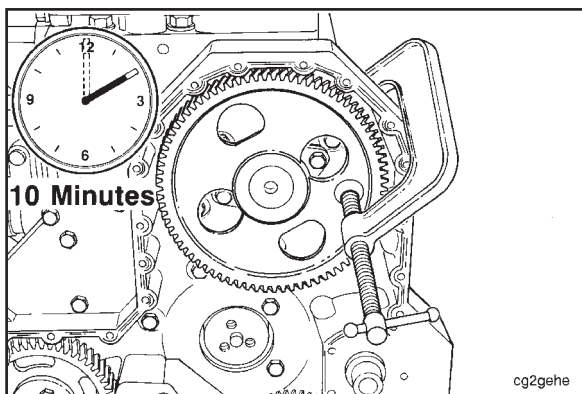
Use insulated gloves, Part No. 3823730, and/or hot clamp pliers, Part No. 3823732, when handling heated parts. Hot parts can cause serious personal injury.

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

▲ CAUTION ▲

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

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

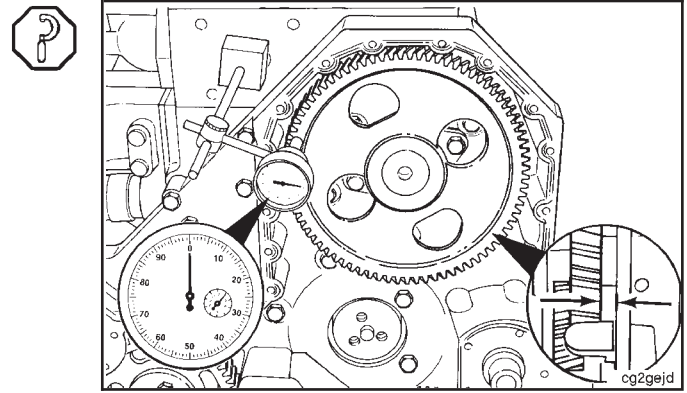


Install a “C-clamp” around the gear housing and the camshaft gear to hold the gear in position as it cools.

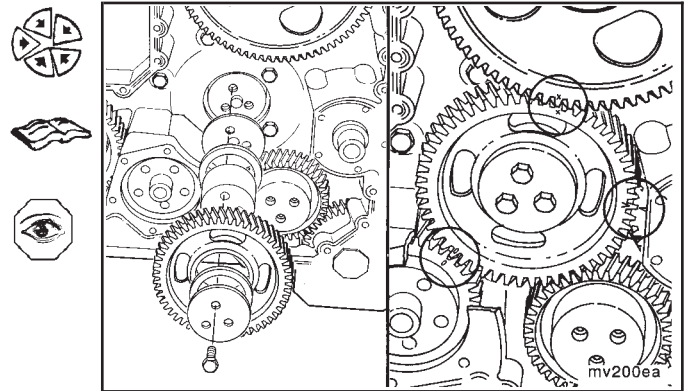
Remove the “C-clamp” after the gear has cooled to room temperature (approximately 10 minutes).

Use a dial indicator to check the end clearance of the gear. Push the camshaft to the rear and set the gauge at "0". Pull the gear out and measure the end clearance.

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



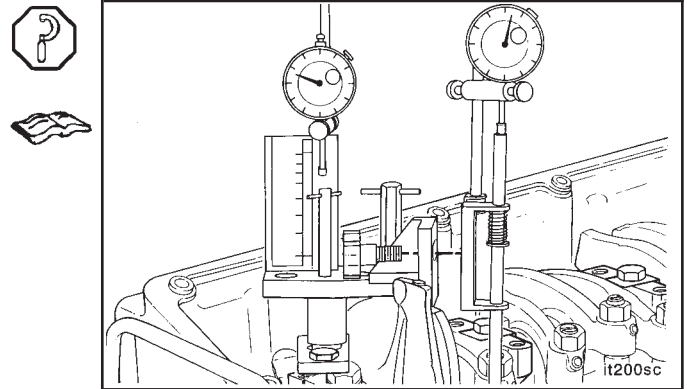
Install the camshaft idler gear. Refer to Procedure 001-036-026.



⚠ CAUTION ⚠

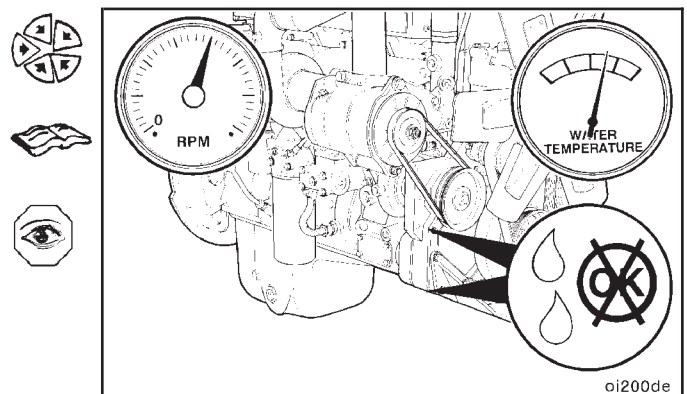
Failure to check the engine timing can cause severe engine damage.

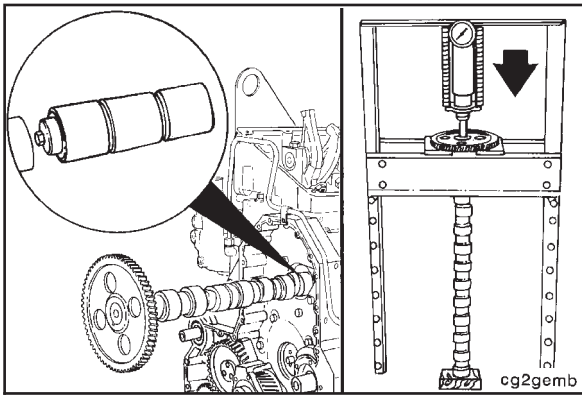
Check the engine timing. Refer to Procedure 006-025.



Install the gear cover. Refer to Procedure 001-031-026.

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





Camshaft Gear (Camshaft Removed) (001-013)



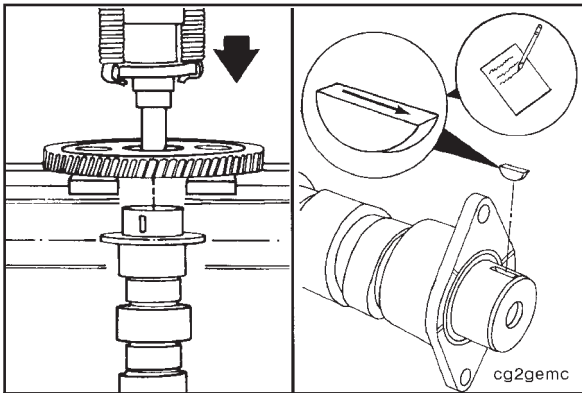
Remove (001-013-002)

Remove the camshaft. Refer to Procedure 001-008-002.



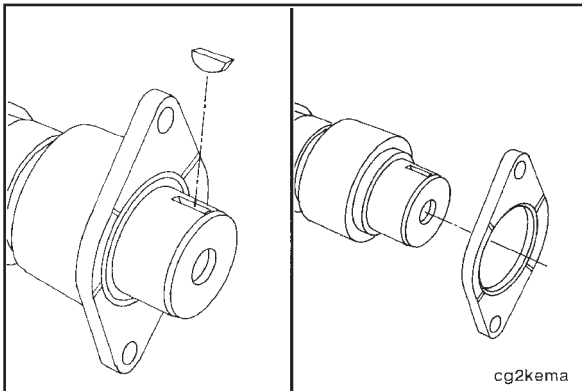
Support the camshaft gear on the center hub when pressing it off the camshaft. Failure to do so can result in damage to the gear.

Install the camshaft and gear assembly in a hydraulic press.



Press the camshaft from the gear.

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



Remove the camshaft key.

Remove the thrust plate.

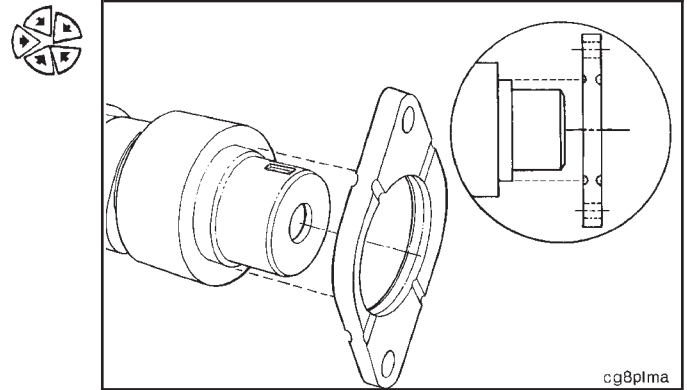
Camshaft Keys			
Key Part No.	Degree of Offset (To the Camshaft)	Change in Push Rod Travel	
		mm	in.
3009953	0.00	0.000	0.0000
3030893	0.25	0.051	0.0020
3009948	0.50	0.102	0.0040
3030894	0.75	0.152	0.0060
3009949	1.00	0.203	0.0080
3030895	1.25	0.254	0.0100
3009950	1.50	0.305	0.0120
3030896	1.75	0.356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

li200nb

Install (001-013-026)

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

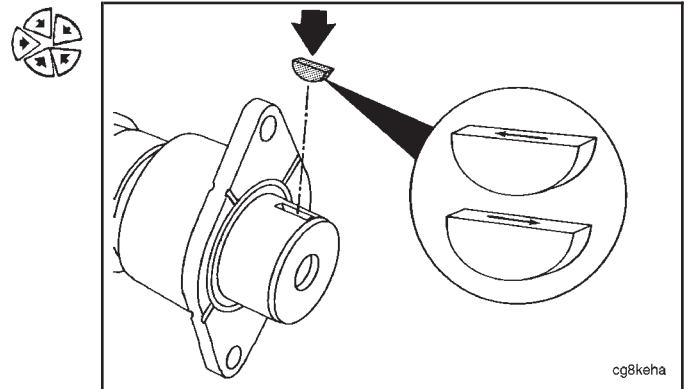
Install the thrust plate on the camshaft.



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

Use a leather hammer to install the camshaft gear key.

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



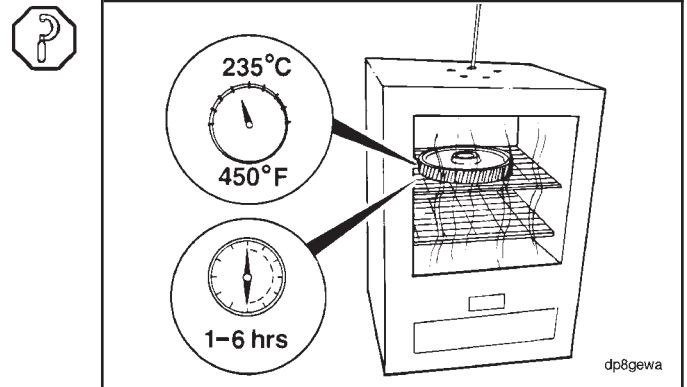
⚠ WARNING ⚠

Use insulated gloves, Part No. 3823730, when handling heated parts. Hot parts can cause serious personal injury.

Heat the gear in an oven for a minimum of one hour, but not longer than six hours.

Temperature 235 °C [450 °F]

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



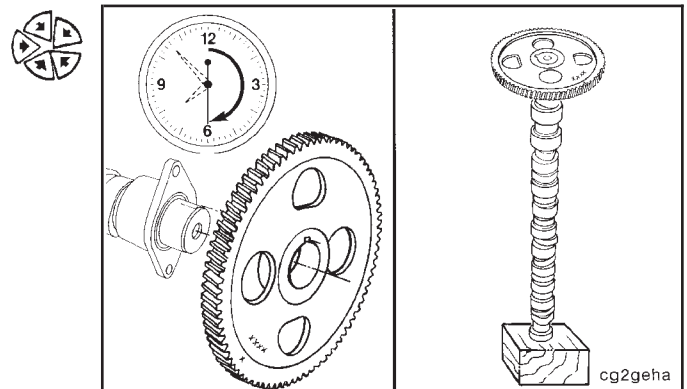
⚠ CAUTION ⚠

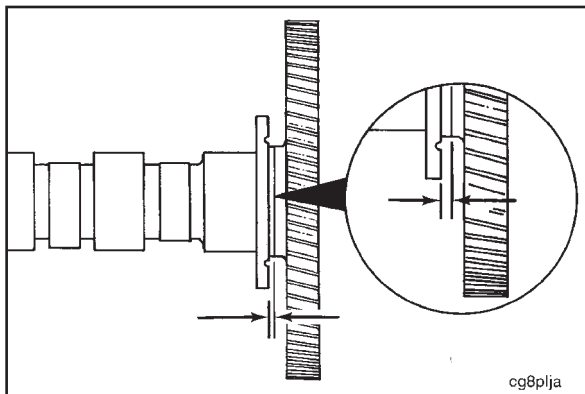
The timing marks and gear part number must be facing away from the camshaft when the gear is installed to prevent engine damage.

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

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

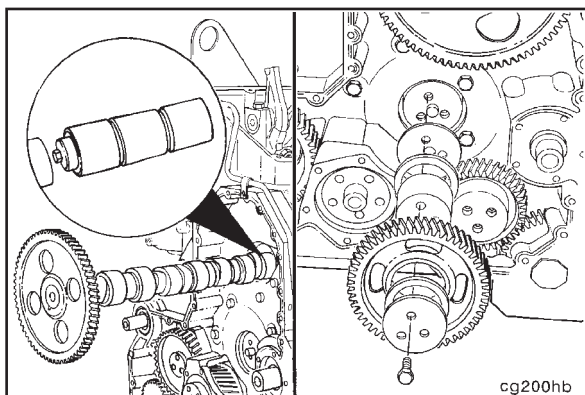
Keep the camshaft in a vertical position with the gear up until the gear has cooled.





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

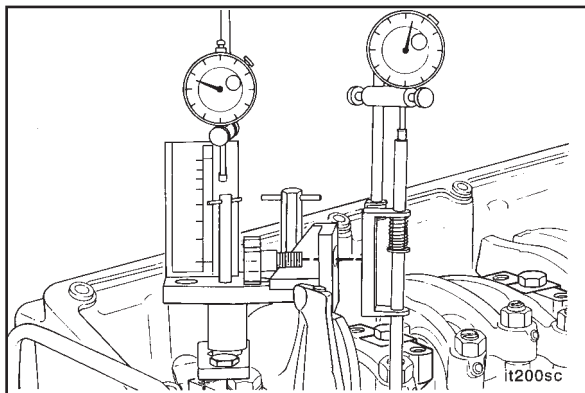
Thrust Plate Clearance		
mm		in
0.13	MIN	0.005
0.33	MAX	0.013



Install the camshaft. Refer to Procedure 001-008-026.



Install the camshaft idler gear. Refer to Procedure 001-036-026.

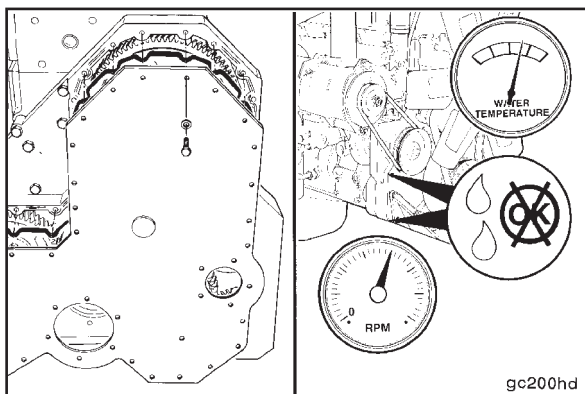


CAUTION

Failure to check engine timing can cause severe engine damage.



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



Install the gear cover. Refer to Procedure 001-031-026.



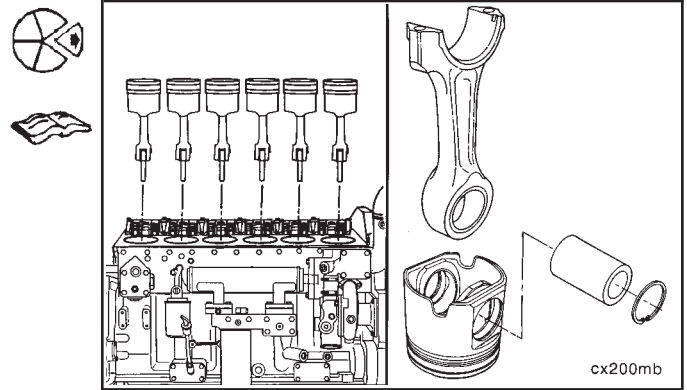
Operate the engine to normal operating temperature and check for leaks.



Connecting Rod (001-014)

Remove (001-014-002)

The piston and connecting rod must be removed as an assembly on M11 engines. Refer to Procedure 001-054-002 for removal instructions.



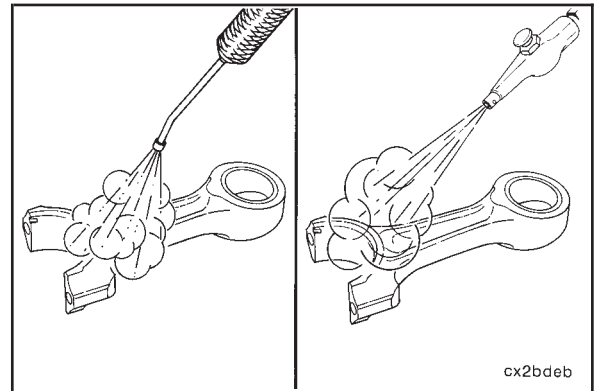
Clean (001-014-006)



WARNING

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

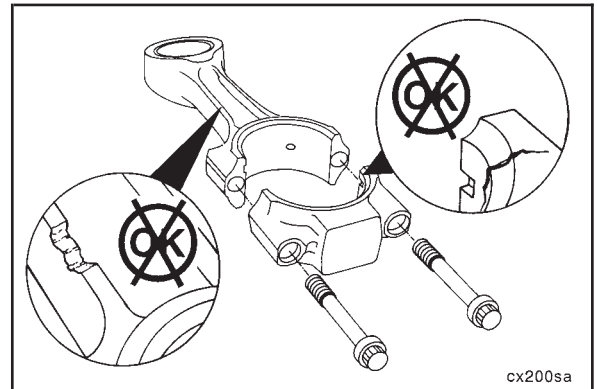
Use steam or solvent to clean the connecting rods. Dry with compressed air.



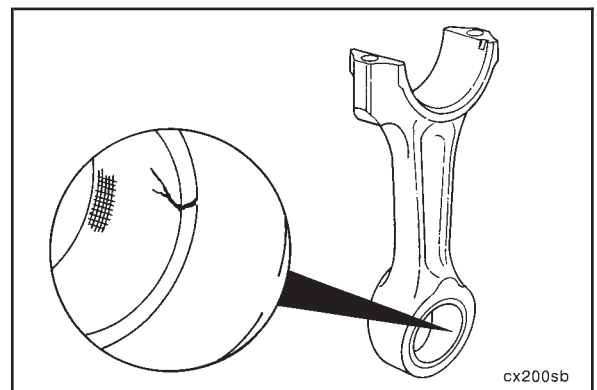
Inspect for Reuse (001-014-007)

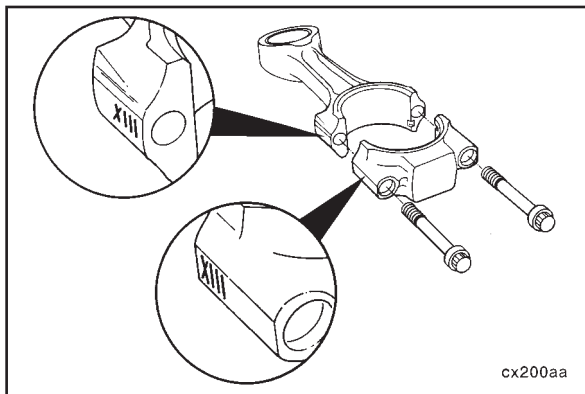
Inspect the connecting rods and caps for damage.

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



Visually inspect the connecting rod pin bore bushing for damage.





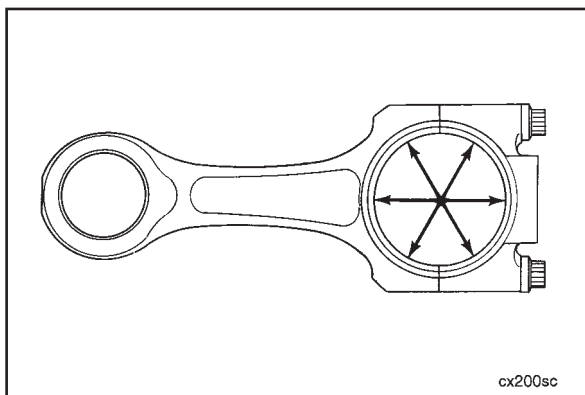
Install the connecting rod caps and capscrews.

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



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

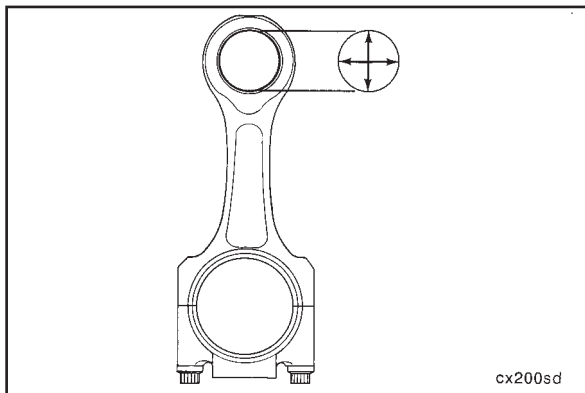
- Torque Value:**
- | | | |
|--------|-----------------------|-------------|
| Step 1 | 68 N•m | [50 ft-lb] |
| 2 | 142 N•m | [105 ft-lb] |
| 3 | 210 N•m | [155 ft-lb] |
| 4 | Loosen completely | |
| 5 | Repeat steps 1 thru 3 | |



Measure the connecting rod crankshaft bore inside diameter.

Connecting Rod Crankshaft Bore I.D.

mm		in
83.975	MIN	3.3061
84.025	MAX	3.3080



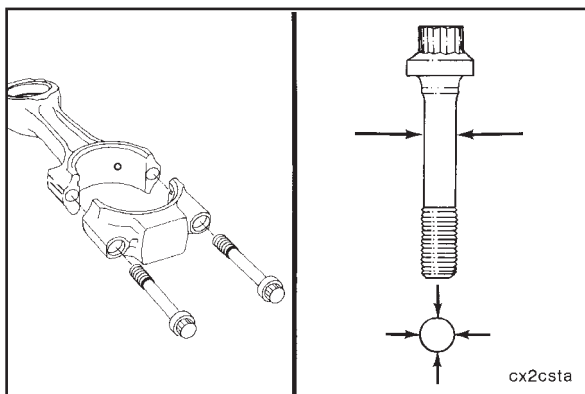
Measure the piston pin bushing inside diameter.

Piston Pin Bushing I.D.



mm		in
54.054	MIN	2.1281
54.099	MAX	2.1299

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



Remove the capscrews and rod caps.



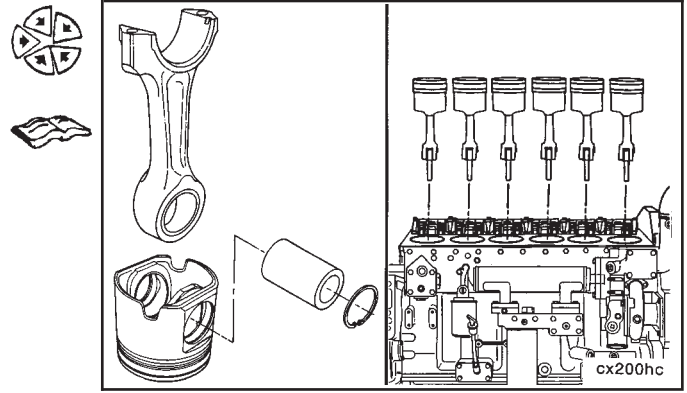
Measure the connecting rod capscrew outside diameter.

Connecting Rod Capscrew O.D.

mm		in
12.60	MIN	0.496
12.80	MAX	0.504

Install (001-014-026)

The piston and connecting rod must be installed as an assembly on M11 engines. Refer to Procedure 001-054-026 for installation instructions.

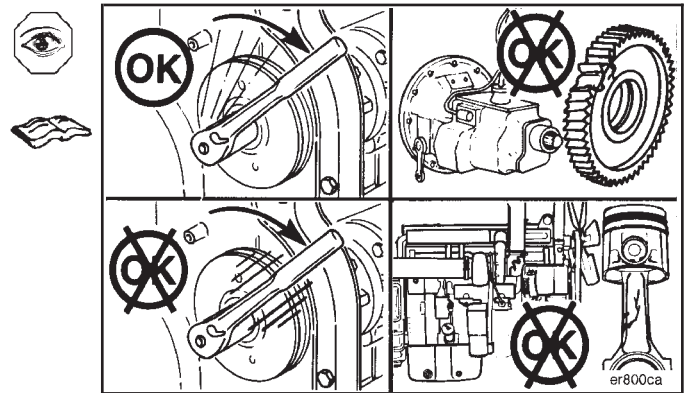


Crankshaft (001-016)

Rotation Check (001-016-052)

Use only the accessory drive shaft to rotate the crankshaft. Rotate the crankshaft **clockwise** through two complete revolutions.

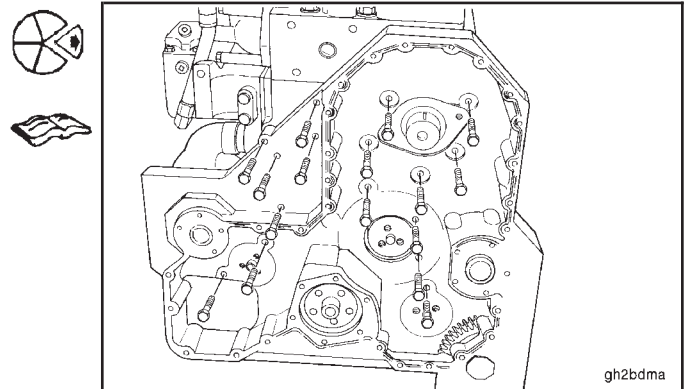
If the engine does **not** turn freely, the equipment can have a malfunction. Refer to the manufacturer's instructions. The engine can have internal problems. Refer to the correct procedure for inspection and replacement of internal engine components.



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

Remove (001-018-002)

Remove the gear housing. Refer to Procedure 001-033-002.

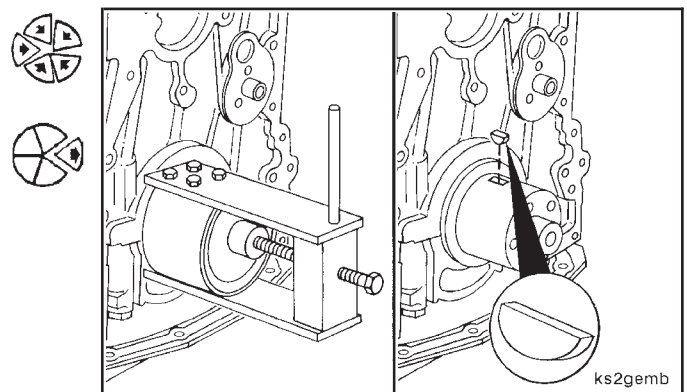


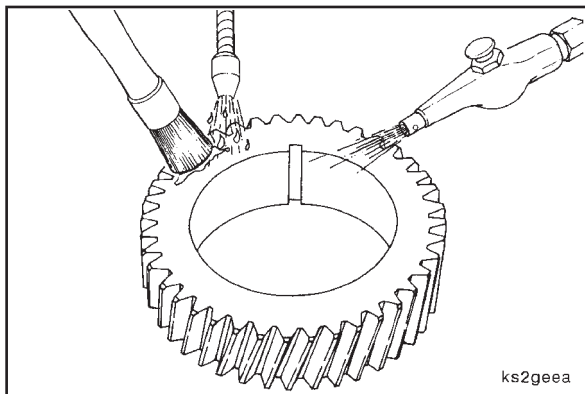
Install crankshaft gear puller, Part No. 3375834, and jaw, Part No. 3375839, on the gear.

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

Remove the crankshaft gear key.

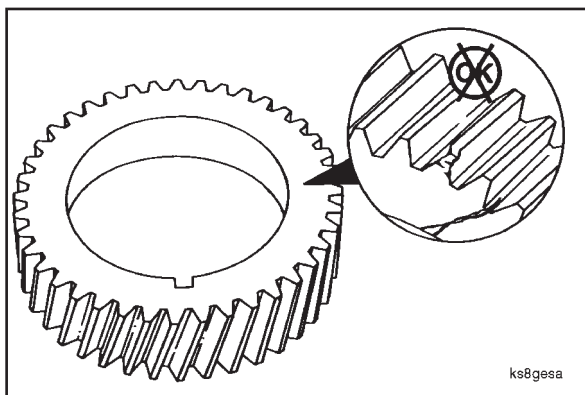
Do **not** damage the crankshaft when removing the key.





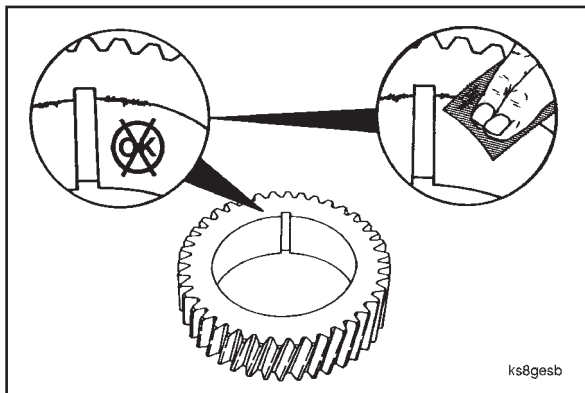
Clean (001-018-006)

Clean the gear with solvent. Dry with compressed air.

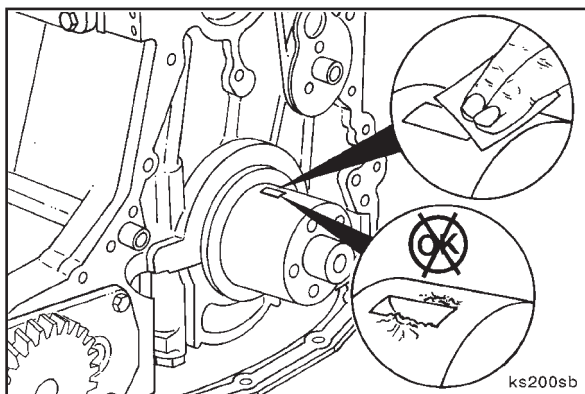


Inspect for Reuse (001-018-007)

Visually inspect the crankshaft gear for cracks, broken or chipped teeth.



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



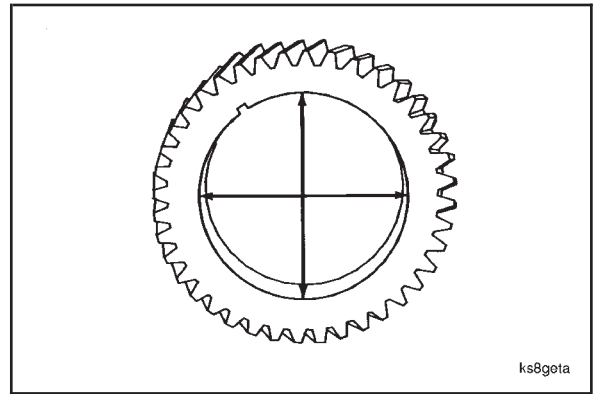
Visually inspect the crankshaft gear journal for burrs or damage.



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

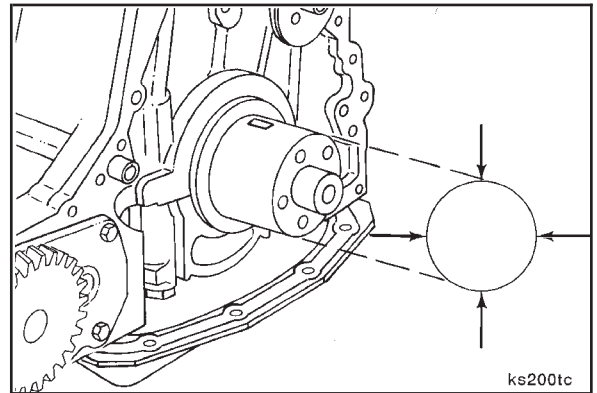
Measure the crankshaft gear bore inside diameter.

Crankshaft Gear Bore I.D.		
mm		in
85.910	MIN	3.3823
85.935	MAX	3.3833



Measure the crankshaft gear journal outside diameter.

Crankshaft Gear Journal O.D.		
mm		in
85.975	MIN	3.3848
86.000	MAX	3.3858



Install (001-018-026)

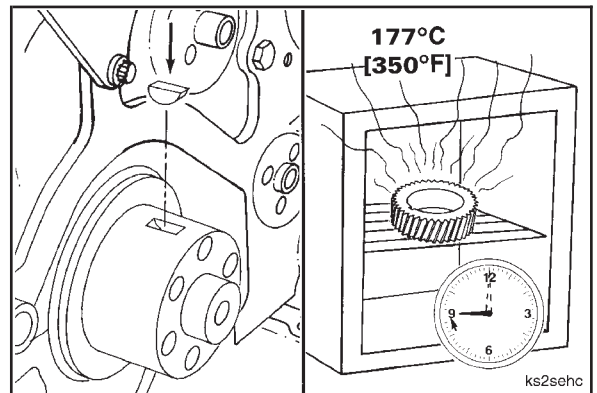
Use a leather hammer to install a new key in the crankshaft keyway.

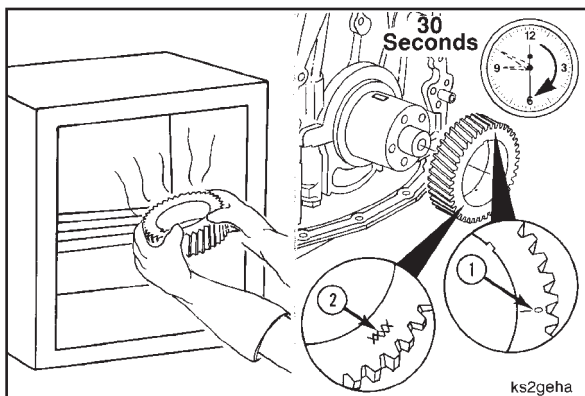


Do not exceed the specified time or temperature when heating the crankshaft gear. The gear and teeth can be damaged.

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

Temperature 177 °C [350 °F]





WARNING

Use insulated gloves, Part No. 3823730, when handling heated parts. Hot parts can cause serious personal injury.

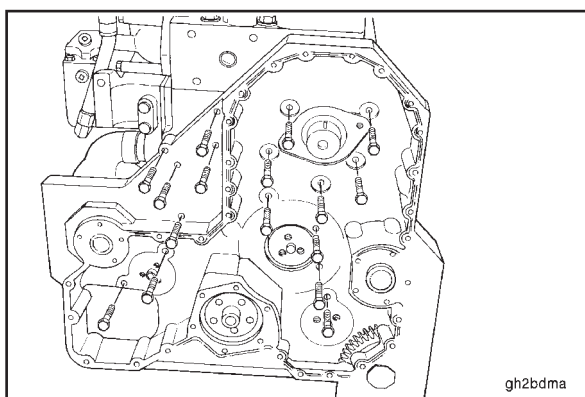
CAUTION

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

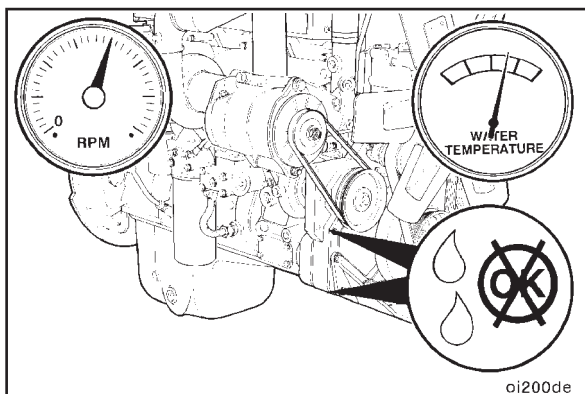
Use Lubriplate™ 105, or equivalent, to lubricate the outside diameter of the crankshaft gear journal.

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

Install the gear housing. Refer to Procedure 001-033-026.



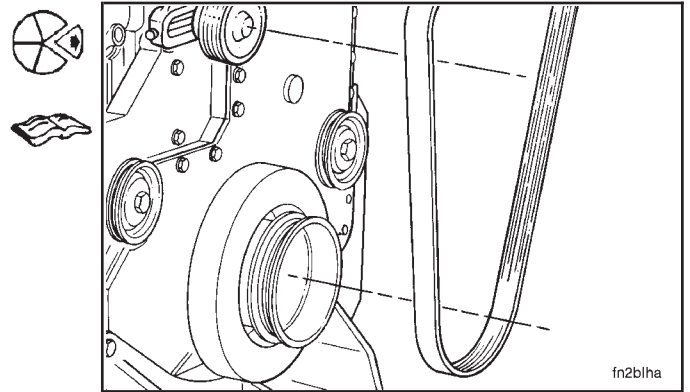
Operate the engine to normal operating temperature and check for leaks.



Crankshaft Pulley (001-022)

Remove (001-022-002)

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

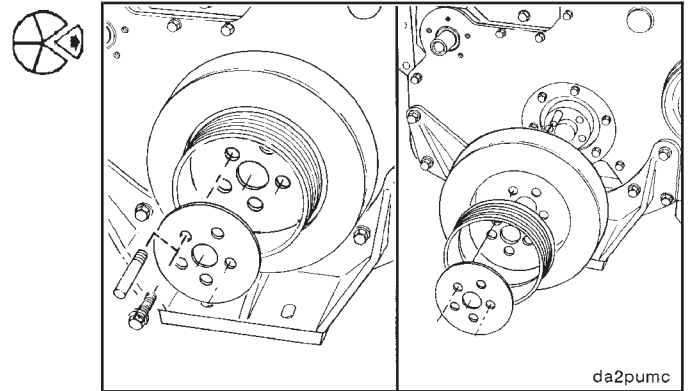


Remove two of the vibration damper and crankshaft pulley retaining capscrews.

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

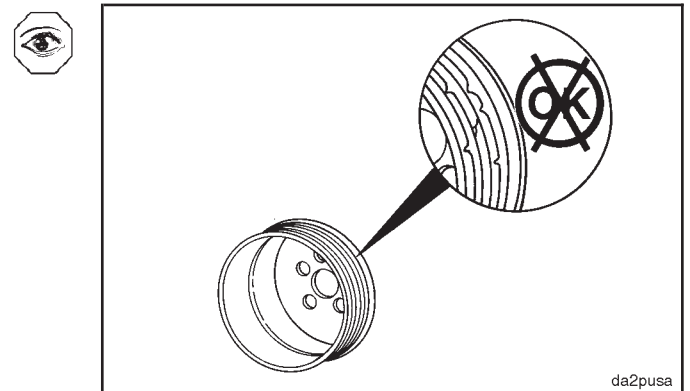
Remove the remaining three capscrews, clamping plate, pulley and damper.

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



Inspect for Reuse (001-022-007)

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

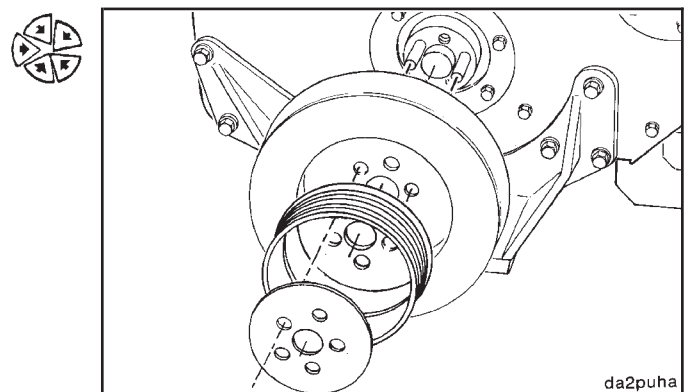


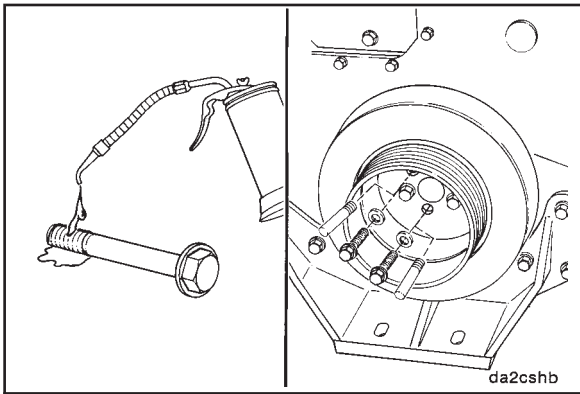
Install (001-022-026)

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

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

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





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

Install three of the five capscrews.

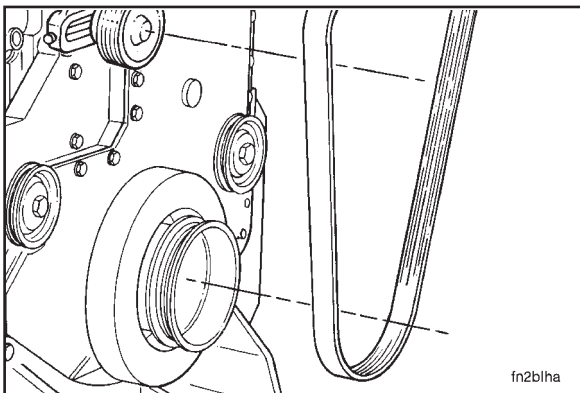


Remove the two guide studs and install the two remaining capscrews.

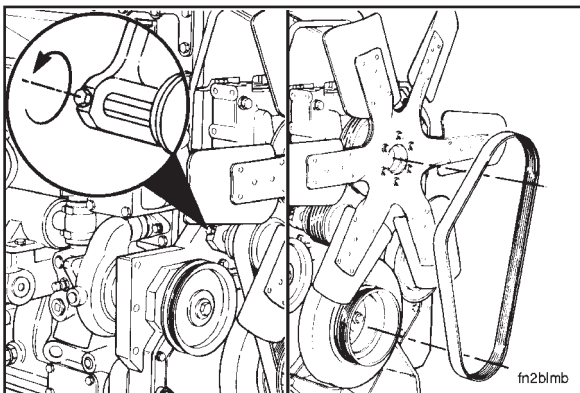
Tighten the capscrews in a start pattern.



Torque Value: 203 N•m [150 ft-lb]



Install and adjust the fan drive belt. Refer to Procedure 008-002-026.

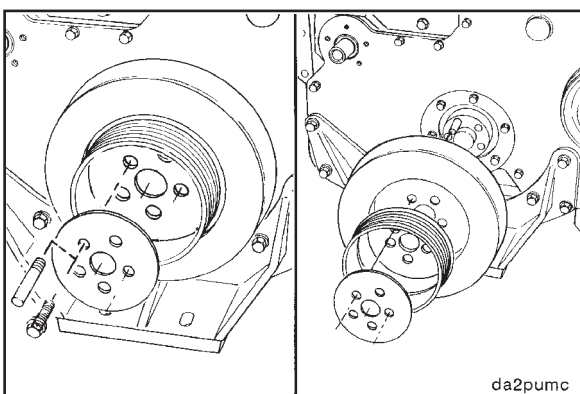


Crankshaft Seal, Front (001-023)

Remove (001-023-002)



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

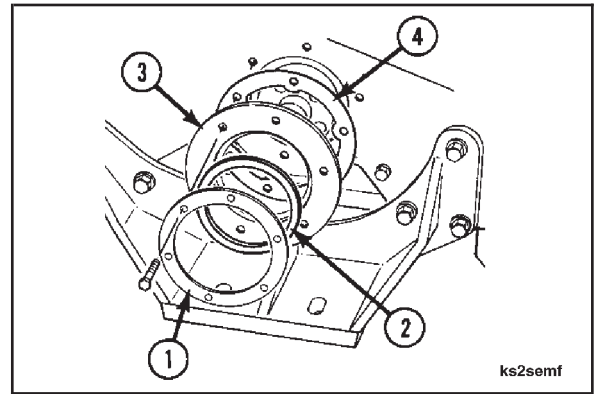


Remove the clamping plate, crankshaft pulley, and vibration damper. Refer to Procedure 001-052-002.



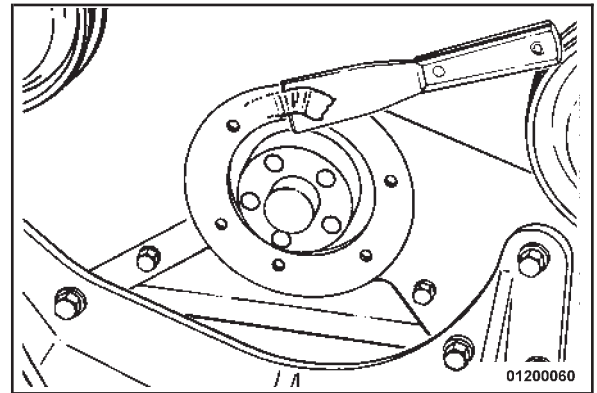
Remove the six capscrews, the clamping ring (1), the oil seal (3), and dust seal (2) together.

Remove the gasket (4).



Clean (001-023-006)

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

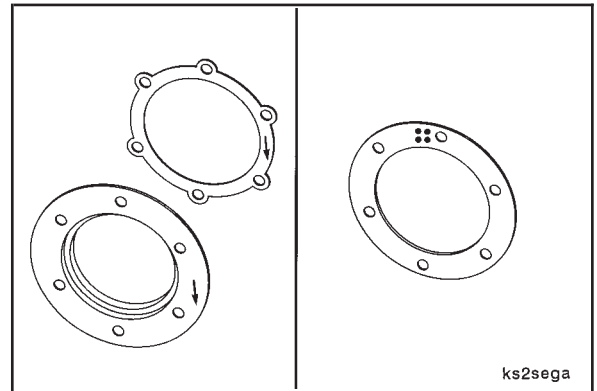


Install (001-023-026)

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

The gear cover, oil seal and carrier gasket are each marked with an arrow located at approximately the 3:00 o'clock location.

The clamping ring is marked with four punch marks which locate at approximately the 11:30 o'clock location.

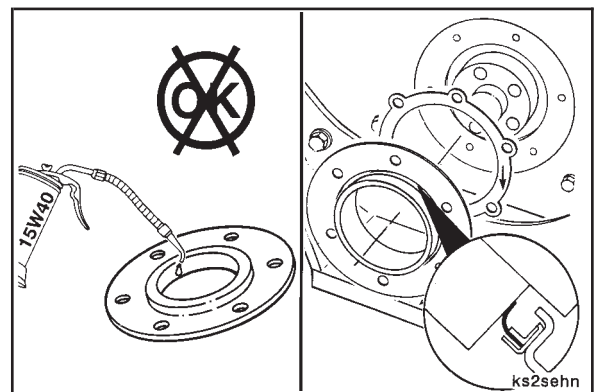


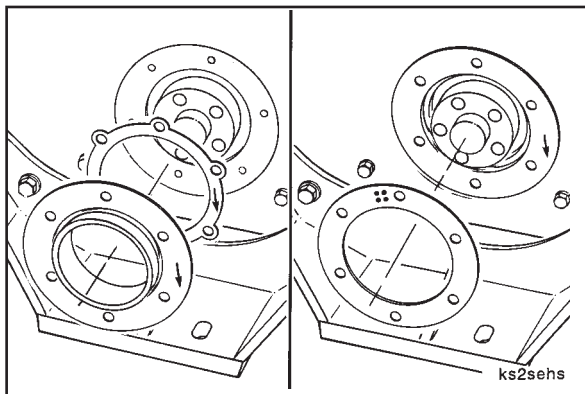
Do **not** use any kind of lubricant to install the seal. The oil seal **must** be installed with the lip of the seal and the crankshaft clean and dry.

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

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

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





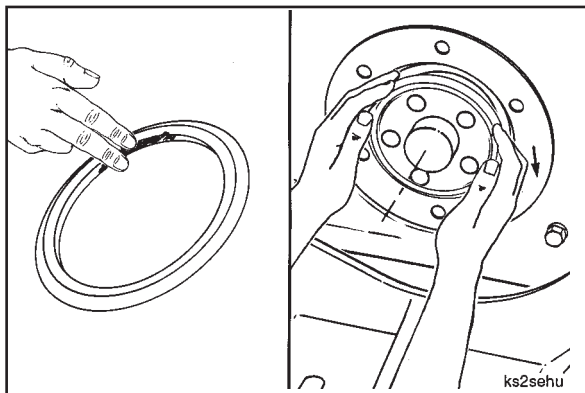
Orient the four punch marks on the clamping ring at the 11:30 o'clock location.



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

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

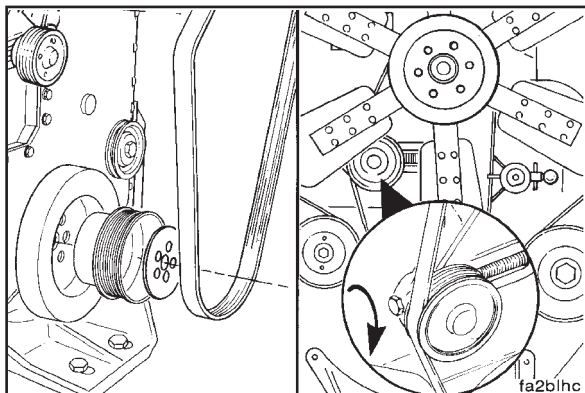
Torque Value: Step 1 7 N•m [60 in-lb]
2 20 N•m [180 in-lb]



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



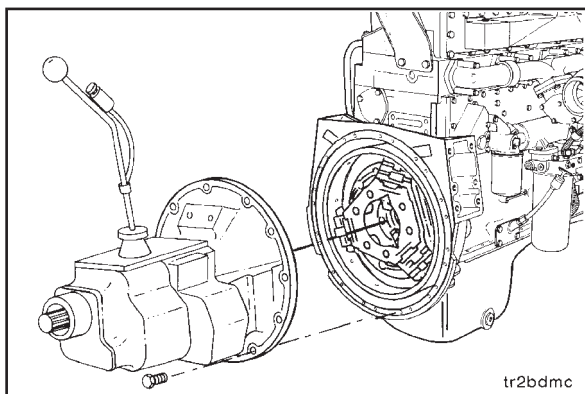
Install the dust seal with the larger outside diameter facing towards the engine. Push the dust seal back on the shaft until the entire seal contacts the oil seal case.



Install the vibration damper, crankshaft pulley and clamping plate. Refer to Procedure 001-052-026.



Install and adjust the fan drive belt. Refer to Procedure 008-002-026.

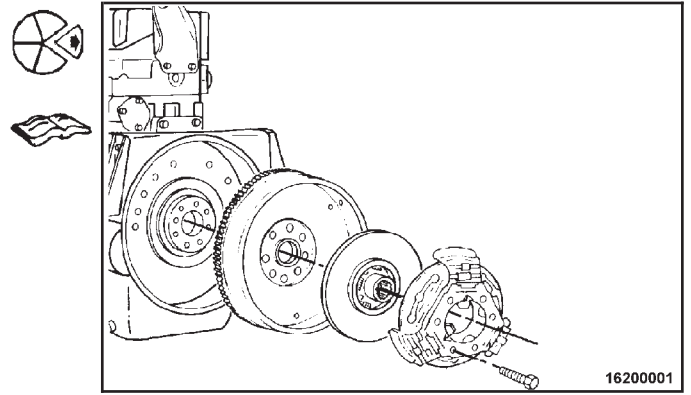


Crankshaft Seal, Rear (001-024) Remove (001-024-002)



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

Remove the clutch and flywheel, if equipped. Refer to Procedure 016-005-002.

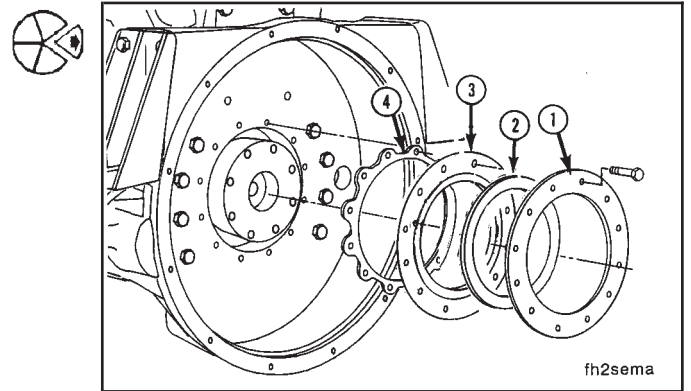


NOTE: On REPTO units, it is necessary to remove the crankshaft gear mounting capscrews before removing the oil seal.

Remove the 12 capscrews and clamping ring (1).

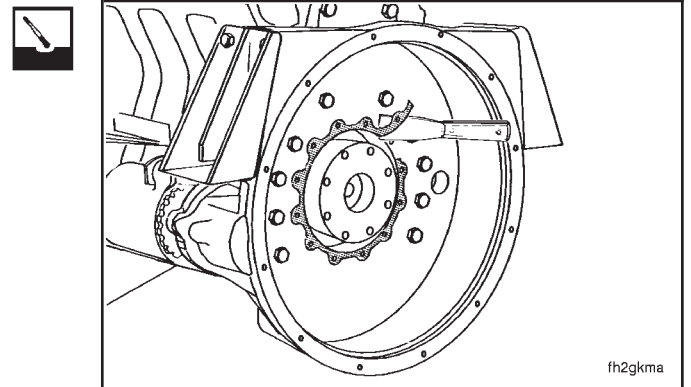
Use a heal bar to remove the oil seal (3) and dust seal (2) together.

Remove the gasket (4).



Clean (001-024-006)

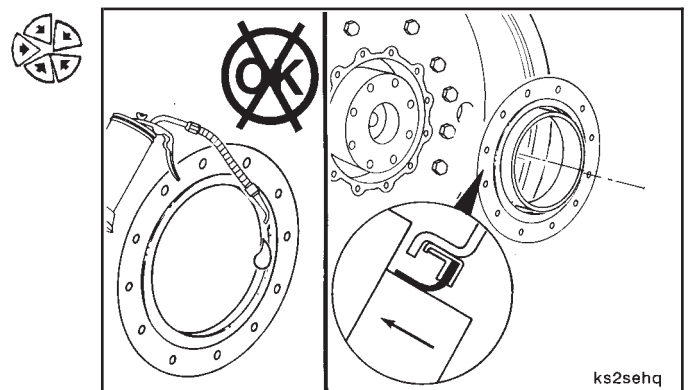
Clean the gasket surface of the flywheel housing.

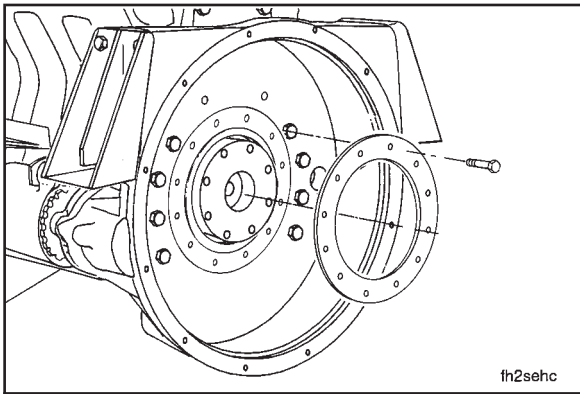


Install (001-024-026)

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

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





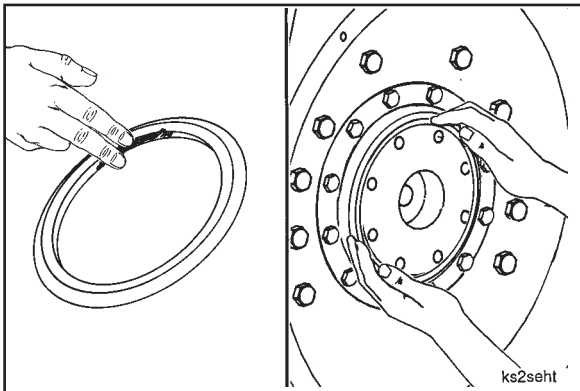
Install the clamping ring using the 12 capscrews (M8-1.25 x 20).

Tighten the capscrews in a star pattern in two steps.



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

fh2sehc



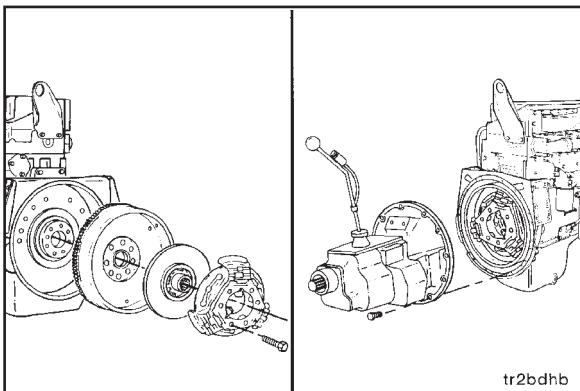
NOTE: If the engine is equipped with a REPTO, do **not** use a dust seal.

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



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

ks2seht

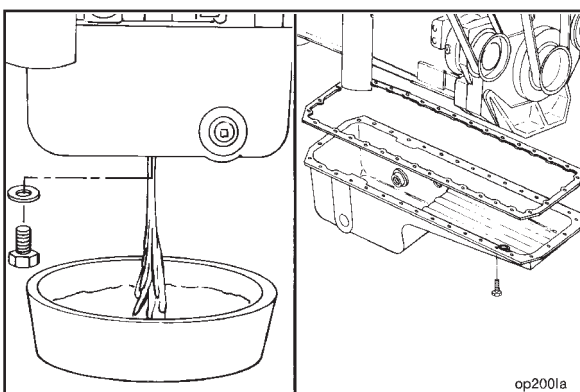


Install the flywheel and clutch, if equipped. Refer to Procedure 016-005-026.

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



tr2bdhb



Cylinder Block and Liner Seats (001-027)



Leak Test (001-027-014)

Drain the engine lubricating oil. Refer to Procedure 007-025-005.

Remove the lubricating oil pan. Refer to Procedure 007-025-002.

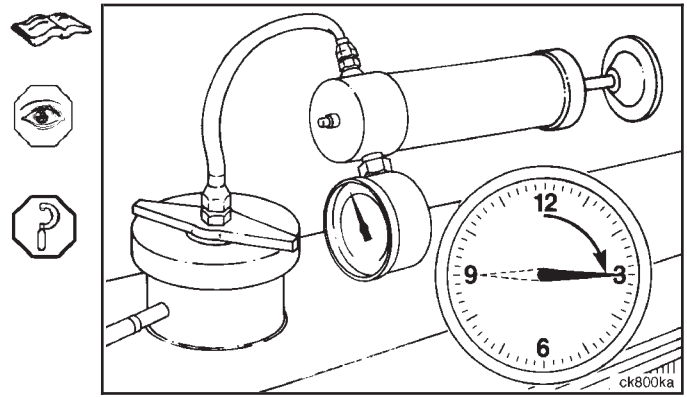
op2001a

M11 Series
Section 1 - Cylinder Block - Group 01

Pressurize the engine cooling system. Refer to Procedure 008-018-013.

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

Air Pressure 138 kPa [20 psi]



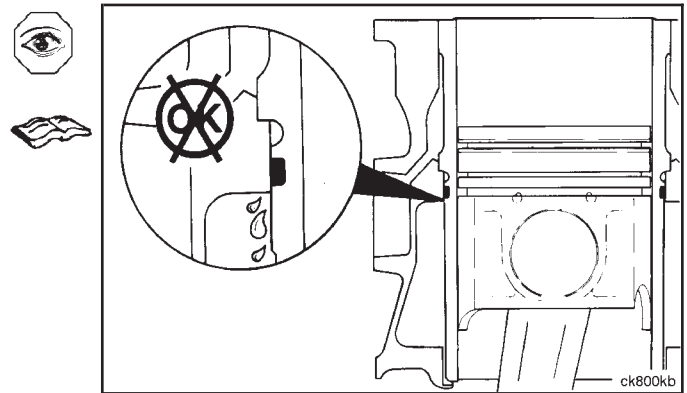
Visually inspect the outside diameter of the cylinder liners and the area below the cylinder liner seats in the cylinder block for coolant leaks.

If a leak is found:

- Remove the cylinder liner(s). Inspect the sealing ring and cylinder liner. Refer to Procedure 001-028-002.

If a leak is found in the cylinder liner seat:

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

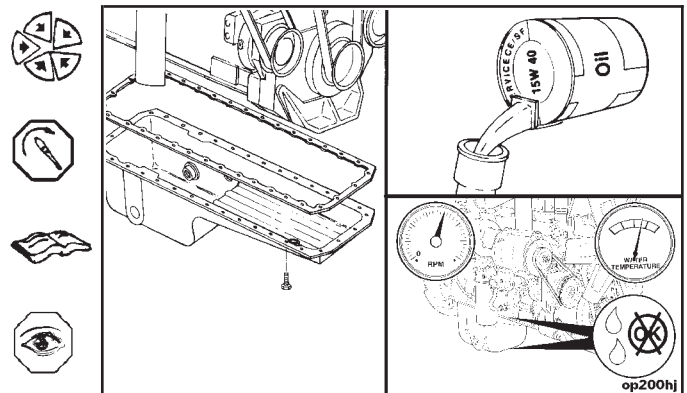


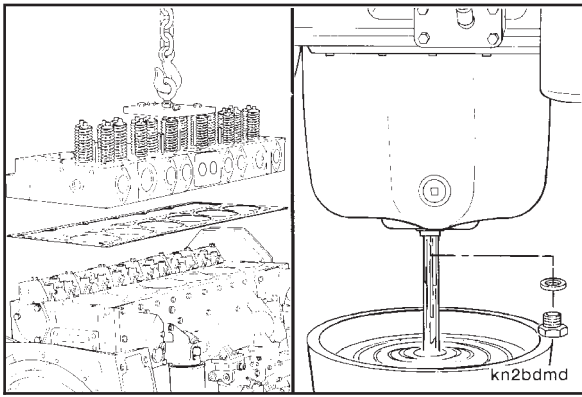
Install a new gasket and the lubricating oil pan. Refer to Procedure 007-025-026. Tighten the oil pan drain plug.

Torque Value: 88 N•m [65 ft-lb]

Fill the engine with clean 15W-40 oil. Refer to Procedure 007-025-028.

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





Cylinder Liner (001-028)

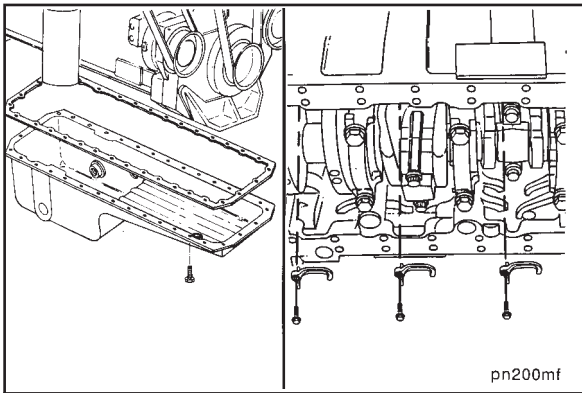
Remove (001-028-002)



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

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

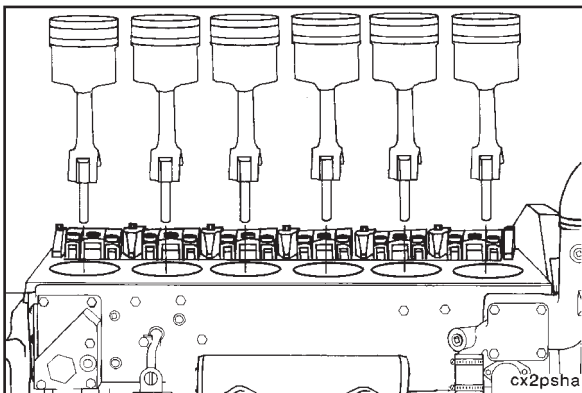
Drain the lubricating oil pan. Refer to Procedure 007-025-005.



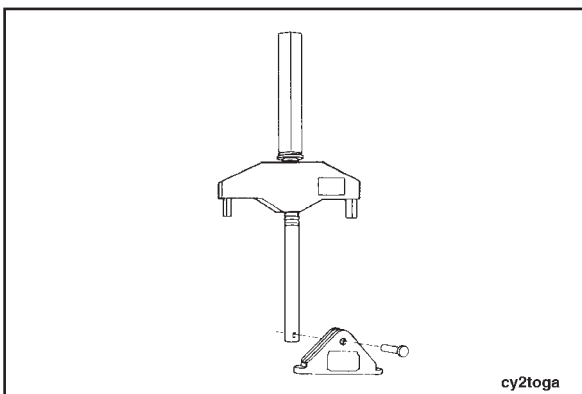
Remove the lubricating oil pan. Refer to Procedure 007-025-002.



Remove the piston cooling nozzles. Refer to Procedure 001-046-002.



Remove the pistons and connecting rods. Refer to Procedure 001-054-002.

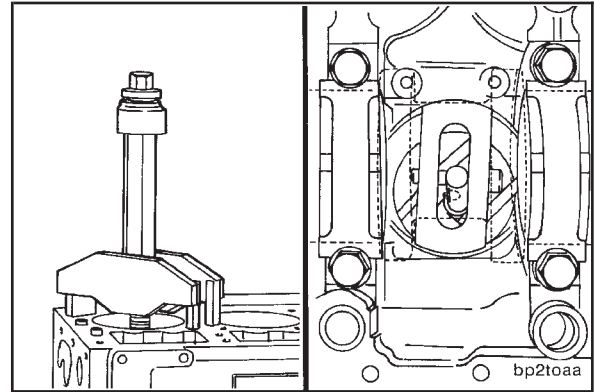


The cylinder liners can be removed by using universal liner puller, Part No. 3375629.

⚠ CAUTION ⚠

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

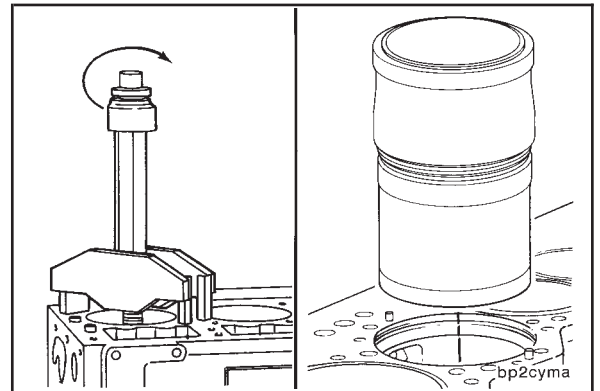
Insert the liner puller in the top of the cylinder block.



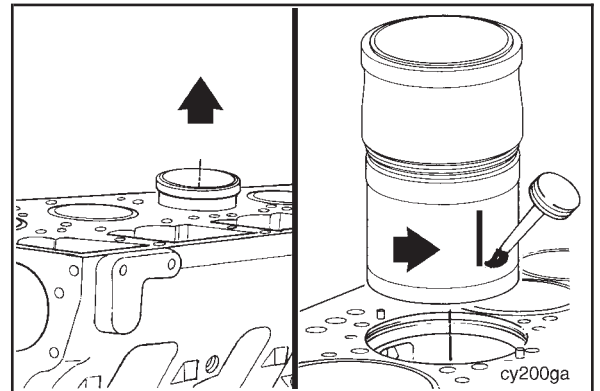
The liner puller **must** be centered on the top of the cylinder block.

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

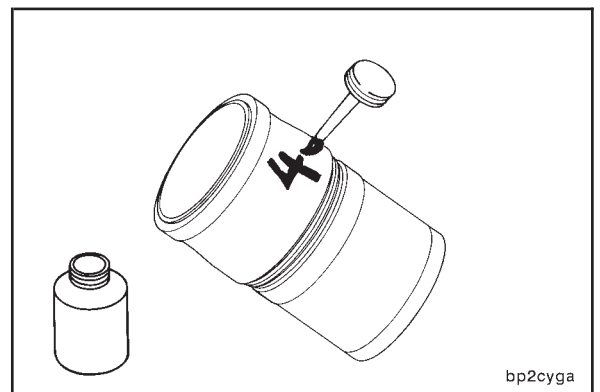
Use both hands to remove the liner.

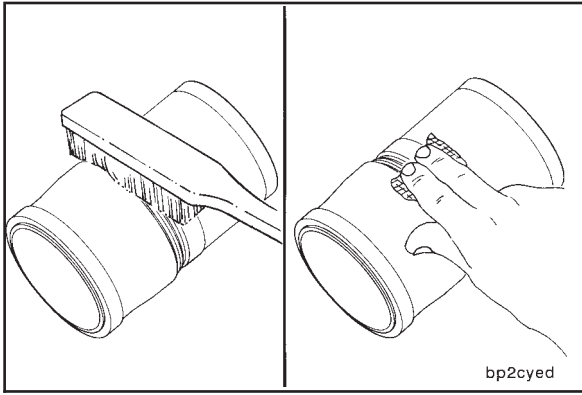


When the liner is removed from the cylinder block, use Dykem® or equivalent, to place a mark on the camshaft side of the liner to show liner orientation.



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





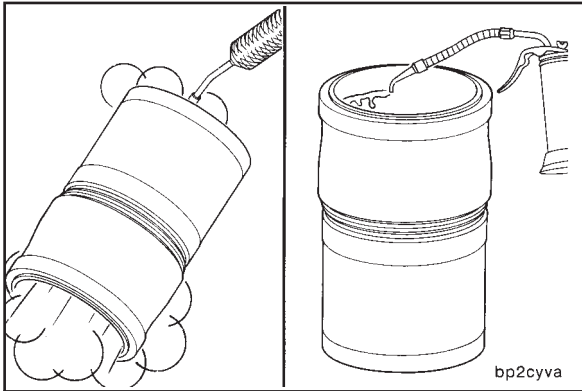
Clean (001-028-006)

CAUTION

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

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

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



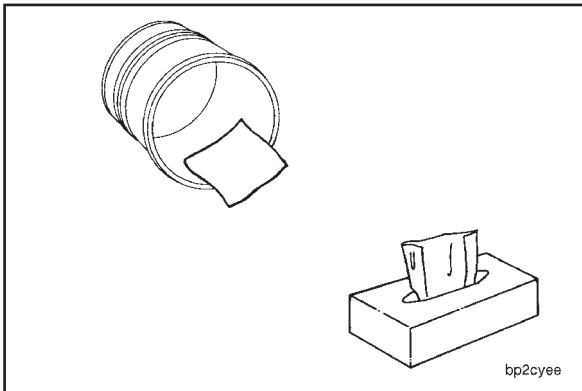
WARNING

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

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

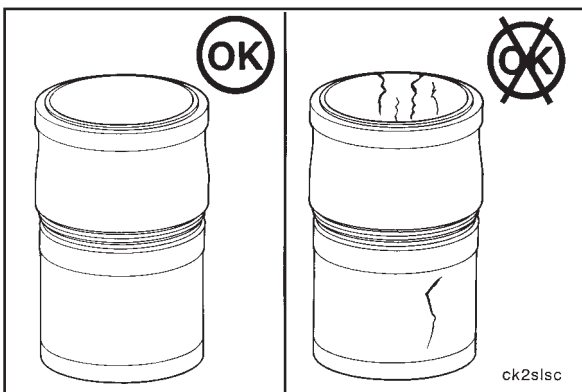
Use clean 15W-40 oil to lubricate the inside diameter of the liners.

Allow the oil to soak in the liner for five to ten minutes.



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

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

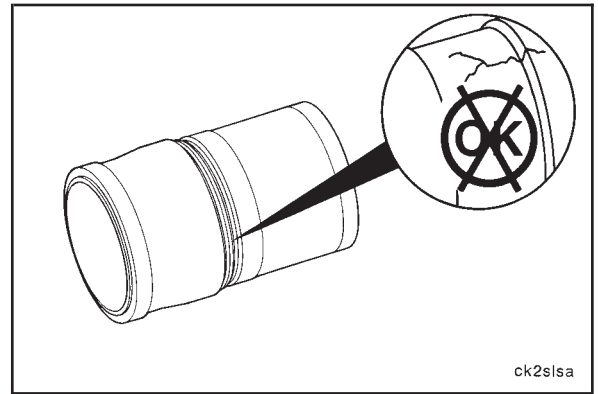


Inspect for Reuse (001-028-007)

Visually inspect the liners for cracks on the inside and outside diameters.

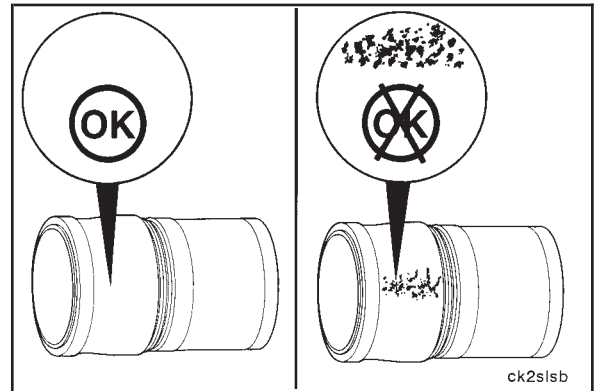
Visually inspect for cracks under the liner flange.

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



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

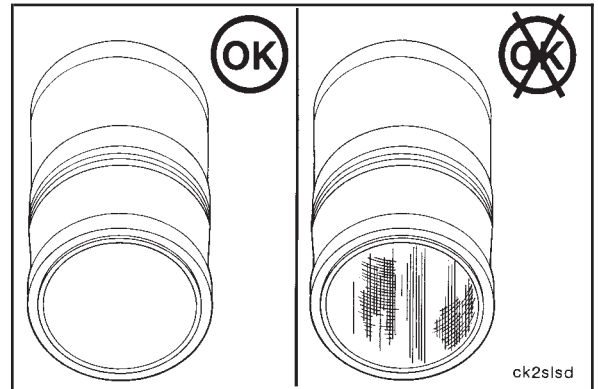
Pits **must not** be more than 1.60 mm [0.060 inch] deep.



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

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

Visually inspect the inside diameter for scuffing or scoring.

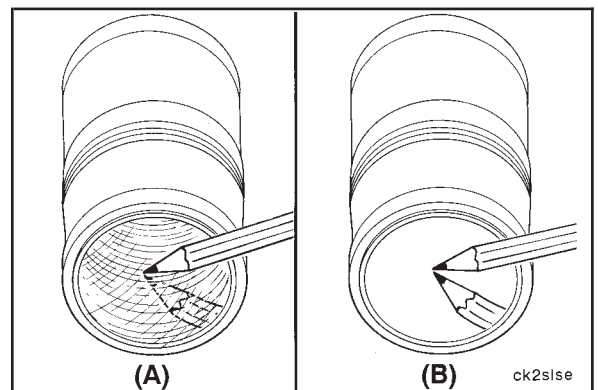


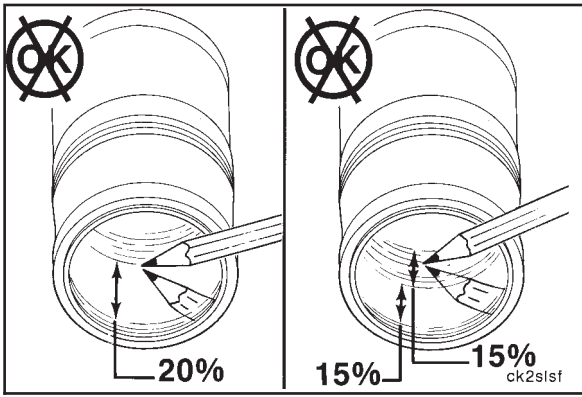
Visually inspect the inside diameter for liner bore polishing.

NOTE: M11 cylinder liners are **not** lubricated.

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

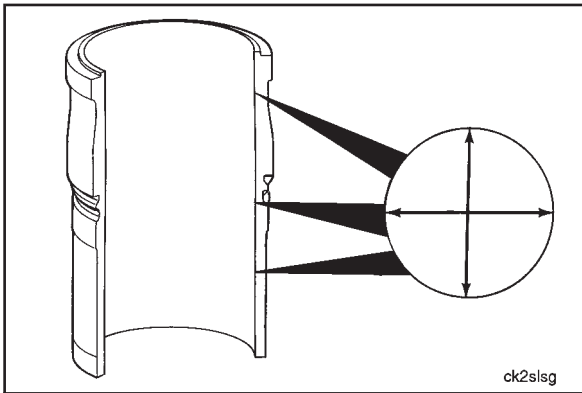
A **heavy polish (B)** produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.





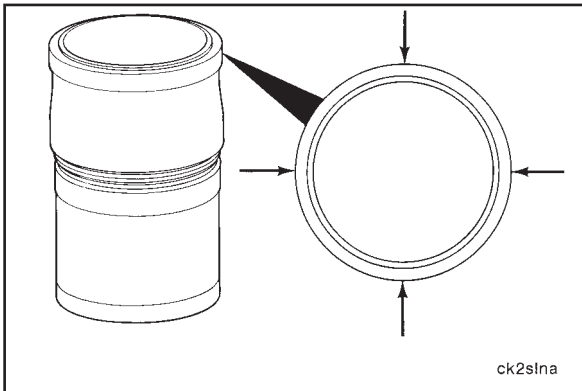
Replace the liner if:

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



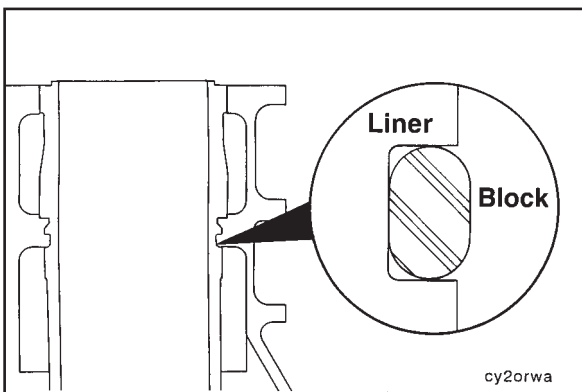
Use a dial bore gauge to measure the liner inside diameter in four places 90 degrees apart at the top and bottom of the piston travel area.

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



Measure the liner top press fit area outside diameter.

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

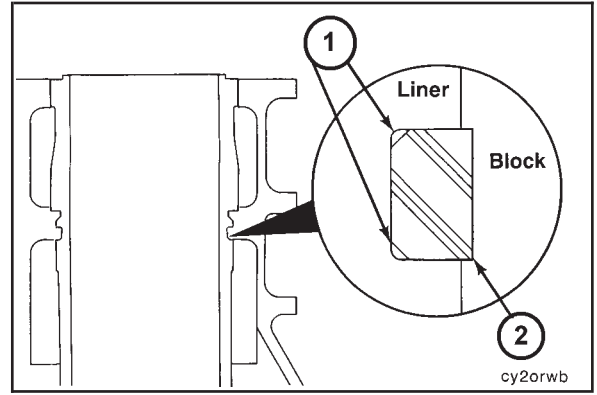


Install (001-028-026)

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

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

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



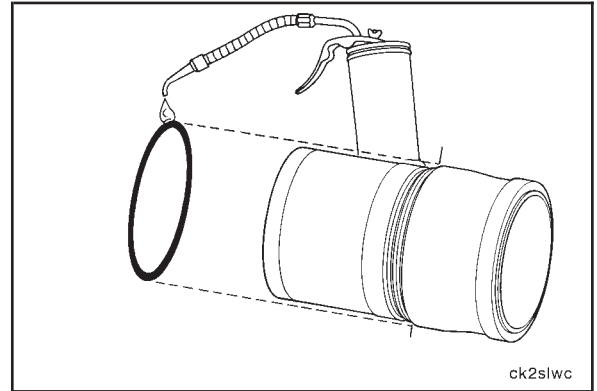
Make sure the cylinder block and all parts are clean before assembly.

CAUTION

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

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

Install the o-ring seal on the liner.

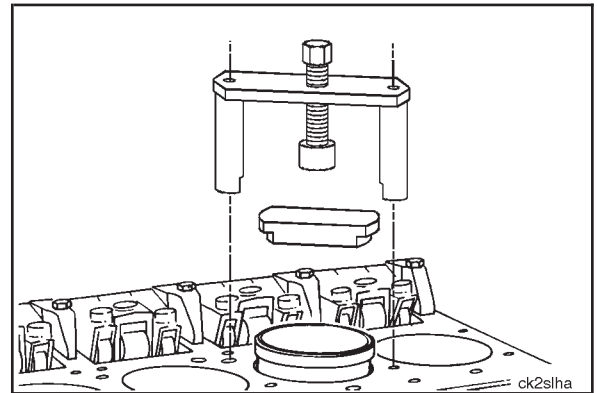


Install the liner into the cylinder block.

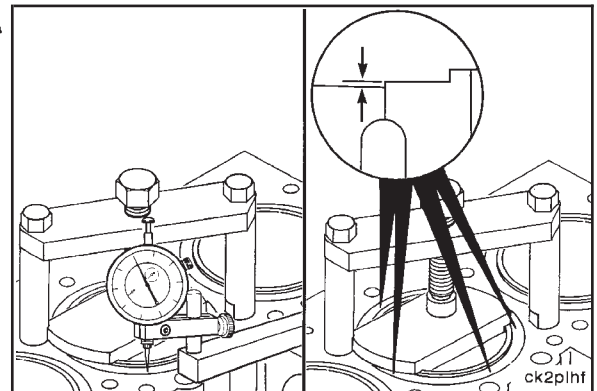
When acceptable reused liners are installed, rotate the liner 90 degrees from their original position in the engine. The thrust and anti-thrust surfaces **must** face the front and back of the cylinder block.

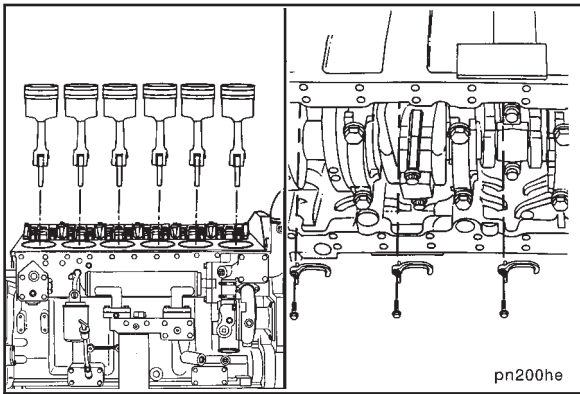
Use cylinder liner driver, Part No. 3376056, and a leather mallet to drive the liner into the cylinder block bore.

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



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

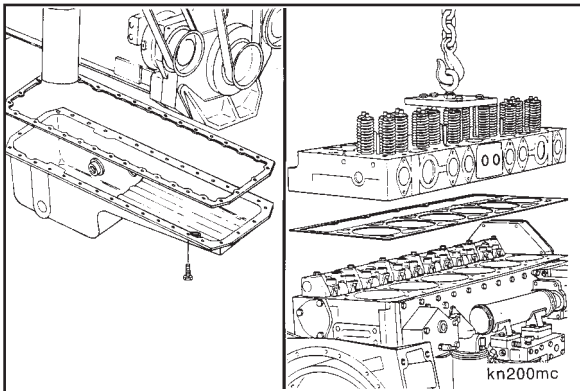




Install the pistons and connecting rods. Refer to Procedure 001-054-026.



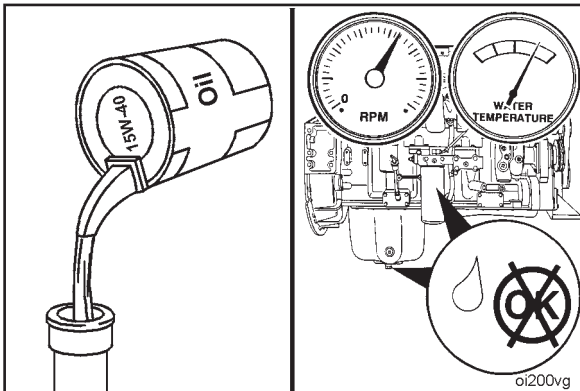
Install the piston cooling nozzles. Refer to Procedure 001-046-026.



Install the lubricating oil pan. Refer to Procedure 007-025-026.



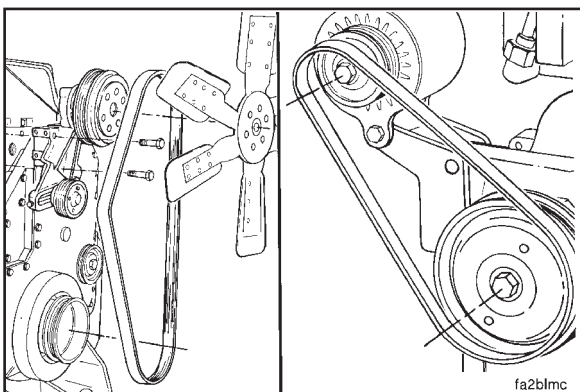
Install the cylinder head. Refer to Procedure 002-004-026.



Fill the engine with lubricating oil. Refer to Procedure 007-025-028.



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



Gear Cover, Front (001-031) Remove (001-031-002)



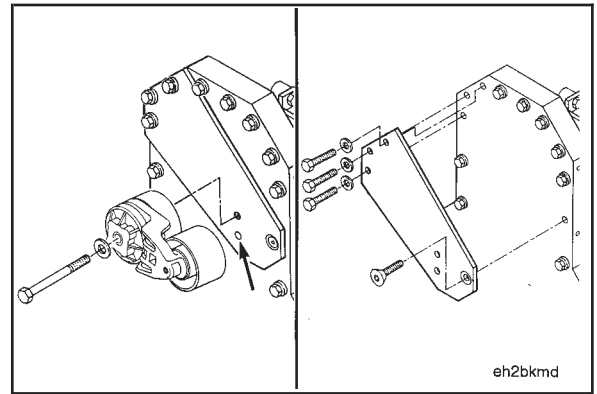
Remove the fan drive belt. Refer to Procedure 008-002-002.

Remove the alternator drive belt. Refer to Procedure 013-005-002.

NOTE: If the engine is equipped with an automatic belt tensioner, refer to Procedure 013-021-002 to remove the alternator belt.

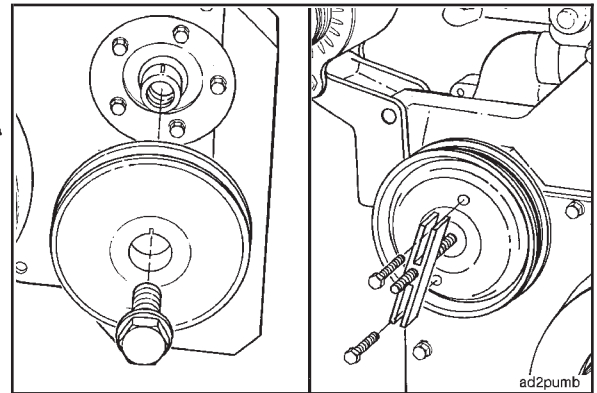
Remove the fan and fan hub support. Refer to Procedure 008-036-002.

If the engine is equipped with an automatic belt tensioner, remove the belt tensioner arm from the tensioner bracket.
Remove the four mounting capscrews and the tensioner bracket from the gear cover.

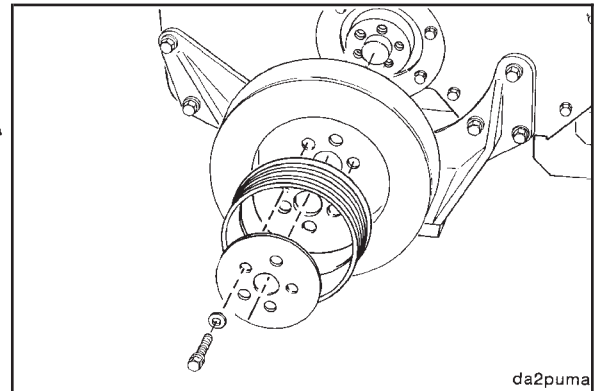


Remove the accessory drive pulley. Refer to Procedure 009-004-002.

Remove the alternator drive pulley. Refer to Procedure 009-010-002.



Remove the clamping plate, crankshaft pulley, and vibration damper. Refer to Procedure 001-052-002.

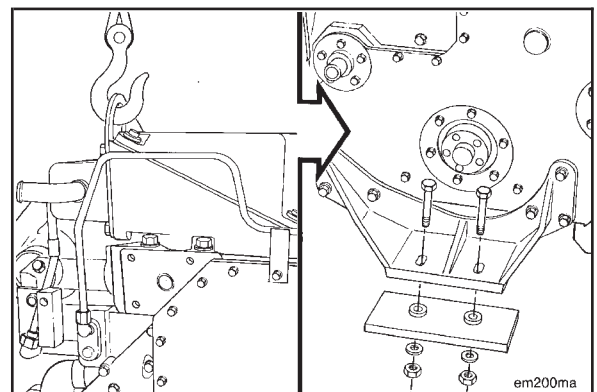


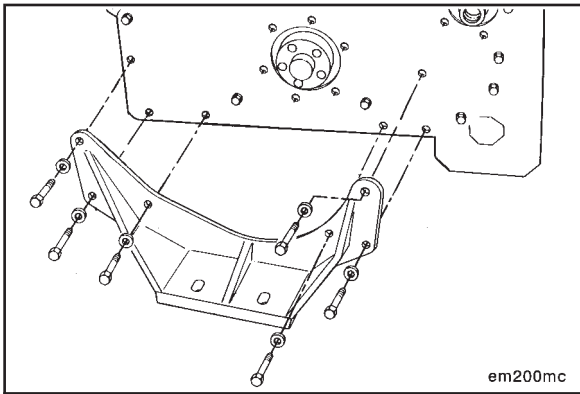
▲ WARNING ▲

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

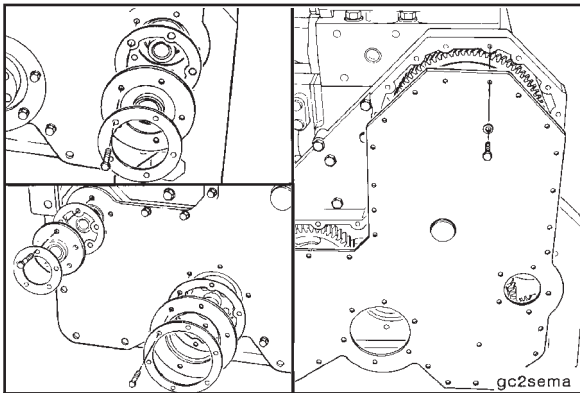
Use an overhead hoist or hydraulic arm to support the engine.

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





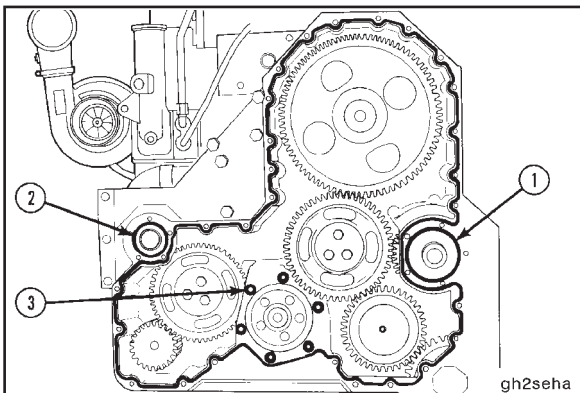
Remove the capscrews and the front engine support.



Remove the oil seals from the gear cover. Refer to Procedures 001-001-002, 001-003-002, and 001-023-002.



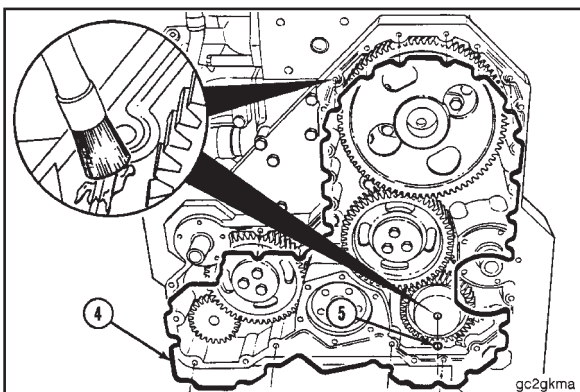
Remove the remaining capscrews and the gear cover.



Clean (001-031-006)

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

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



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

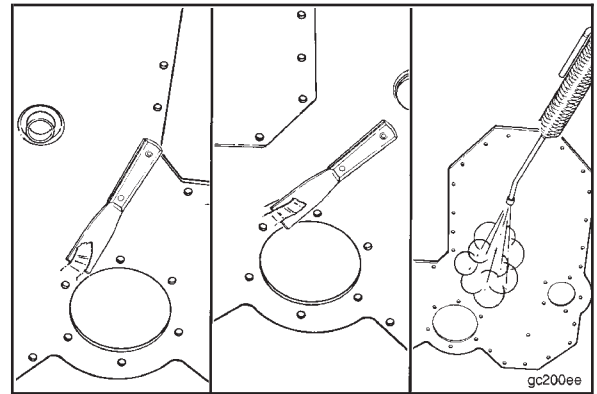
Remove the o-ring (5) at the front of the hydraulic drive idler retainer and clean the groove.

Clean the sealing surface on the rear face of the gear cover.
Clean the oil seal carrier gasket surfaces.

⚠ WARNING ⚠

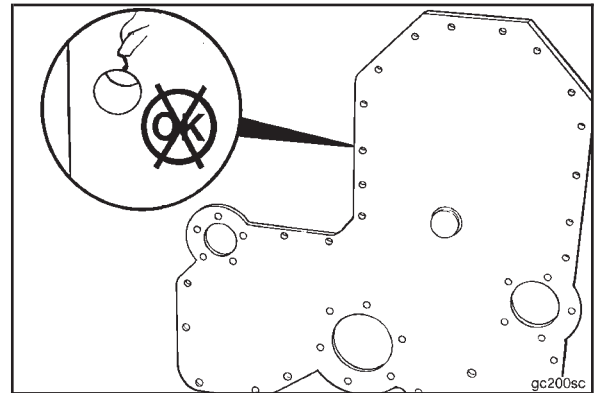
When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

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

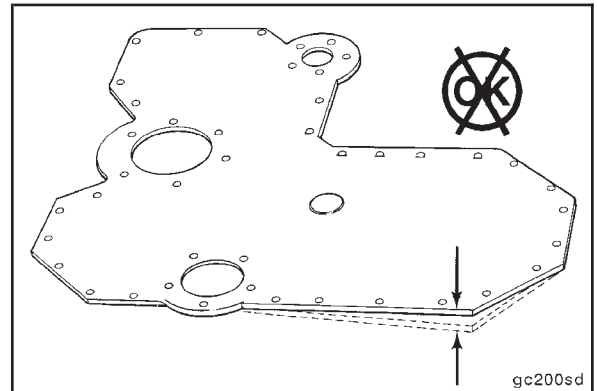


Inspect for Reuse (001-031-007)

Visually inspect the gear cover for cracks or damage.
If the cover is cracked, it **must** be replaced.

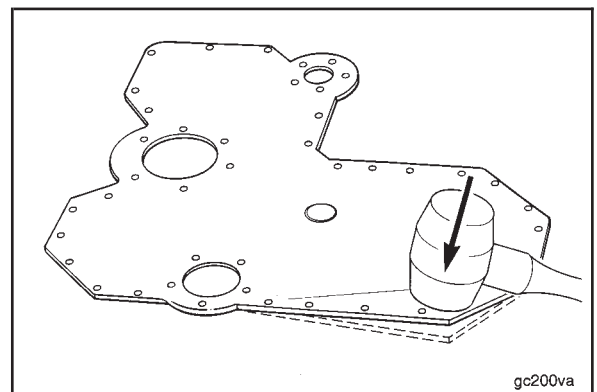


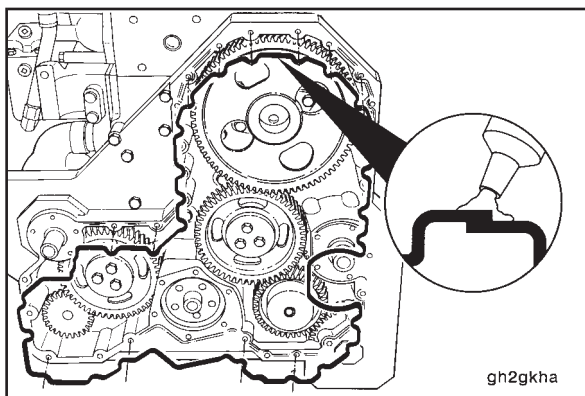
Put the gear cover on a flat surface and visually inspect the gear cover for flatness.



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

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

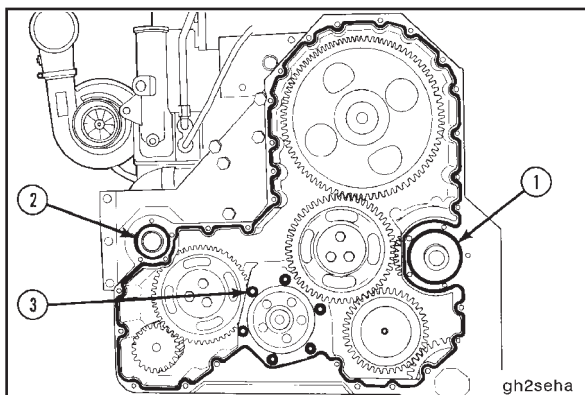




Install (001-031-026)

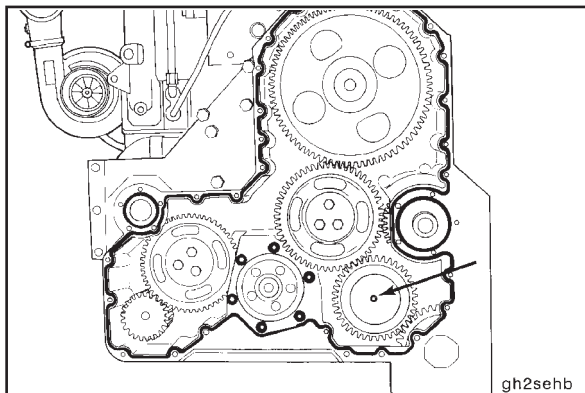
Insert a new seal into the groove on the front of the gear housing.

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

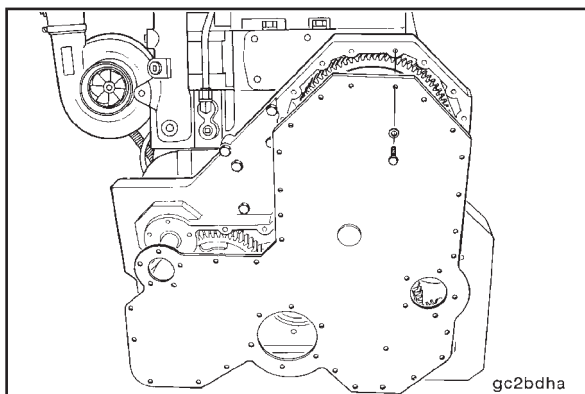


Install a new seal ring at the accessory drive (1) and water pump (2) locations.

Install six new cap screw o-rings at the crankshaft seal cap screw locations (3).



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



Install the gear cover and mounting cap screws.

NOTE: Do not install the front engine support cap screws at this time.



Tighten the cap screws.

Torque Value: 6 N•m [55 in-lb]

NOTE: This is not the final torque value.

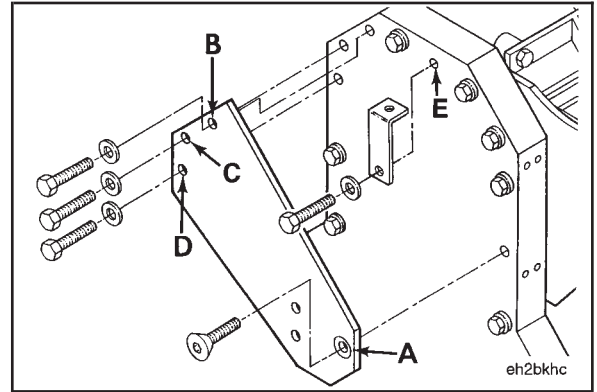
M11 Series
Section 1 - Cylinder Block - Group 01

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

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

Torque Value: 6 N•m [55 in-lb]

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

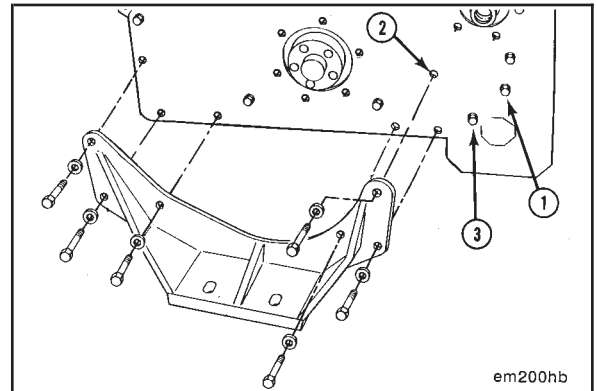


Apply a coating of thread sealant, Part No. 3823494, to the three capscrews at locations (1), (2) and (3).

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

Torque Value: 6 N•m [55 in-lb]

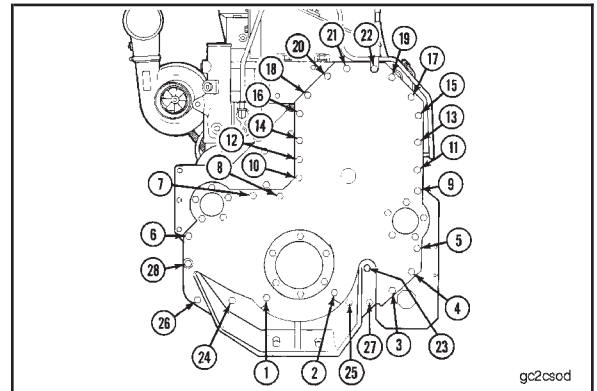
NOTE: This is **not** the final torque value.



Tighten the gear cover capscrews in the sequence shown.

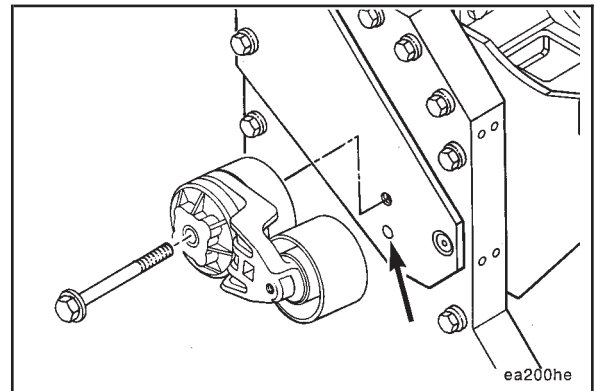
Torque Value:

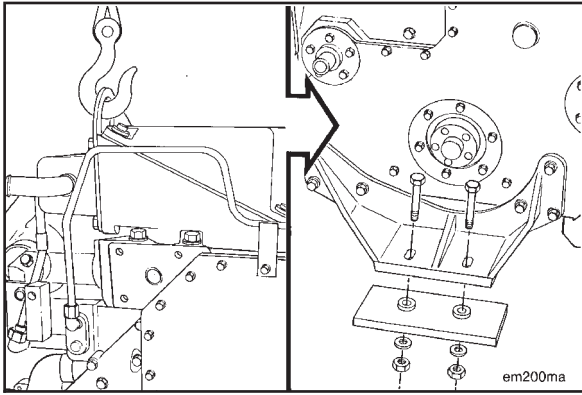
Capscrews 1 thru 22:	20 N•m	[15 ft-lb]
Capscrews 23 thru 28:	68 N•m	[50 ft-lb]



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

Torque Value: 43 N•m [32 ft-lb]



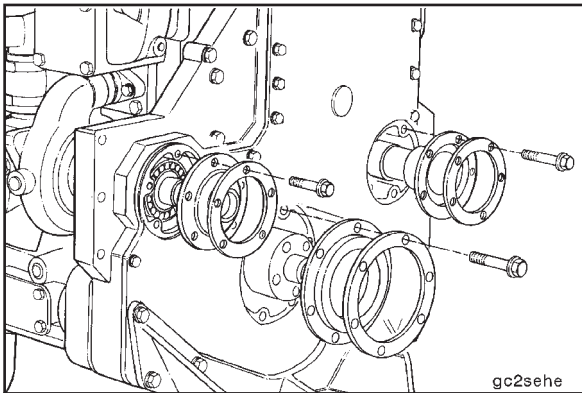


Lower the engine onto the crossmember.

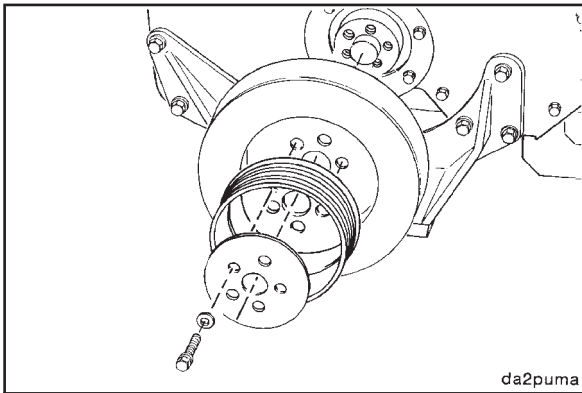
Install the front support to crossmember.



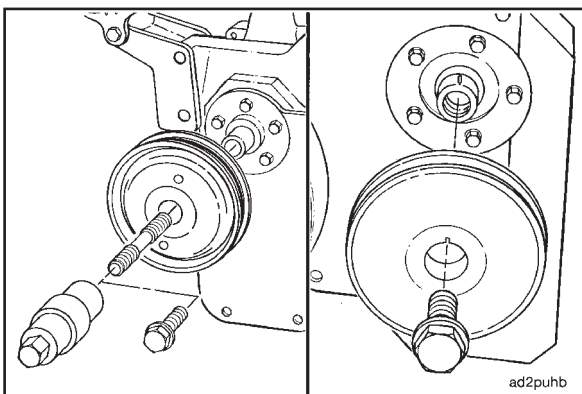
Install the capscrews and tighten. Refer to the manufacturer's specifications for the correct torque value.



Install the gear cover oil seals. Refer to Procedures 001-001-026, 001-003-026, and 001-023-026.



Install the vibration damper, crankshaft pulley and clamping plate. Refer to Procedure 001-052-026.



Install the alternator drive pulley. Refer to Procedure 009-010-026.



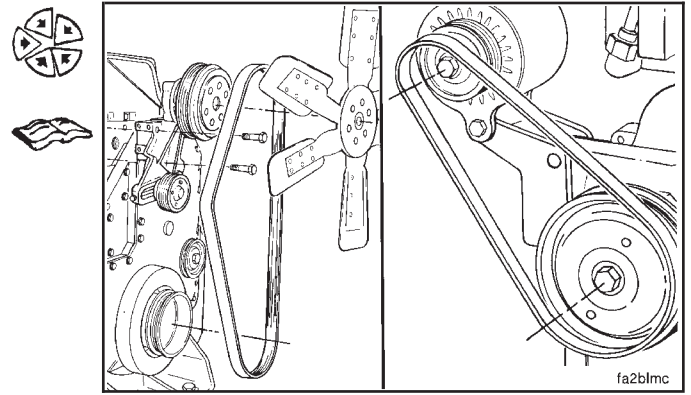
Install the accessory drive pulley. Refer to Procedure 009-004-026.

Install the fan hub support and fan. Refer to Procedure 008-036-026.

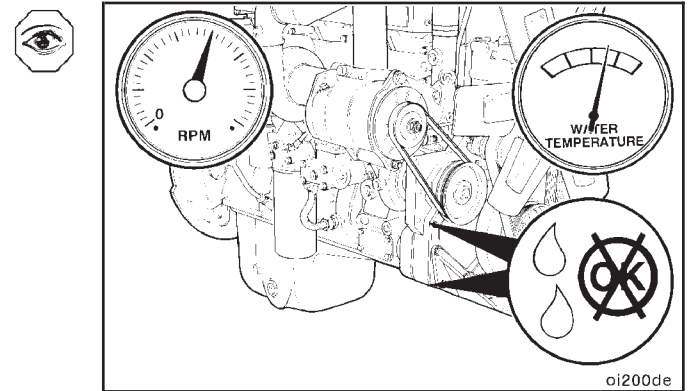
Install and adjust the fan drive belt. Refer to Procedure 008-002-026.

Install and adjust the alternator drive belt. Refer to Procedure 013-005-026.

NOTE: If the engine is equipped with an automatic belt tensioner, refer to Procedure 013-021-026 to install the alternator belt.

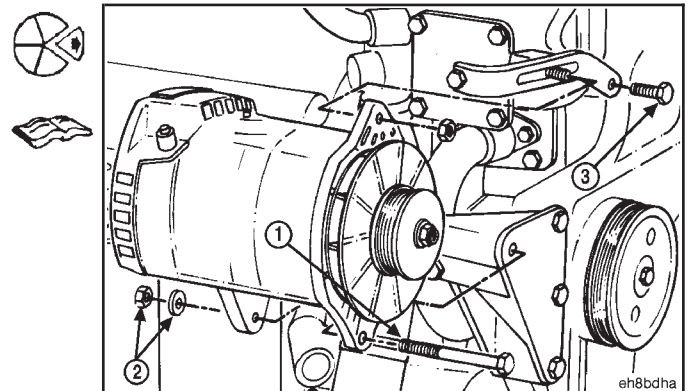


Operate the engine to normal operating temperature and check for leaks.

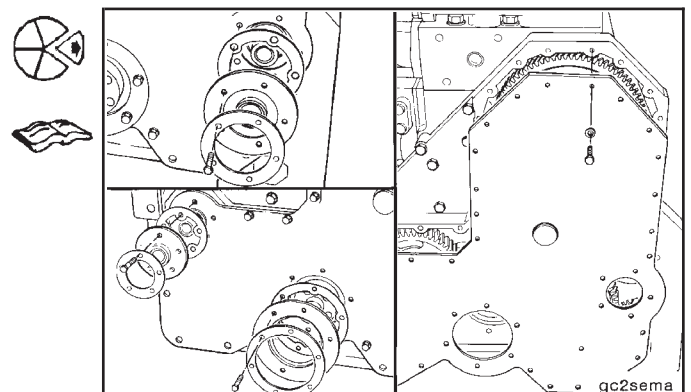


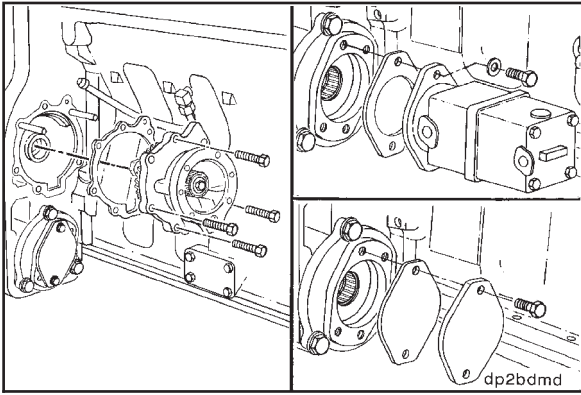
Gear Housing, Front (001-033)
Remove (001-033-002)

Remove the alternator and alternator bracket. Refer to Procedure 013-001-002.



Remove the gear cover. Refer to Procedure 001-031-002.

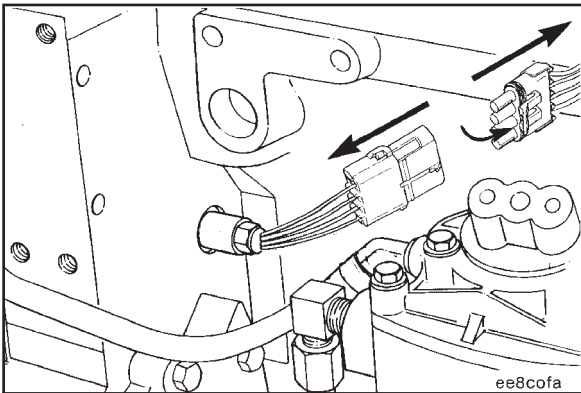




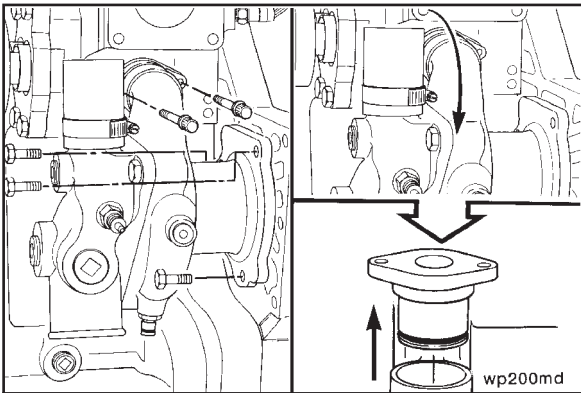
Remove the accessory drive. Refer to Procedure 009-001-002.



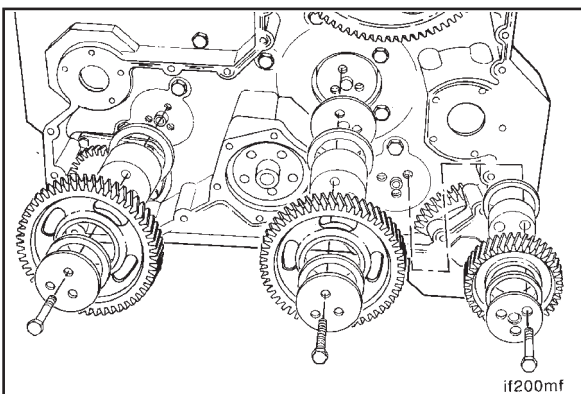
Remove the hydraulic pump, if equipped. Refer to Procedure 009-016-002.



On SELECT™ or SELECT™ Plus engines, disconnect the engine position wire connector and remove the engine position sensor from the back side of the housing.



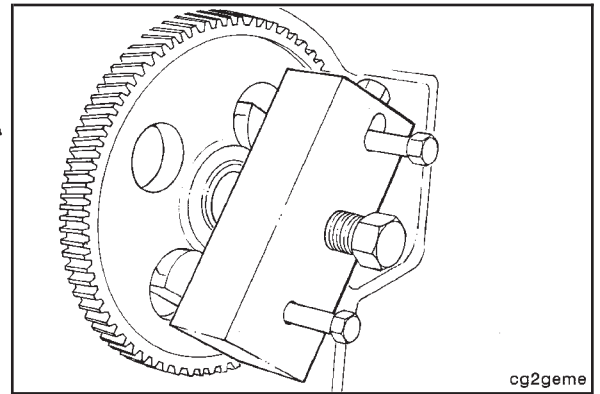
Remove the water pump. Refer to Procedure 008-062-002.



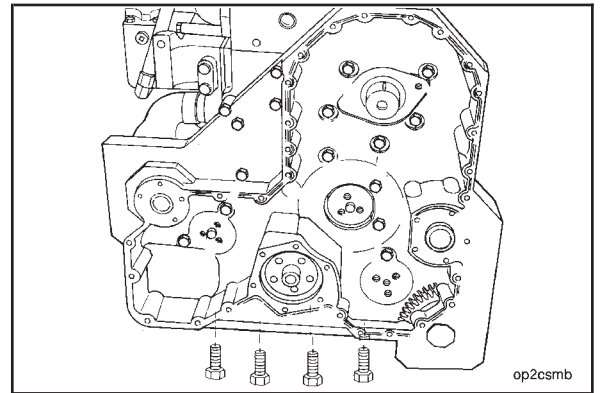
Remove the idler gears. Refer to Procedures 001-036-002, 001-039-002, and 001-040-002..



Remove the camshaft gear, or the camshaft and gear assembly. Refer to Procedure 001-012-002 or 001-008-002 respectively.



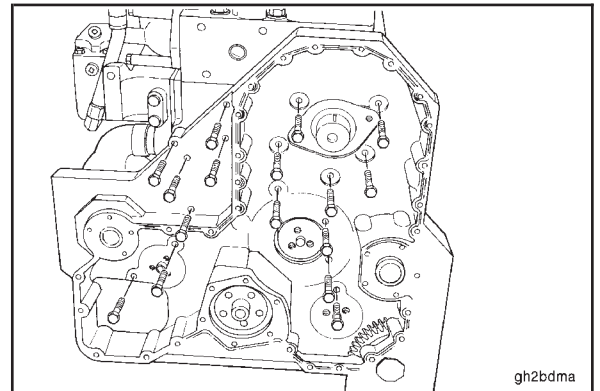
Remove the four oil pan to gear housing capscrews.



Remove the capscrews that secure the gear housing to the cylinder block.

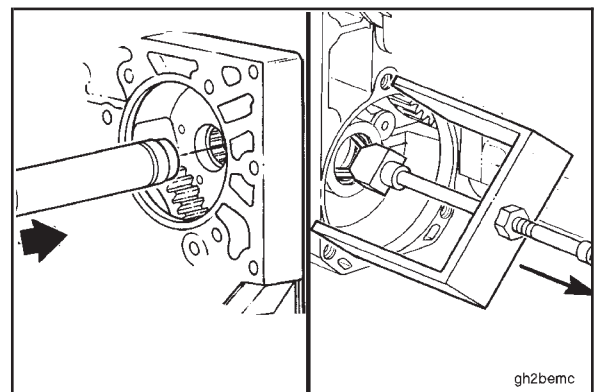
NOTE: Be careful **not** to damage the oil pan gasket when removing the gear housing. If the gasket is damaged, the oil pan **must** be removed and the gasket replaced.

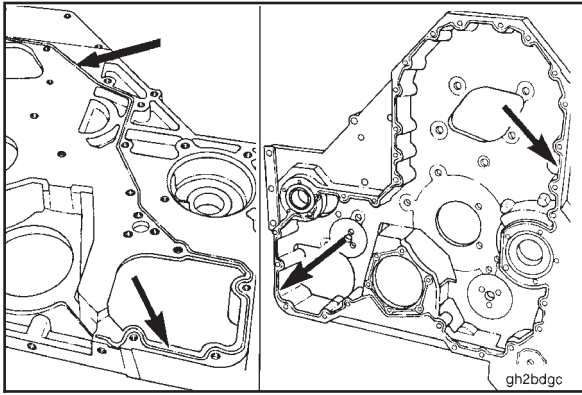
Remove the gear housing from the cylinder block.



Use bearing driver kit, Part No. 3824117, to remove the water pump drive needle bearing.

Use bearing puller kit, Part No. 3823774, to remove the hydraulic drive needle bearing.





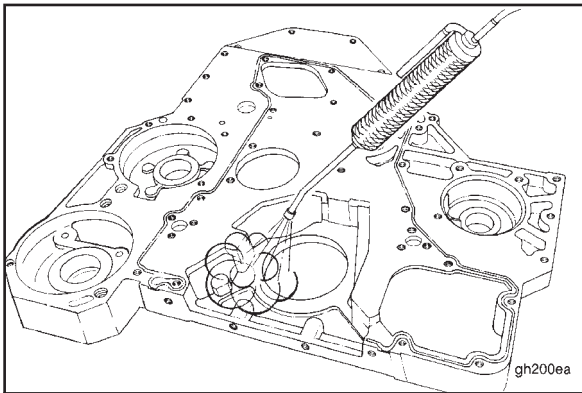
Clean (001-033-006)

Remove the RTV sealant from the rear surface of the gear housing.



Remove the seal in the grooves on the front surface of the gear housing.

Use a wire brush, rounded blade or screwdriver, to clean the grooves on both sides.

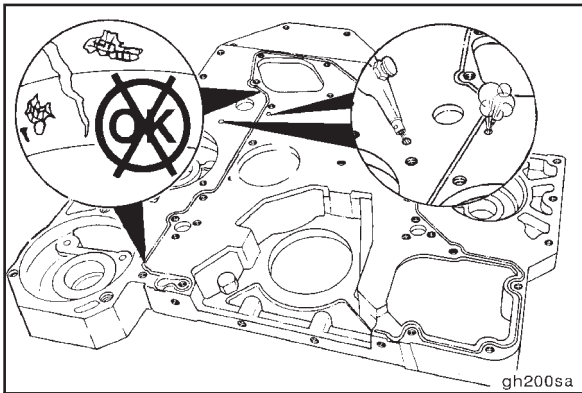


⚠ WARNING ⚠

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



Use steam or solvent to clean the gear housing and dry with compressed air.



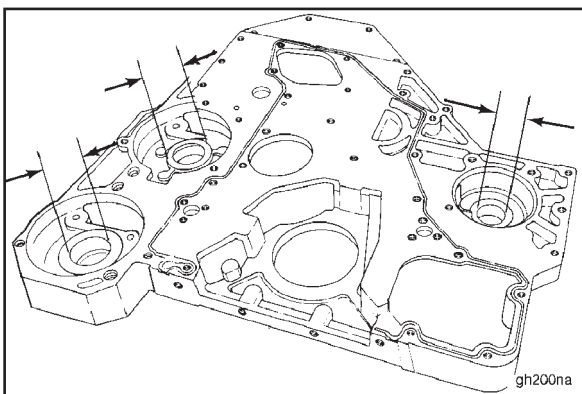
Inspect for Reuse (001-033-007)

Visually inspect the gear housing for cracks or other damage.

Visually inspect the seal grooves on both sides of the housing for debris or damage.

Inspect the o-ring groove at the accessory drive oil jumper gallery for cracks or damage.

Use compressed air to make sure the oil jumper gallery to the accessory drive is free of any obstructions.



Measure the inside diameter of the bearing bores at the accessory drive, water pump drive, and hydraulic drive.

Gear Housing Bearing Bore I.D.			
	mm		in
Hydraulic Drive	41.967	MIN	1.6522
	41.992	MAX	1.6532
Water Pump	36.967	MIN	1.4553
	36.992	MAX	1.4564
Accessory Drive	45.100	MIN	1.7756
	45.125	MAX	1.7766

Install (001-033-026)



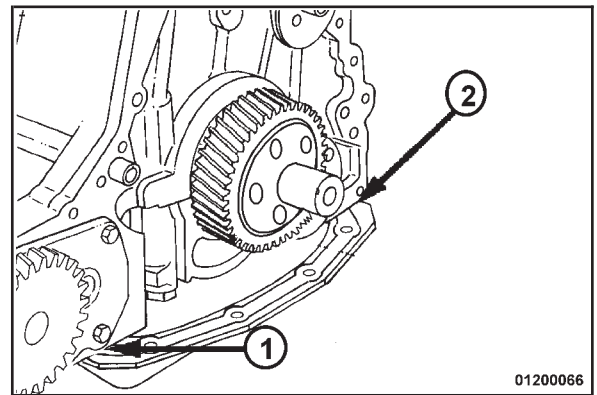
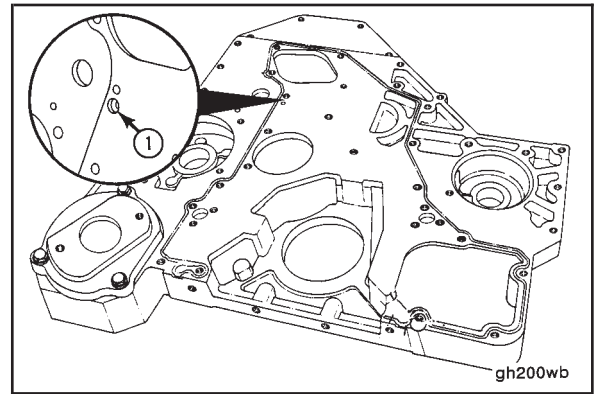
Avoid the use of excessive amounts of sealant, which could result in blocked oil passages in the engine.

Install a new o-ring, Part No. 3883150, into the rear of the gear housing at the oil jumper gallery (1) for the accessory drive support. Be sure to keep sealant from the hole.

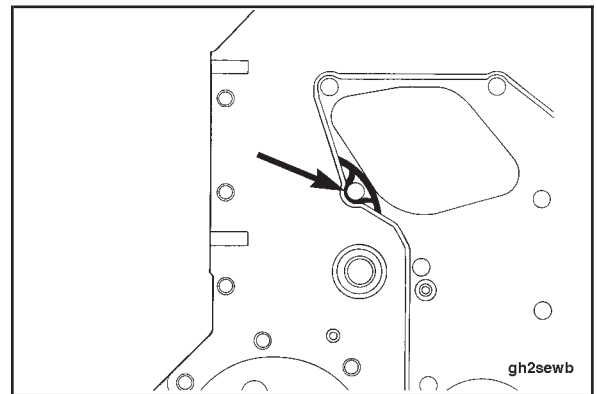
NOTE: Sealant requires assembly in ten minutes or less. It is best to apply the sealant and then immediately assemble the parts.

Apply a bead of sealant, Part No. 3823494, to the groove in the rear of the gear housing. Completely fill the groove so that approximately 1/16 to 1/8 inch of the bead is raised above the block mounting surface of the gear housing.

Apply a 2 mm [1/6 in] bead of sealant, Part No. 3823494, to the oil pan and cylinder block gear housing joint.



Apply additional sealant in the area by the camshaft opening as shown in the graphic.



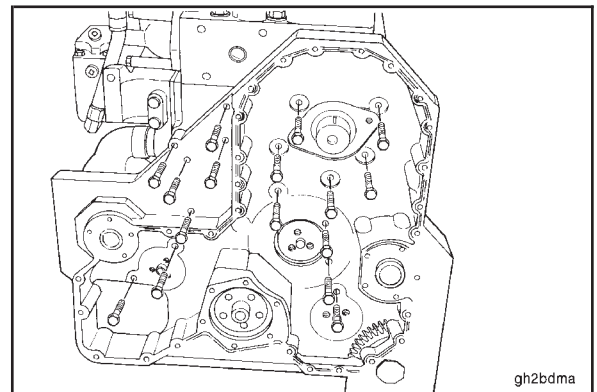
Install two guide pins, Part No. 3376488, in the gear housing end of the cylinder block.

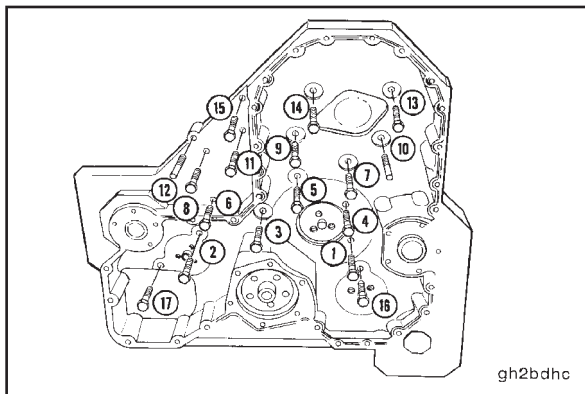
NOTE: Use care **not** to damage the oil pan gasket while installing the gear housing.

Install the gear housing and 10 capscrews (M10-1.50 x 25) in the inner part of the gear housing.

Install five capscrews (M10-1.50 x 50) on the outer surface of the housing.

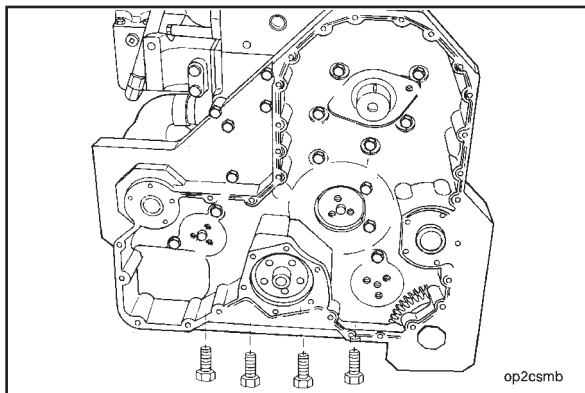
Remove the guide pins and install the two remaining capscrews (M10-1.50 x 25).





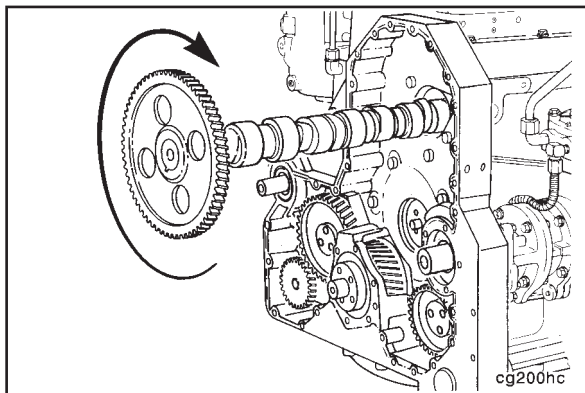
Tighten the capscrews in the sequence shown.

Torque Value: Step 1 20 N•m [15 ft-lb]
2 68 N•m [50 ft-lb]

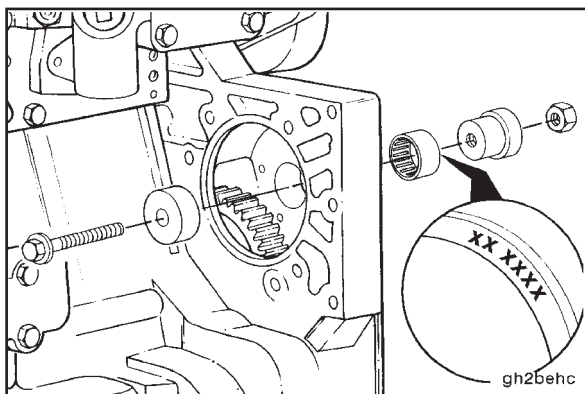


Install the four oil pan to gear housing capscrews.

Torque Value: 47 N•m [35 ft-lb]



Install the camshaft gear, or camshaft and gear assembly. Refer to Procedures 001-012-026 or 001-008-026 respectively.



Use bearing driver kit, Part No. 3824117, to install a new needle bearing in the water pump drive bore of the gear housing.



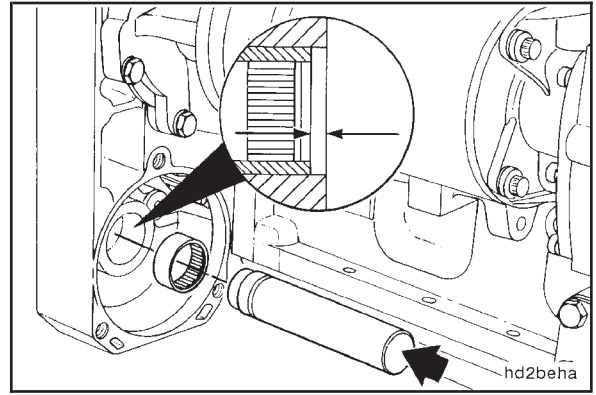
NOTE: The bearing **must** be installed with the part number side of the bearing against the installation tool to prevent damage to the bearing during the installation.

Install the bearing from the front side of the gear housing until the bearing is flush with the front edge of the housing bore.

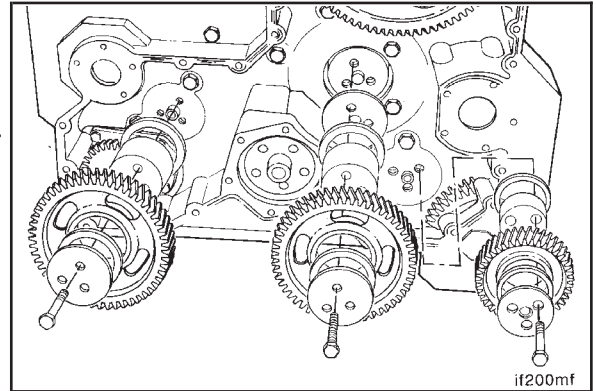
Use bearing installation tool, Part No. 3823776 included in bearing puller kit, Part No. 3823774, to install a new needle bearing in the hydraulic drive bore of the gear housing.

Tap the bearing gently until it comes in contact with the shoulder in the housing.

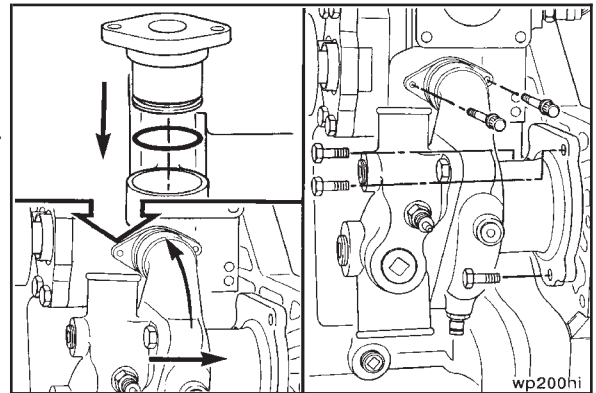
The bearing **must** be 0.25 to 0.76 [0.010 to 0.030 in] past the outside edge of the gear housing bore surface.



Install the idler gears. Refer to Procedures 001-036-026, 001-039-026, and 001-040-026.



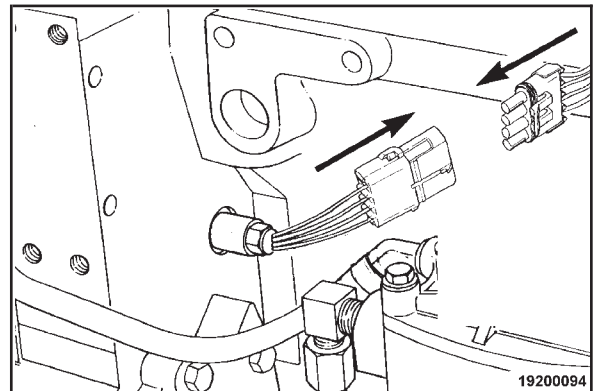
Install the water pump. Refer to Procedure 008-062-026.

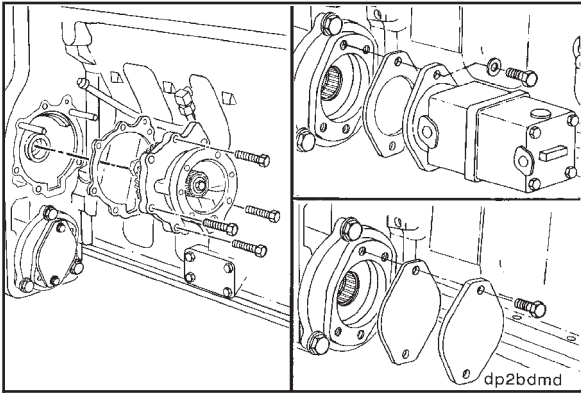


Install the engine position sensor in the back side of the gear housing.

Torque Value: 34 N•m [25 ft-lb]

Connect the sensor to the engine wiring harness.

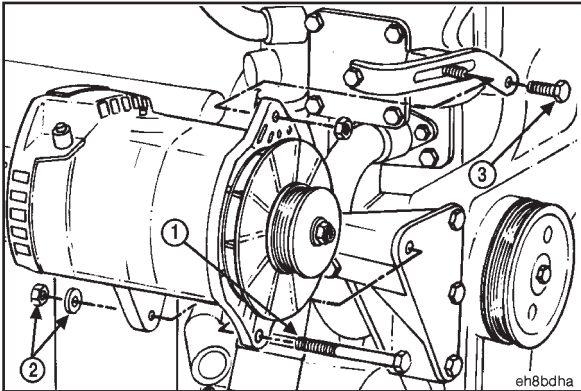




Install the accessory drive. Refer to Procedure 009-001-026.



Install the hydraulic drive, if equipped. Refer to Procedure 009-016-026.

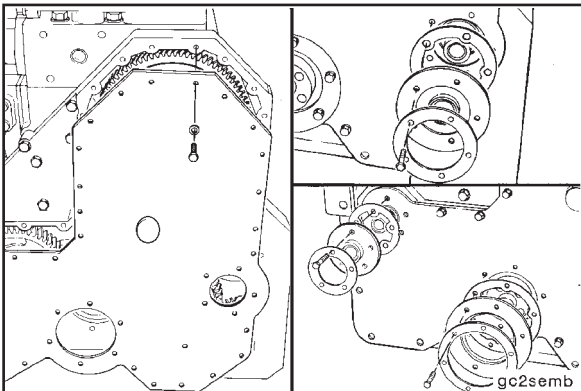


Install the alternator bracket with two M10-1.50 x 30 capscrews.

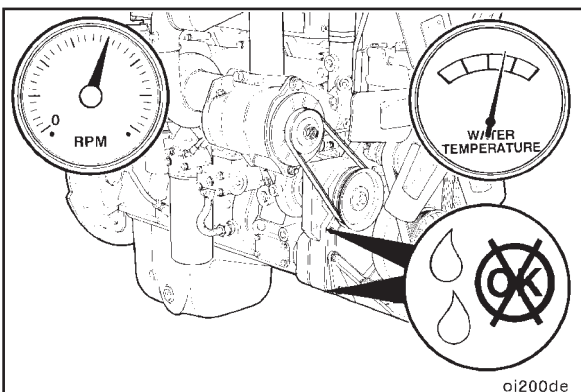
Torque Value: 47 N•m [35 ft-lb]



Install the alternator. Refer to Procedure 013-001-026.



Install the gear cover. Refer to Procedure 001-031-026.

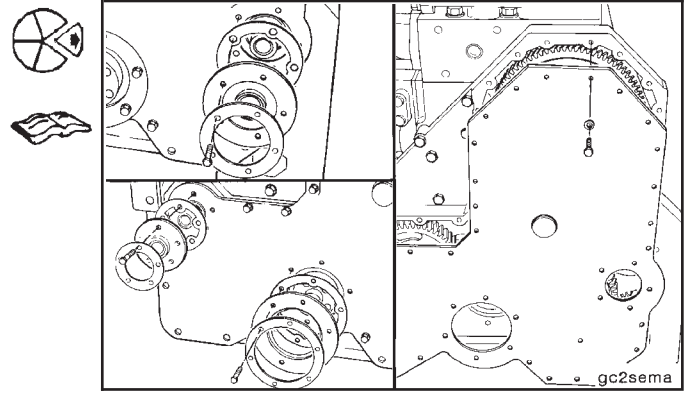


Operate the engine to normal operating temperature and check for leaks.

Idler Gear, Camshaft (001-036)

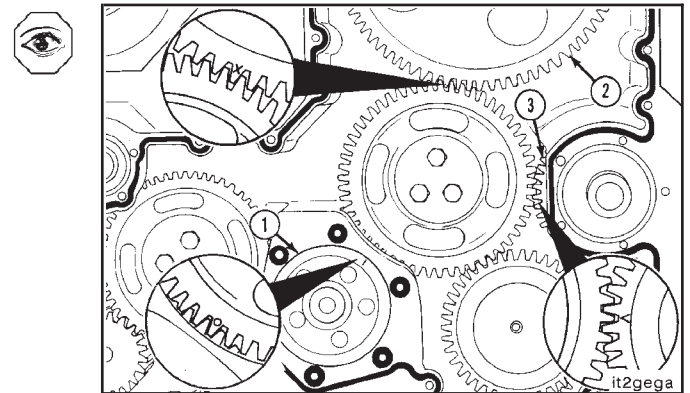
Remove (001-036-002)

Remove the gear cover. Refer to Procedure 001-031-002.



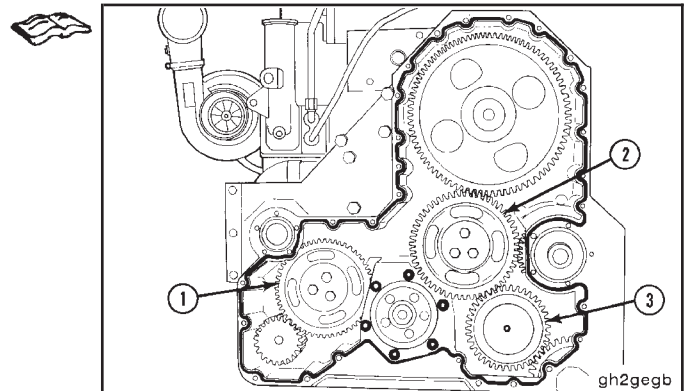
Before removing the idler gear, use the accessory drive shaft to rotate the crankshaft until the timing marks on the crankshaft gear (1), camshaft gear (2), and accessory drive gear (3) are completely engaged in the camshaft idler gear.

NOTE: Due to the camshaft idler gear having more gear teeth than the crankshaft gear, the camshaft idler gear timing marks will **not** align with the crankshaft, camshaft and accessory drive gears timing marks on every engine revolution.



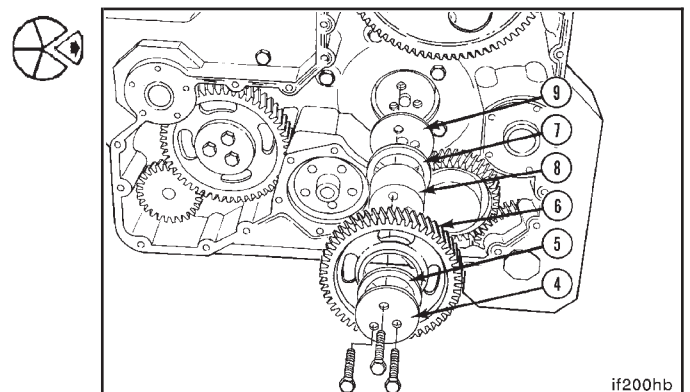
Three idler gear assemblies are used:

- Water pump idler gear (1)
- Camshaft idler gear (2)
- Hydraulic pump idler gear (3)

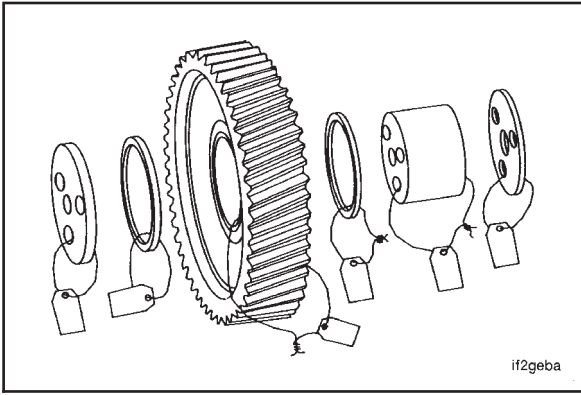


To remove the camshaft idler gear assembly, remove:

- The three capscrews
- Cover plate (4)
- Front thrust bearing (5)
- Idler gear (6)
- Rear thrust bearing (7)
- Idler gear shaft (8)
- Wear plate (9)

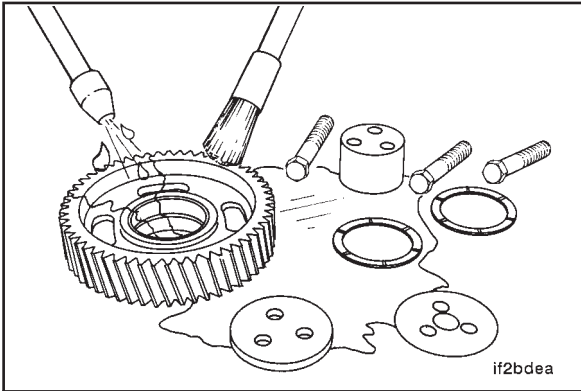


Mark or tag the individual pieces of the idler gear assembly and attach them together.



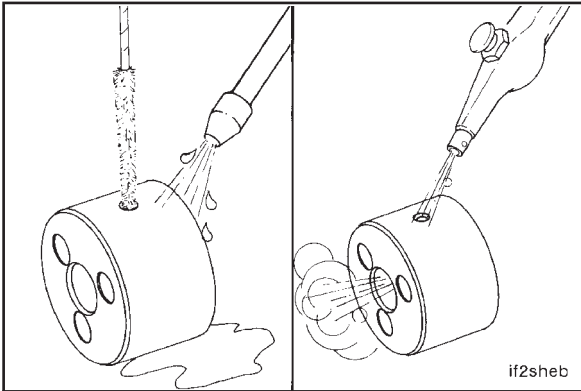
Clean (001-036-006)

Clean the parts with solvent. Dry with compressed air.



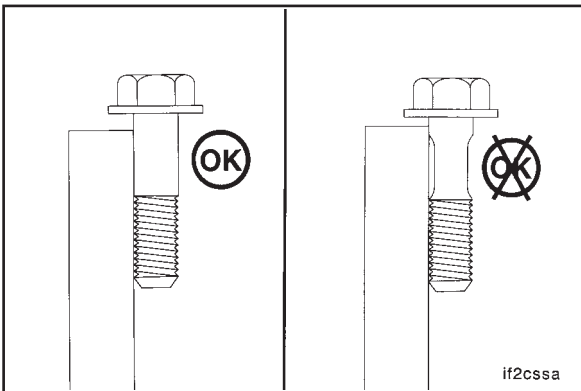
Use a bristle brush to clean the oil drillings in the idler gear shaft.

Blow out the oil drillings with compressed air.

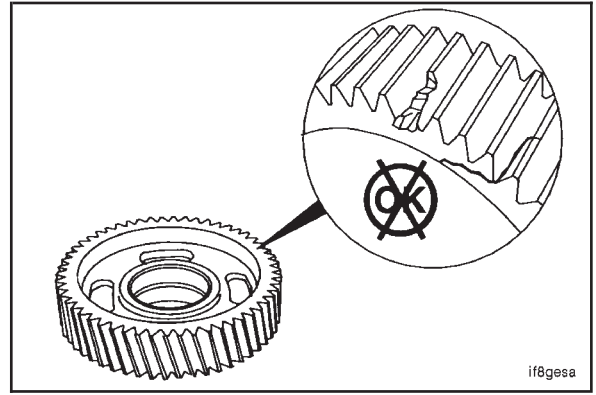


Inspect for Reuse (001-036-007)

Use a straight edge to inspect the retaining capscrews for necking. If necking is observed, do **not** reuse the capscrews. They **must** be replaced.



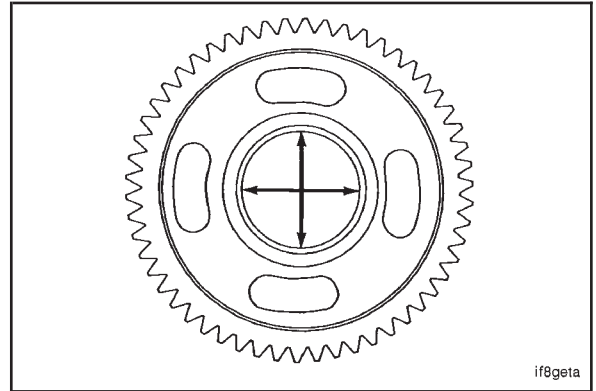
Visually inspect the idler gear for chipped, broken or cracked teeth.



Measure the inside diameter of the idler gear bushing bore.



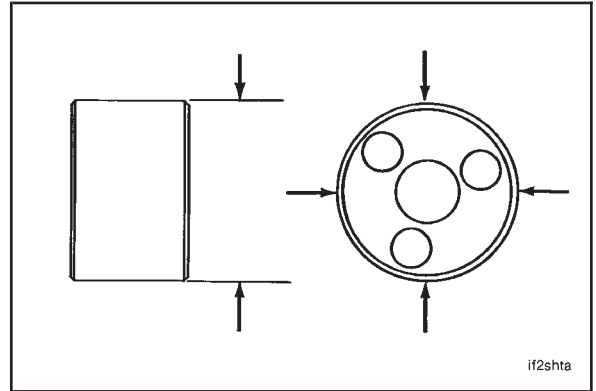
Camshaft Idler Gear Bushing Bore I.D.		
mm		in
60.045	MIN	2.3640
60.100	MAX	2.3661



Measure the outside diameter of the idler gear shaft.



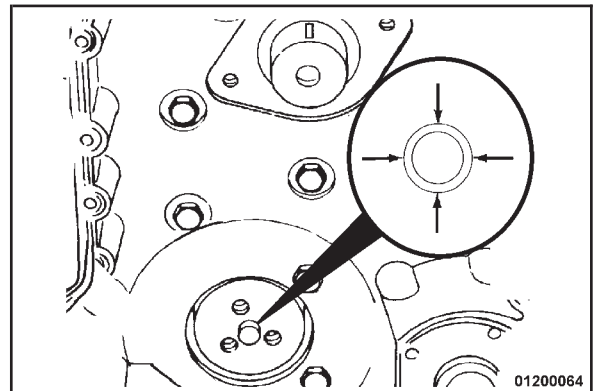
Camshaft Idler Gear Shaft O.D.		
mm		in
59.975	MIN	2.3612
60.008	MAX	2.3625

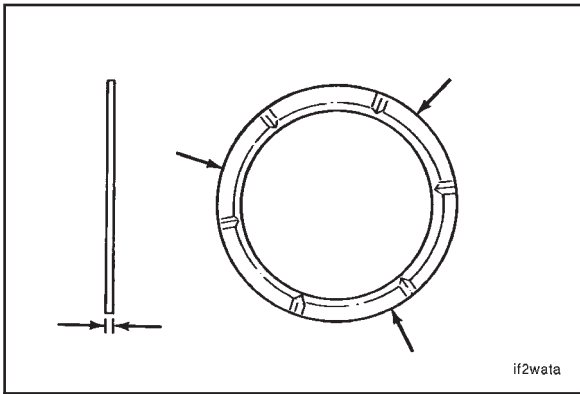


Measure the outside diameter of the camshaft idler shaft ring dowel.



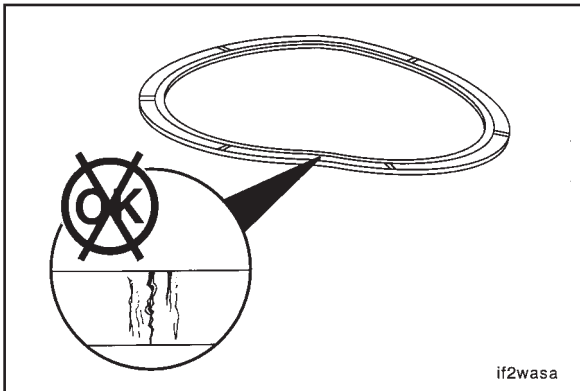
Camshaft Idler Ring Dowel O.D.		
mm		in
19.217	MIN	0.7566
19.243	MAX	0.7576



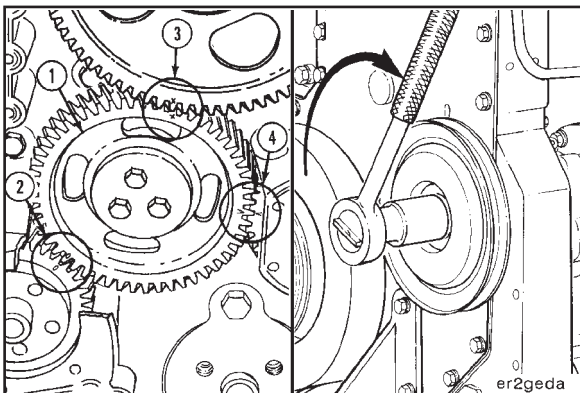


Measure the thrust washer thickness in three places 120 degrees apart.

Camshaft Idler Thrust Washer Thickness		
mm		in
2.400	MIN	0.0945
2.470	MAX	0.0972



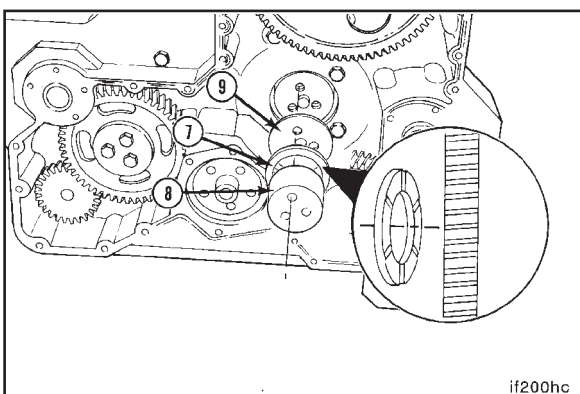
Flex the thrust washers approximately 3 to 6 mm [1/8 to 1/4 in] and inspect the surfaces for cracks.



Install (001-036-026)

When installing the camshaft idler gear (1), make certain the timing mark "0" on the crankshaft gear (2), timing mark "X" on the camshaft gear (3), and timing mark "V" on the accessory drive gear (4) are aligned as shown.

The marks on the idler gears should match the same mark on each of the other gears.



NOTE: Only the camshaft idler gear has a wear plate.

Use Lubriplate® 105, or equivalent, to lubricate the wear plate, thrust bearing and idler gear.



Install the camshaft idler gear wear plate (9).



The grooved side of the rear thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Install the idler gear shaft (8) and rear thrust bearing (7).

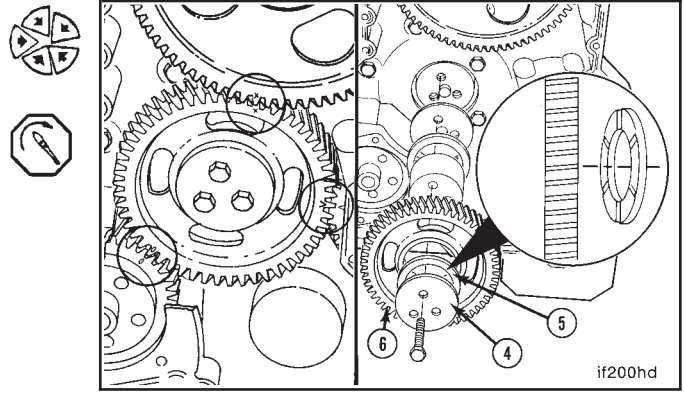
CAUTION

The grooved side of the front thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Align the timing marks and install the idler gear (6), front thrust bearing (5) and gear retainer (4).

Install the retaining capscrews and tighten.

- Torque Value:** Step 1 61 N•m [45 ft-lb]
2 Rotate 60 degrees

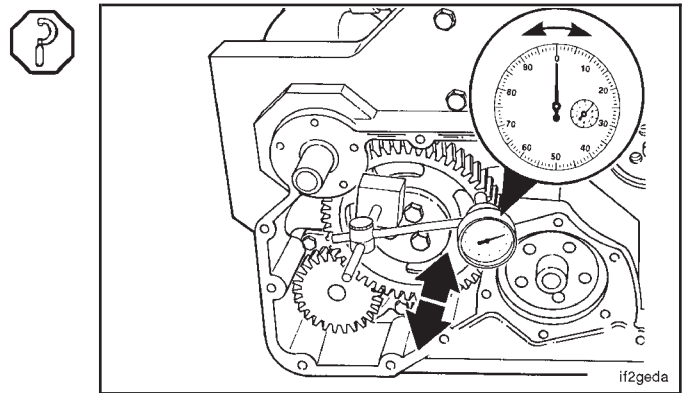


The following idler gear end clearance and backlash checks apply to all three idler gears. The same **MINIMUM** and **MAXIMUM** values apply also.

Use a dial indicator gauge with a magnetic base to measure the idler gear end clearance.

Place the contact tip of the gauge against the face of the idler gear.

Idler Gear End Clearance		
mm		in
0.30	MIN	0.012
0.53	MAX	0.021

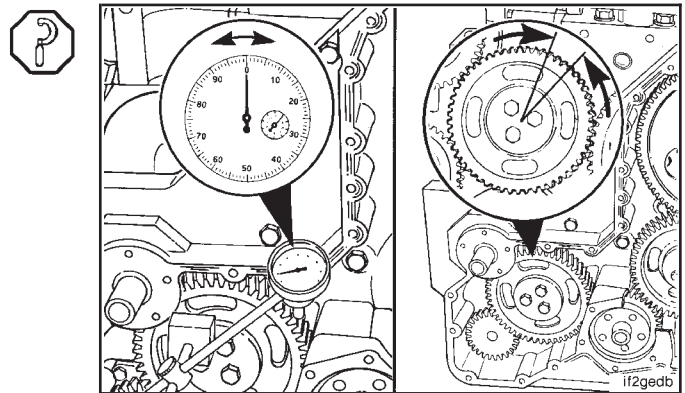


Use a dial indicator gauge with a magnetic base to measure the idler gear backlash.

Place the contact tip of the gauge against a tooth on the idler gear.

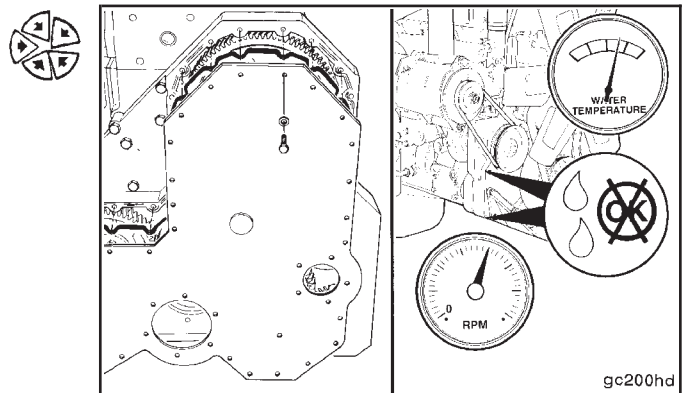
NOTE: Do **not** allow the mating gears to move while measuring the backlash.

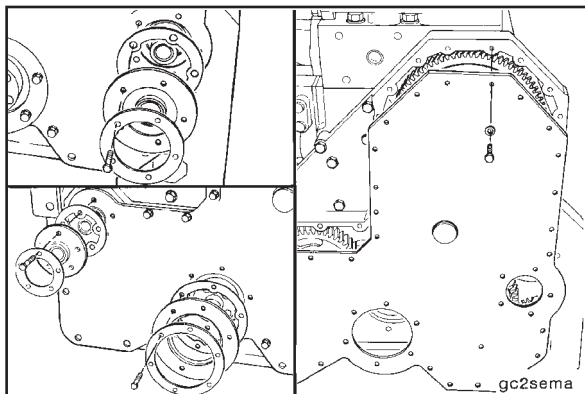
Idler Gear Backlash		
mm		in
0.08	MIN	0.003
0.38	MAX	0.015



Install the gear cover. Refer to Procedure 001-031-026.

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

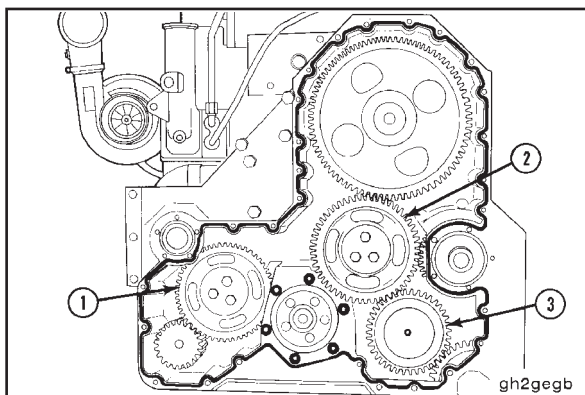




Idler Gear, Hydraulic Pump (001-039) Remove (001-039-002)

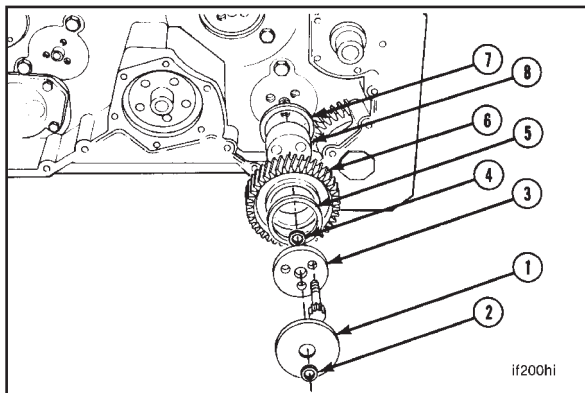


Remove the gear cover. Refer to Procedure 001-031-002.



Three idler gear assemblies are used:

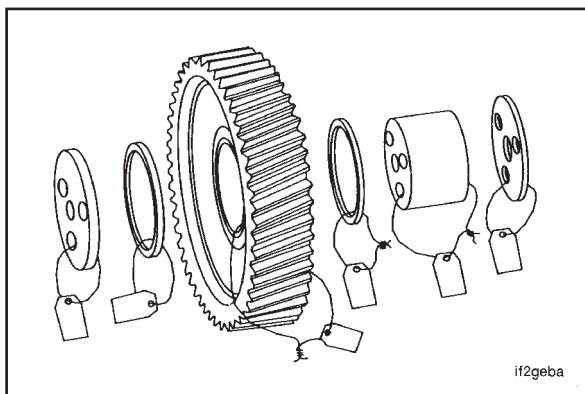
- Water pump idler gear (1)
- Camshaft idler gear (2)
- Hydraulic pump idler gear (3)



To remove the hydraulic drive idler gear assembly, remove:

- Mounting spacer (1)
- Rectangular seal (2)
- The three twelve-point capscrews
- Gear retainer (3)
- Rectangular seal (4)
- Front thrust bearing (5)
- Idler gear (6)
- Rear thrust bearing (7)
- Idler gear shaft (8)

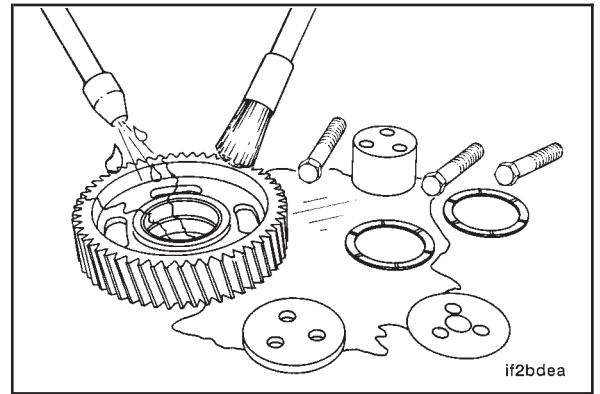
NOTE: SAE 'A' drives do **not** use a rectangular seal (4) on the rear surface of the gear retainer.



Mark or tag the individual pieces of the idler gear assembly and attach them together.

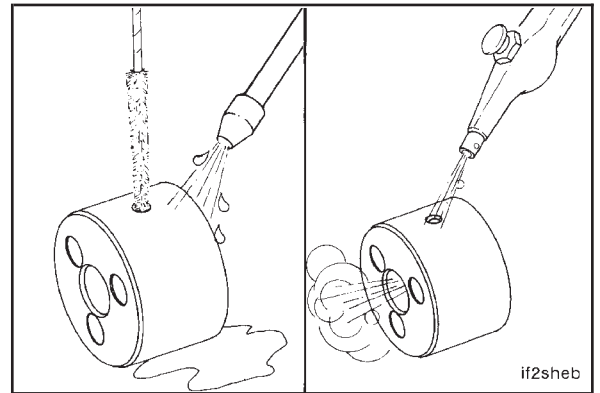
Clean (001-039-006)

Clean the parts with solvent. Dry with compressed air.



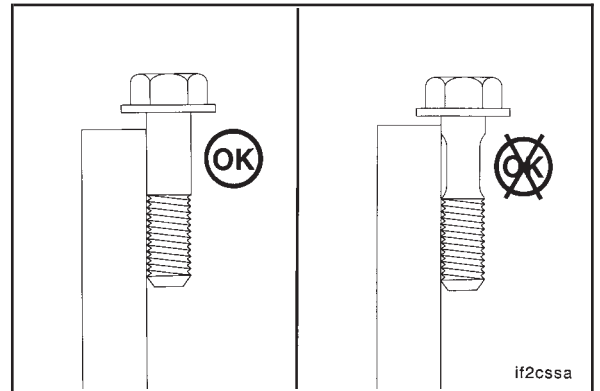
Use a bristle brush to clean the oil drillings in the idler gear shaft.

Blow out the oil drillings with compressed air.

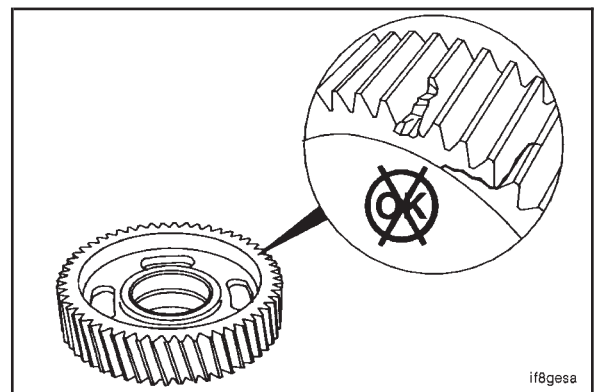


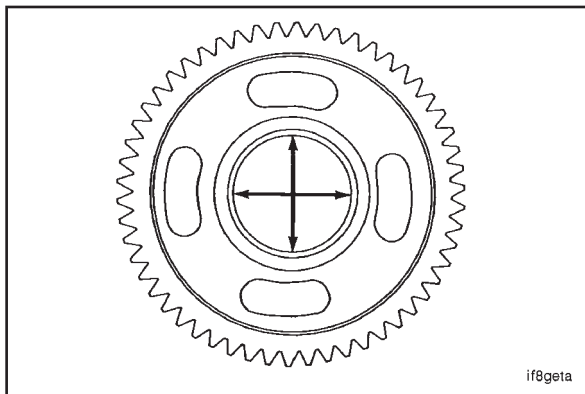
Inspect for Reuse (001-039-007)

Use a straight edge to inspect the retaining capscrews for necking. If necking is observed, do **not** reuse the capscrews. They **must** be replaced.



Visually inspect the idler gear for chipped, broken or cracked teeth.



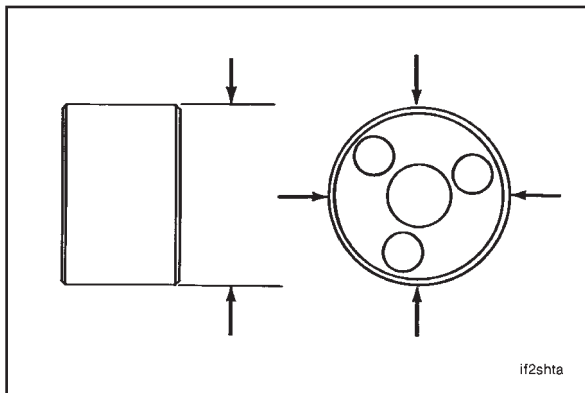


if8geta



Measure the inside diameter of the idler gear bushing bore.

Hydraulic Drive Idler Gear Bushing Bore I.D.		
mm		in
60.045	MIN	2.3640
60.100	MAX	2.3661

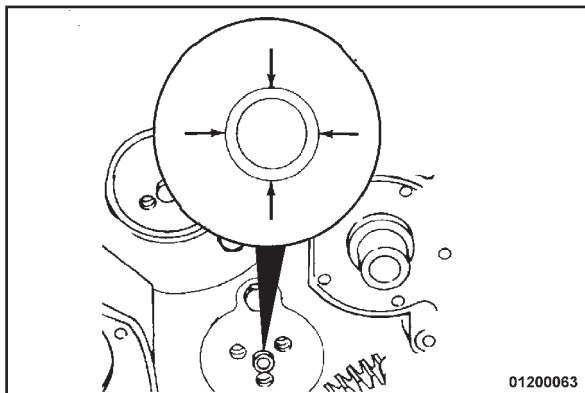


if2shta



Measure the outside diameter of the idler gear shaft.

Hydraulic Drive Idler Gear shaft O.D.		
mm		in
59.975	MIN	2.3612
60.008	MAX	2.3625

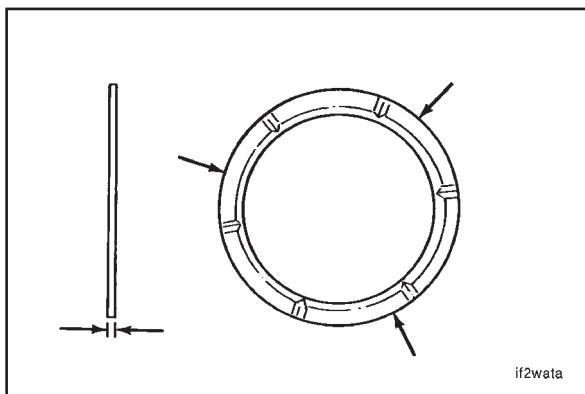


01200063



Measure the outside diameter of the ring dowel.

Hydraulic Drive Idler Ring Dowel O.D.		
mm		in
19.217	MIN	0.7566
19.243	MAX	0.7576



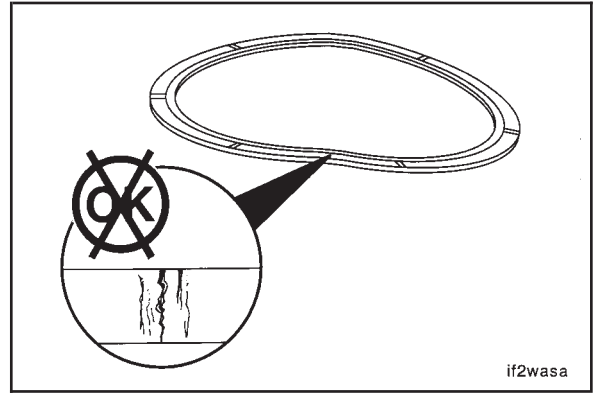
if2wata



Measure the thrust washer thickness in three places 120 degrees apart.

Hydraulic Drive Idler Thrust Washer Thickness		
mm		in
2.400	MIN	0.0945
2.470	MAX	0.0972

Flex the thrust washers approximately 3 to 6 mm [1/8 to 1/4 in] and inspect the surfaces for cracks.



Install (001-039-026)

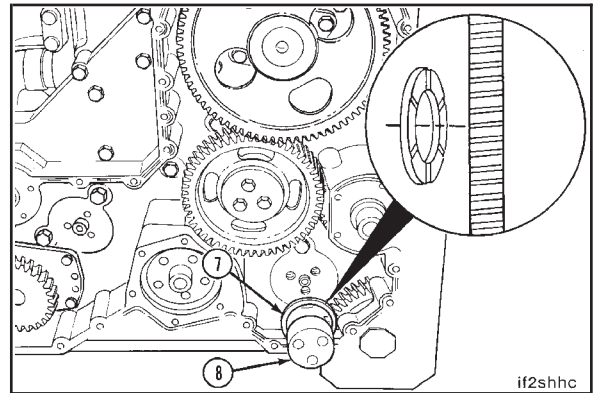
Use Lubriplate® 105, or equivalent, to lubricate the wear plate, thrust bearing and idler gear.



The grooved side of the rear thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

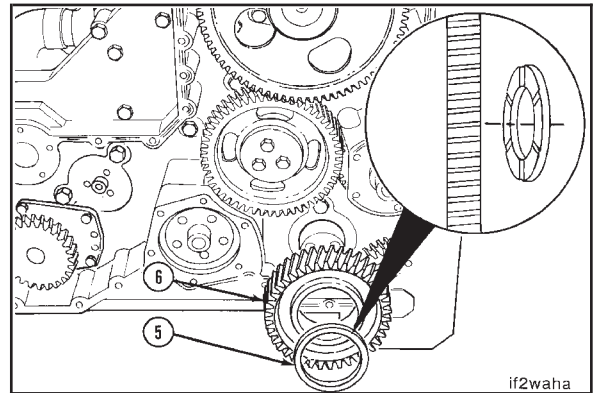
Install the idler gear shaft (8) and rear thrust bearing (7).

NOTE: When a SAE B drive is used, a special hydraulic drive idler shaft with two oil holes is used. With the engine in the upright position, orient the shaft so that one oil hole is at 12:00 o'clock and the other at 4:00 o'clock.



The grooved side of the front thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Install the idler gear (6) and front thrust bearing (5).

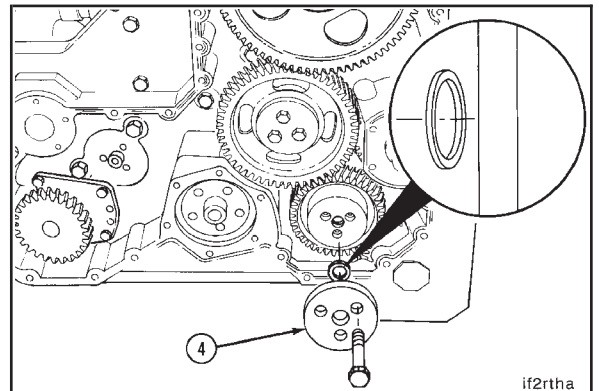


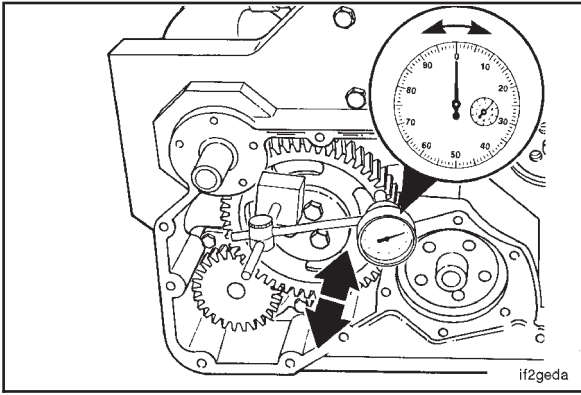
NOTE: On SAE "B" drives, install a new rectangular seal on the rear surface of the gear retainer (4) before installing the retainer.

Install the gear retainer (4).

Install the three retaining capscrews and tighten.

Torque Value: Step 1 61 N•m [45 ft-lb]
2 Rotate 60 degrees



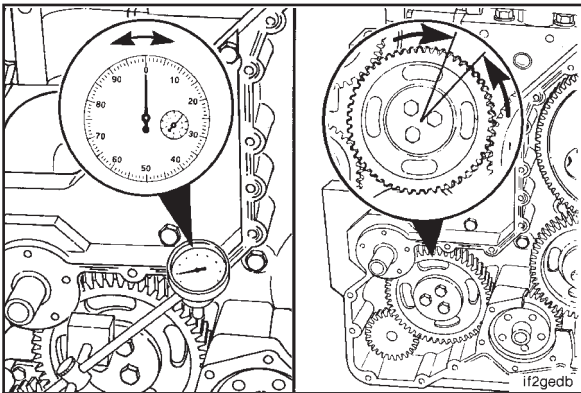


The following idler gear end clearance and backlash checks apply to all three idler gears. The same **MINIMUM** and **MAXIMUM** values apply also.

Use a dial indicator gauge with a magnetic base to measure the idler gear end clearance.

Place the contact tip of the gauge against the face of the idler gear.

Idler Gear End Clearance		
mm		in
0.30	MIN	0.012
0.53	MAX	0.021

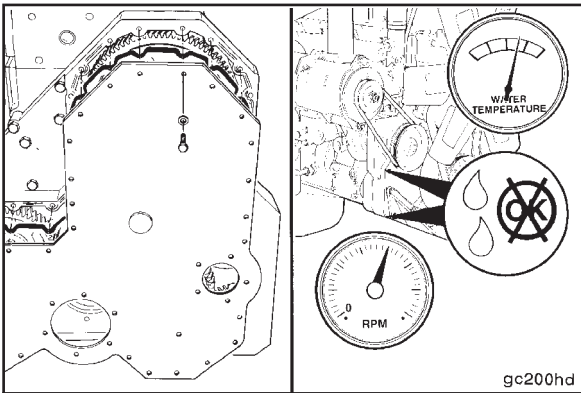


Use a dial indicator gauge with a magnetic base to measure the idler gear backlash.

Place the contact tip of the gauge against a tooth on the idler gear.

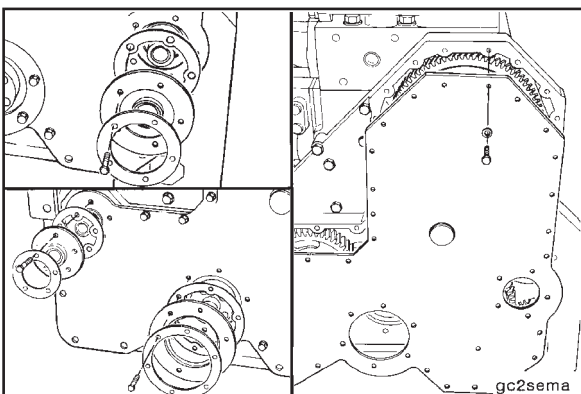
NOTE: Do **not** allow the mating gears to move while measuring the backlash.

Idler Gear Backlash		
mm		in
0.08	MIN	0.003
0.38	MAX	0.015



Install the gear cover. Refer to Procedure 001-031-026.

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



Idler Gear, Water Pump (001-040) Remove (001-040-002)

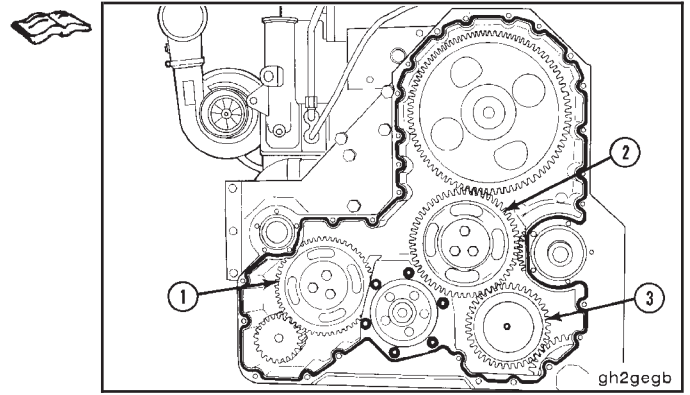


Remove the gear cover. Refer to Procedure 001-031-002.

Three idler gear assemblies are used:

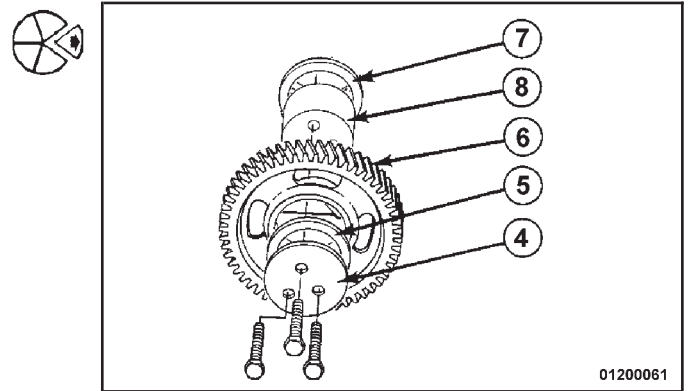
- Water pump idler gear (1)
- Camshaft idler gear (2)
- Hydraulic pump idler gear (3)

NOTE: The water pump **must** be removed before the water pump idler gear (1) can be removed. Refer to Procedure 008-062-002.

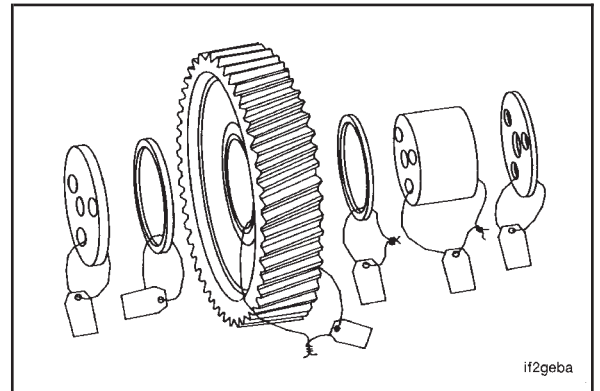


To remove the water pump idler gear assembly, remove:

- The three capscrews
- Cover plate (4)
- Front thrust bearing (5)
- Idler gear (6)
- Rear thrust bearing (7)
- Idler gear shaft (8)

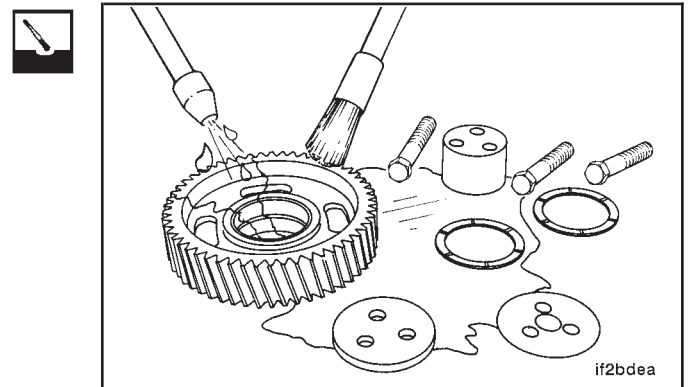


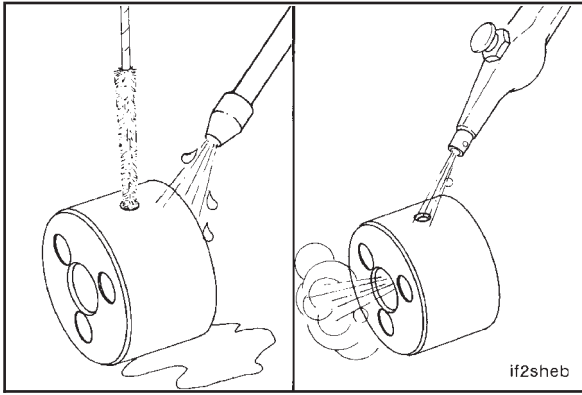
Mark or tag the individual pieces of the idler gear assembly and attach them together.



Clean (001-040-006)

Clean the parts with solvent. Dry with compressed air.

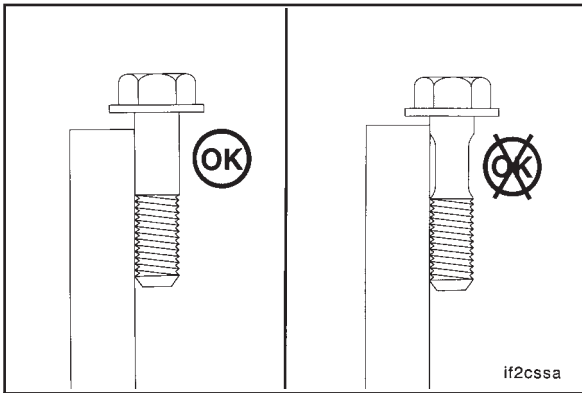




Use a bristle brush to clean the oil drilling in the idler gear shaft.

Blow out the oil drilling with compressed air.

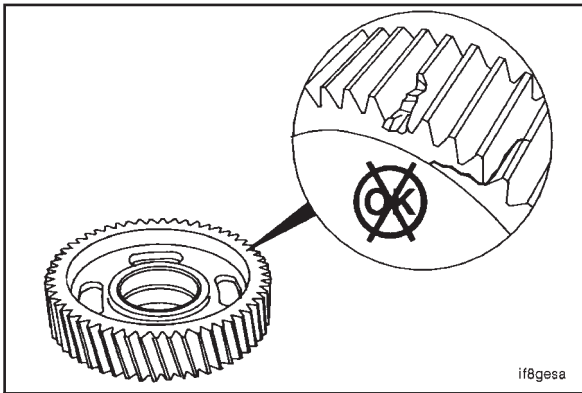
if2sheb



Inspect for Reuse (001-040-007)

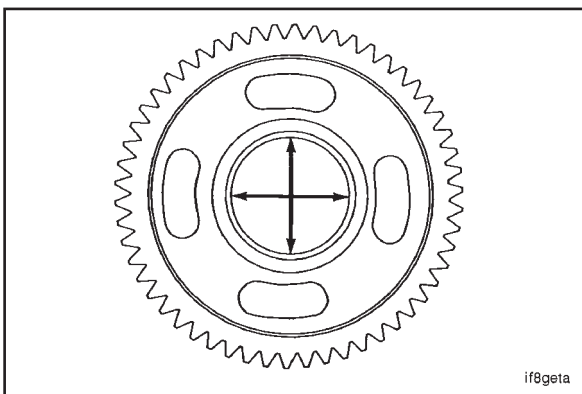
Use a straight edge to inspect the retaining capscrews for necking. If necking is observed, do **not** reuse the capscrews. They **must** be replaced.

if2cssa



Visually inspect the idler gear for chipped, broken or cracked teeth.

if8gesa



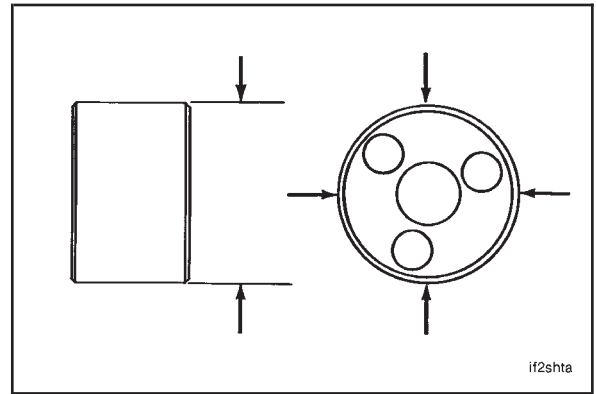
Measure the inside diameter of the idler gear bushing bore.

Water Pump Idler Gear Bushing Bore I.D.		
mm		in
60.045	MIN	2.3640
60.100	MAX	2.3661

if8geta

Measure the outside diameter of the idler gear shaft.

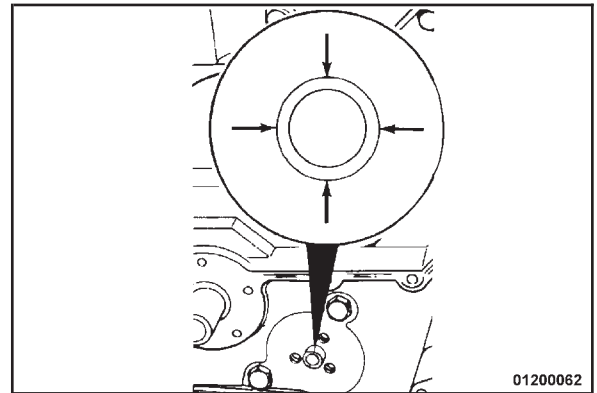
Water Pump Idler Gear Shaft O.D.		
mm		in
59.975	MIN	2.3612
60.008	MAX	2.3625



if2shta

Measure the outside diameter of the ring dowel.

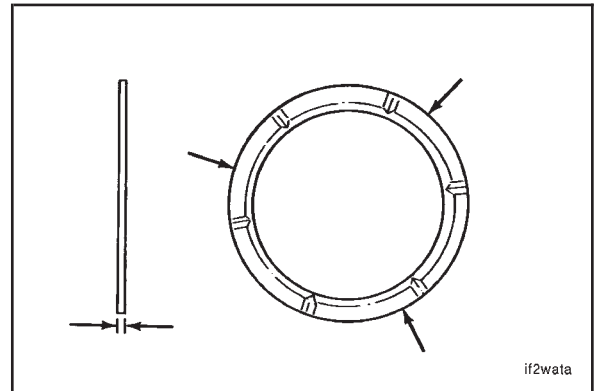
Water Pump Idler Ring Dowel O.D.		
mm		in
19.217	MIN	0.7566
19.243	MAX	0.7576



01200062

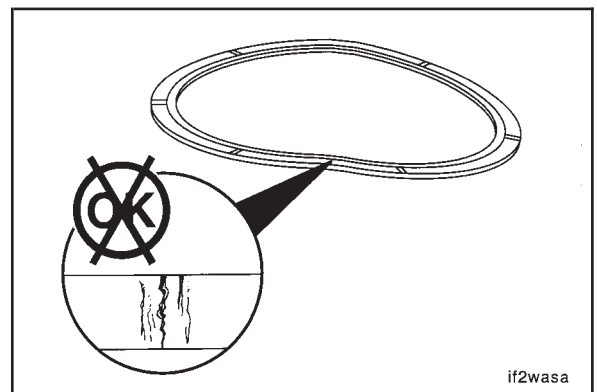
Measure the thrust washer thickness in three places 120 degrees apart.

Water Pump Idler Thrust Washer Thickness		
mm		in
2.400	MIN	0.0945
2.470	MAX	0.0972

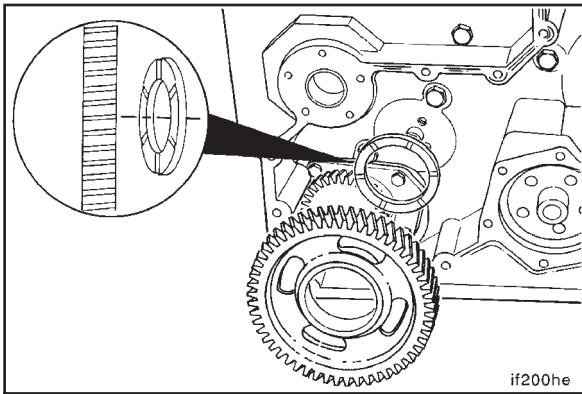


if2wata

Flex the thrust washers approximately 3 to 6 mm [1/8 to 1/4 in] and inspect the surfaces for cracks.



if2wasa



Install (001-040-026)

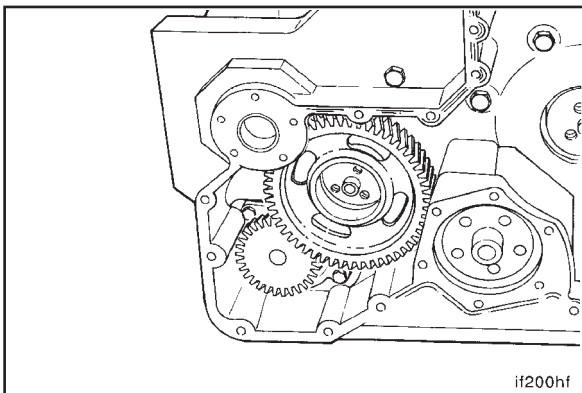
⚠ CAUTION ⚠

The grooved side of the rear thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

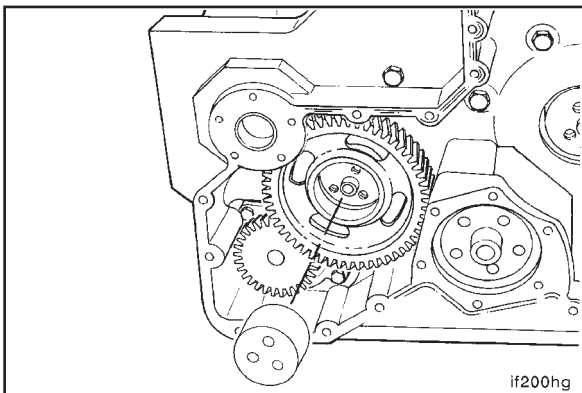
Use Lubriplate® 105, or equivalent, to lubricate the thrust bearings and idler gear shaft.

Install the rear thrust bearing.

Install the idler gear without the shaft.

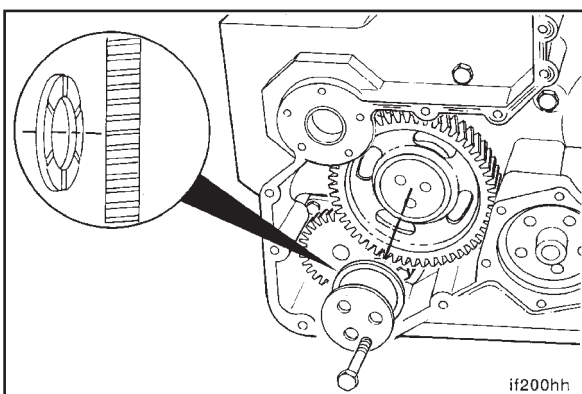


Align the inside diameter of the rear thrust bearing with the inside diameter of the idler gear.



The shaft **must** pass through the gear and pilot into the rear thrust bearing. After installation, the shaft **must** protrude only slightly more than the thickness of the front thrust bearing. Excessive shaft protrusion beyond the thickness of the front thrust bearing indicates the shaft is **not** properly piloted into the rear thrust bearing.

Install the shaft into the gear bore.



⚠ CAUTION ⚠

The grooved side of the front thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Install the front thrust bearing.

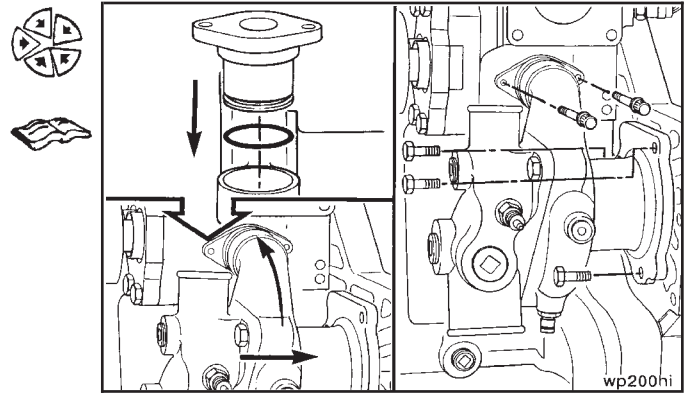
Install the gear retainer.

Install the capscrews and tighten.

Torque Value: Step 1 61 N•m [45 ft-lb]
2 Rotate 60 degrees



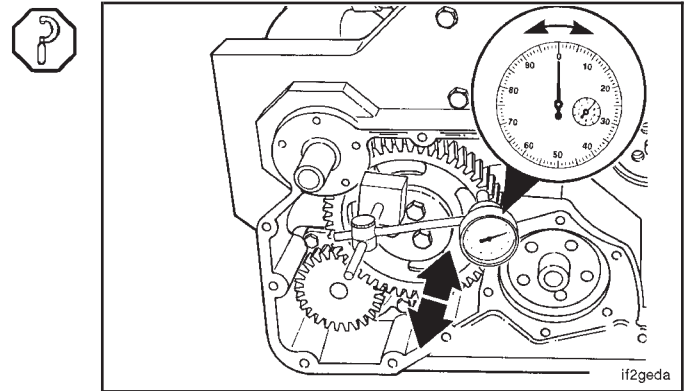
Install the water pump. Refer to Procedure 008-062-026.



The following idler gear end clearance and backlash checks apply to all three idler gears. The same **MINIMUM** and **MAXIMUM** values apply also.

Use a dial indicator gauge with a magnetic base to measure the idler gear end clearance.

Place the contact tip of the gauge against the face of the idler gear.

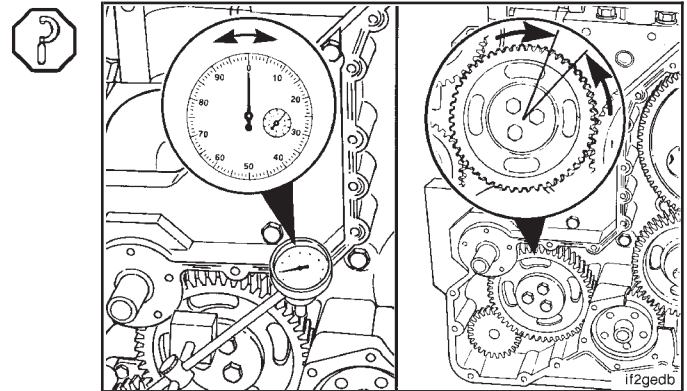


Idler Gear End Clearance		
mm		in
0.30	MIN	0.012
0.53	MAX	0.021

Use a dial indicator gauge with a magnetic base to measure the idler gear backlash.

Place the contact tip of the gauge against a tooth on the idler gear.

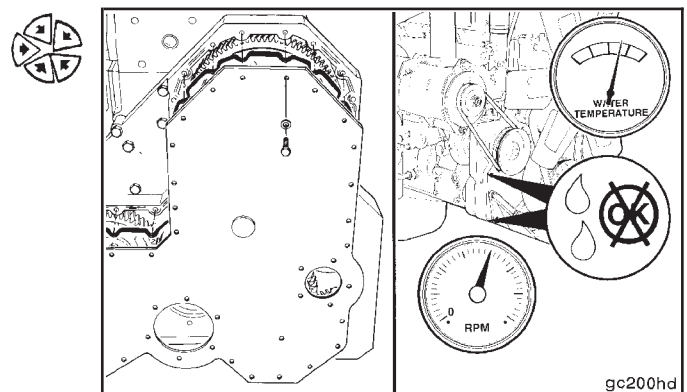
NOTE: Do **not** allow the mating gears to move while measuring the backlash.

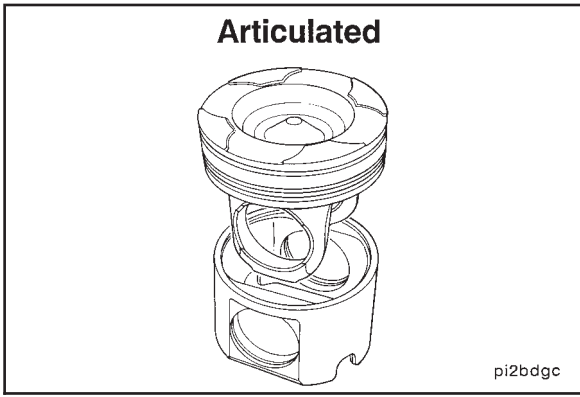


Idler Gear Backlash		
mm		in
0.08	MIN	0.003
0.38	MAX	0.015

Install the gear cover. Refer to Procedure 001-031-026.

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





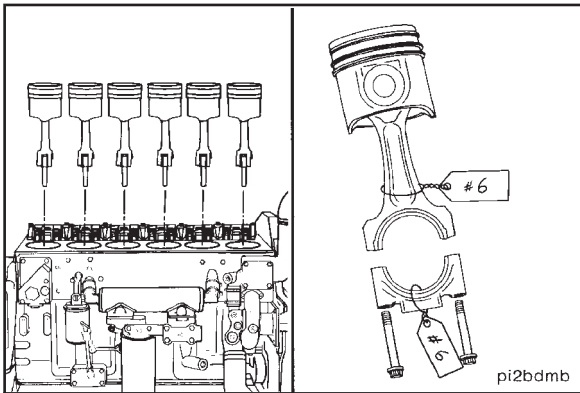
Piston (001-043)

General Information

All M11 engines are equipped with articulated pistons.

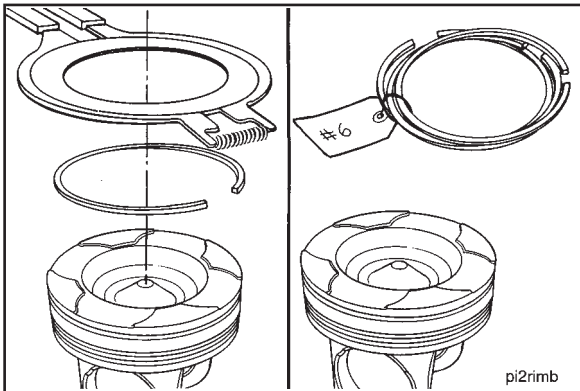
The articulated piston is a two piece piston consisting of a forged steel crown and an aluminum skirt.

A closed chamber oil gallery is located on the underside of the crown of the piston to provide more oil contact with the piston and give better piston cooling. Piston cooling nozzle targeting is critical because of the closed chamber oil gallery.



Remove (001-043-002)

The piston and connecting rod **must** be removed as an assembly. To remove the piston and connecting rod, refer to Procedure 001-054-002.

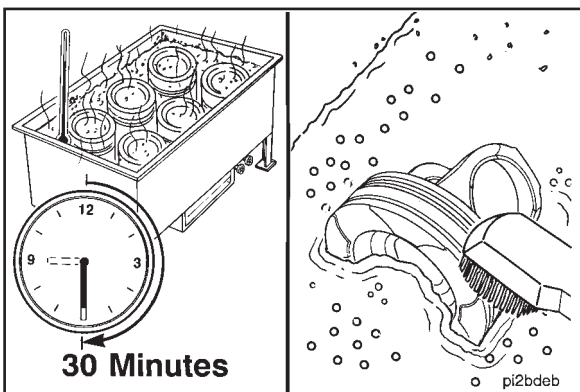


Disassemble (001-043-003)

Refer to Procedure 001-054-003 to disassemble the piston and connecting rod assembly.



NOTE: Refer to Procedure 001-047 for piston ring inspection.



Clean (001-043-006)

CAUTION



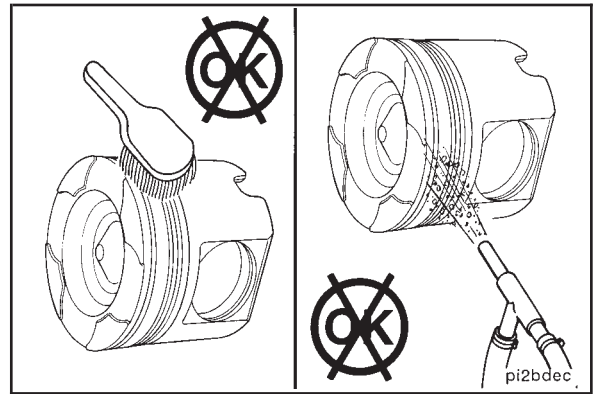
Be sure the cleaning solvent is approved for aluminum. Damage to the pistons can result if the wrong solution is used.

Allow the pistons to soak for a minimum of 30 minutes in a tank containing an approved cleaning solvent for aluminum.

Use a hot soapy solution and a non-metallic brush to remove carbon deposits.

⚠ CAUTION ⚠

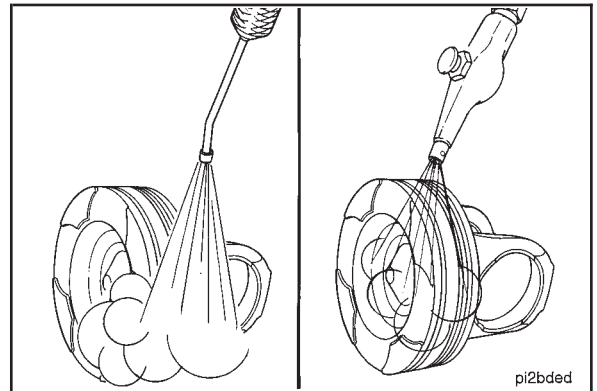
Do not use a metal brush. A metal brush will damage the piston ring grooves. Do not use glass beads to clean the grooves. Walnut shell or plastic bead, Part No. 3822735, blasting can be used on ring grooves on the dome or crown of the piston. Use the minimum effective pressure and do not concentrate the spray in one area for an extended period of time. The recommended blast pressure for plastic bead blasting is 276 kPa [40 psi]. Do not use glass beads or walnut shell blasting on the aluminum piston pin bores or articulated piston skirts. This can cause piston pin bore damage.



⚠ WARNING ⚠

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

Use steam to clean the pistons.
Dry with compressed air.

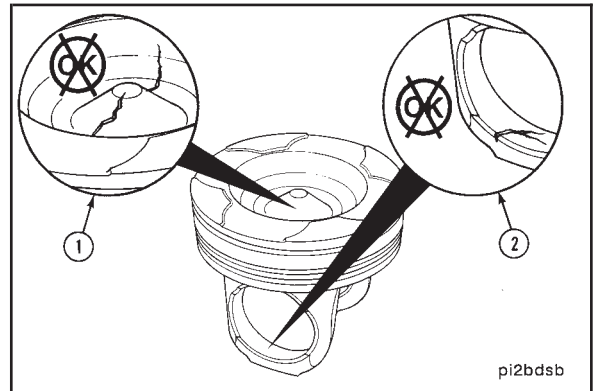


Inspect for Reuse (001-043-007)

Articulated Piston

Visually inspect the piston bowl (1) and crown piston pin bore (2) for cracks or damage.

Do **not** use pistons with cracks. If the crown is cracked, it **must** be replaced.

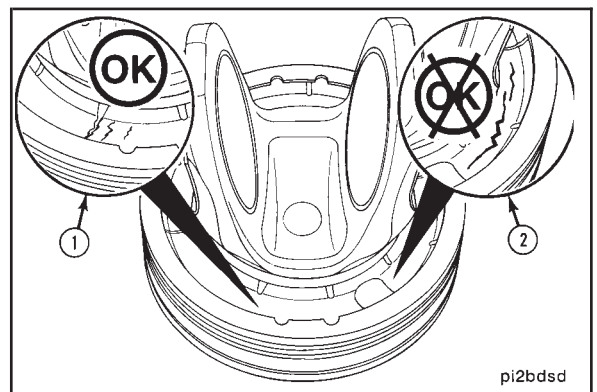


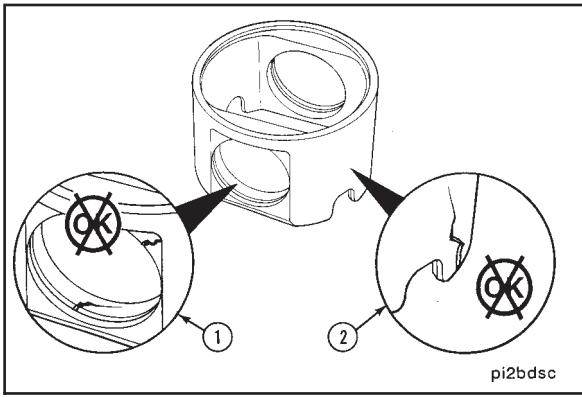
Visually inspect the piston gallery cover plate in the piston crown for cracks or looseness.

If the cover plate has a radial crack (1), the crown can be reused.

If the cover plate has a circumferential crack (2), the piston crown **must** be replaced.

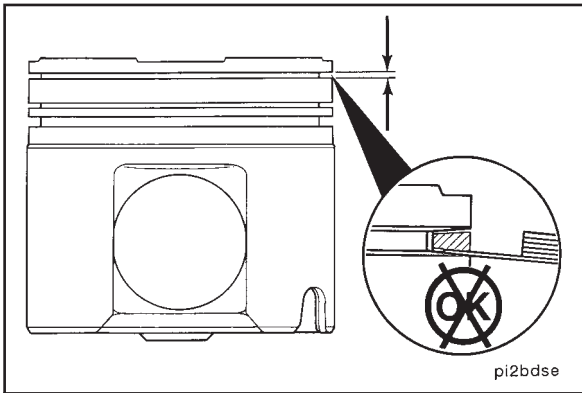
If the gallery is loose, the piston crown **must** be replaced.





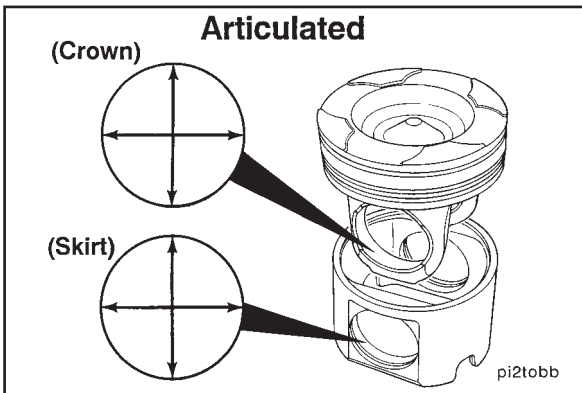
Visually inspect the piston skirt pin bore (1) and sides (2) for cracks or damage.

Do **not** use pistons with cracks. If the skirt is cracked, it **must** be replaced.



The ring groove can be inspected with a new ring and a feeler gauge.

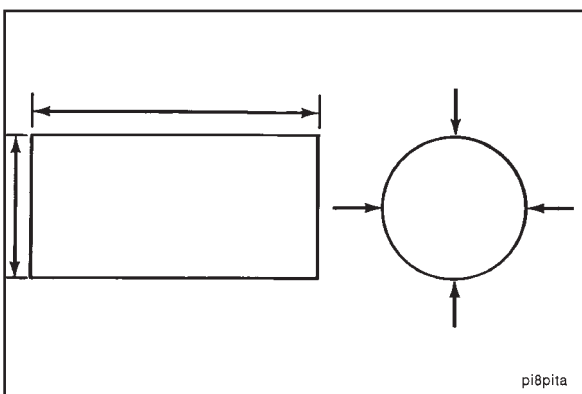
Hold a new ring in the groove even with the outside diameter of the piston. Install a 0.15 mm [0.006 inch] feeler gauge. If the feeler gauge enters the groove without resistance, there is too much wear. Replace the piston.



Measure the piston pin bore inside diameter.

Articulated Piston Pin Bore I.D. (Crown)		
mm		in
54.040	MIN	2.1276
54.055	MAX	2.1281

Articulated Piston Pin Bore I.D. (Skirt)		
mm		in
54.007	MIN	2.1263
54.015	MAX	2.1266



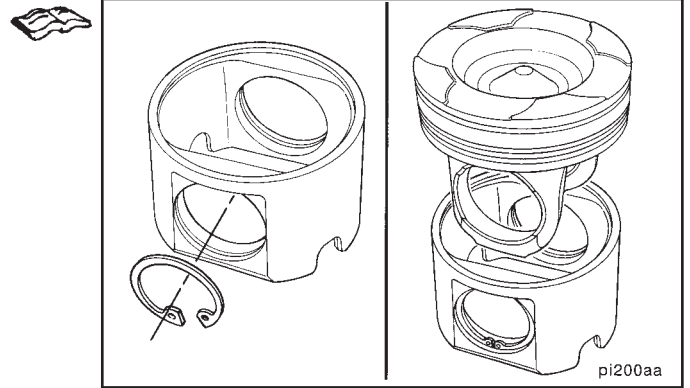
Measure the piston pin outside diameter and length.

Piston Pin O.D.		
mm		in
53.997	MIN	2.1259
54.003	MAX	2.1261

Piston Pin Length		
mm		in
101.70	MIN	4.0039
102.00	MAX	4.0157

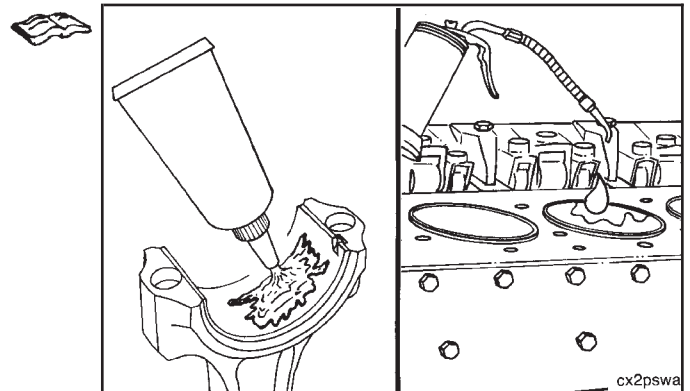
Assemble (001-043-025)

Refer to Procedure 001-054-025 for piston and connecting rod assembly instructions.



Install (001-043-026)

The piston and connecting rod must be installed as an assembly on M11 engines. Refer to Procedure 001-054-026 for installation instructions.

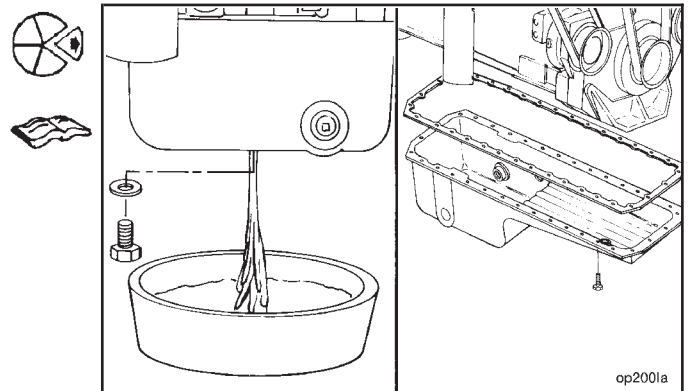


Piston Cooling Nozzle (001-046)

Remove (001-046-002)

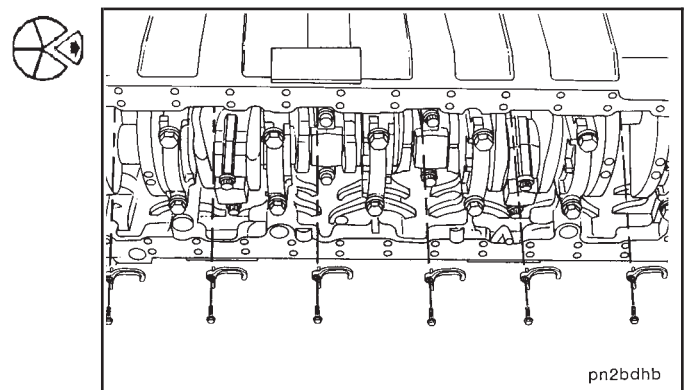
Drain the lubricating oil. Refer to Procedure 007-025-005.

Remove the lubricating oil pan. Refer to Procedure 007-025-002.



Remove the piston cooling nozzles.

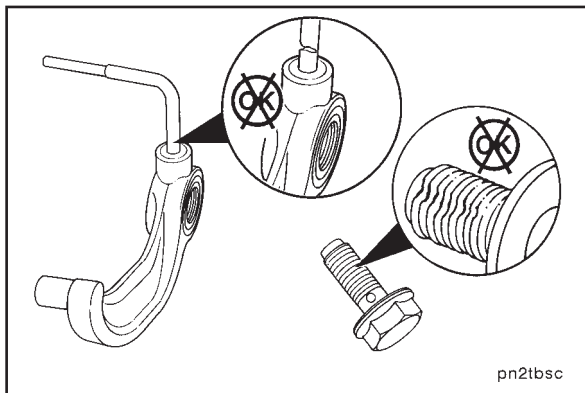
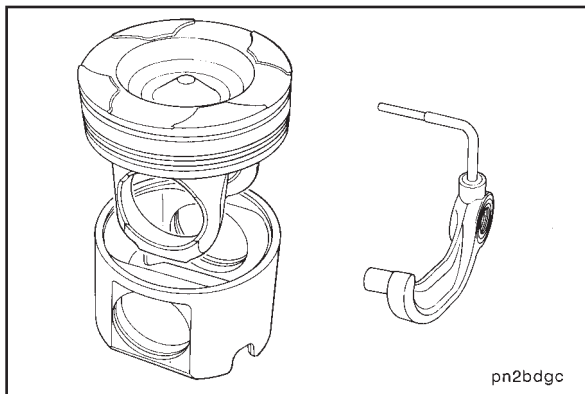
NOTE: The crankshaft **must** be rotated to allow access to remove all the nozzles.



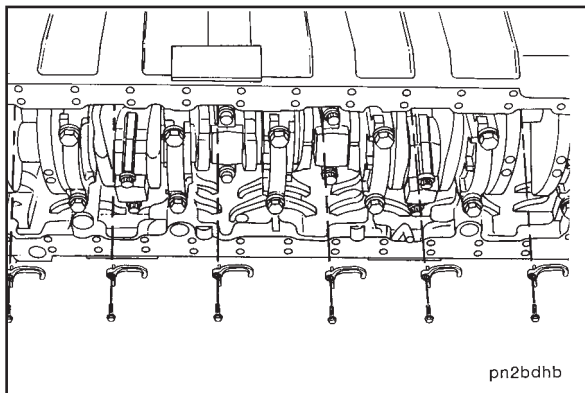
Inspect for Reuse (001-046-007)

Measure the piston cooling nozzle length.

Piston Cooling Nozzle Length		
mm		in
44.5	NOMINAL	1.752



Inspect the capscrews, washers and piston cooling nozzles for damage.



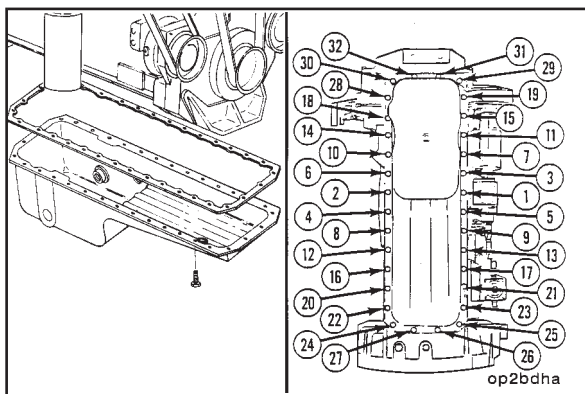
Install (001-046-026)

Install the nozzles, washers and capscrews.

Tighten the capscrews.

Torque Value: 24 N•m [18 ft-lb]

NOTE: The crankshaft **must** be rotated to allow access to install all the nozzles.

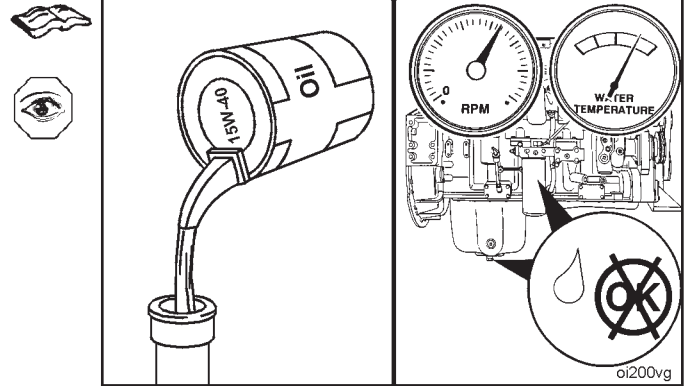


Install the lubricating oil pan. Refer to Procedure 007-025-026.



Fill the engine with lubricating oil. Refer to Procedure 007-025-028.

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

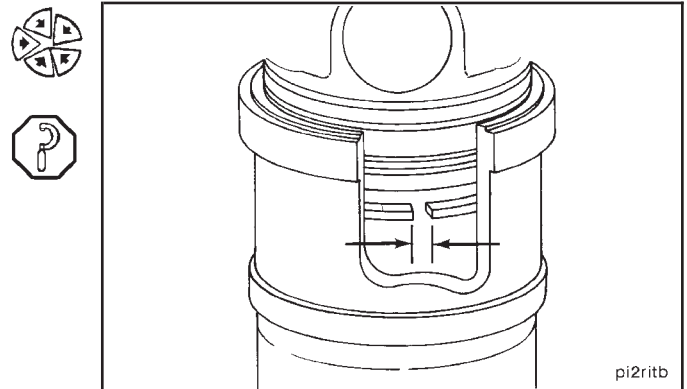


Piston Rings (001-047) Inspect for Reuse (001-047-007)

To check the ring gap, install the piston rings in the wear area of the cylinder liner in which they will be used.

Use a feeler gauge to measure the ring gap. Replace the ring if it does **not** meet the following specifications.

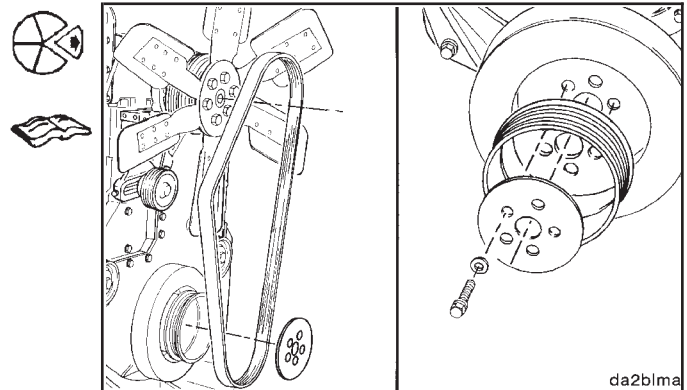
	Piston Ring Gap		
	mm		in
Top	0.46	MIN	0.018
	0.71	MAX	0.028
Intermediate	0.76	MIN	0.030
	1.14	MAX	0.045
Oil	0.25	MIN	0.010
	0.64	MAX	0.025

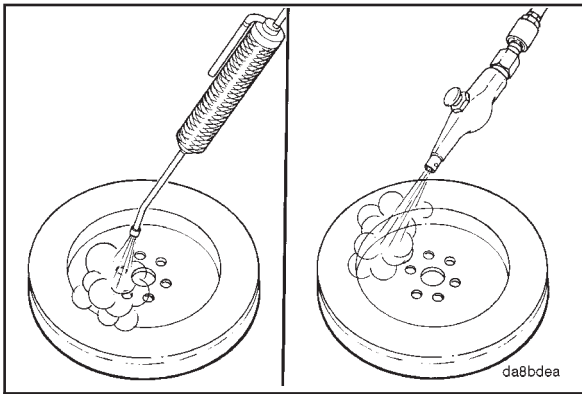


Vibration Damper (001-052) Remove (001-052-002)

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

Remove the clamping plate, crankshaft pulley and vibration damper. Refer to Procedure 001-022-002.



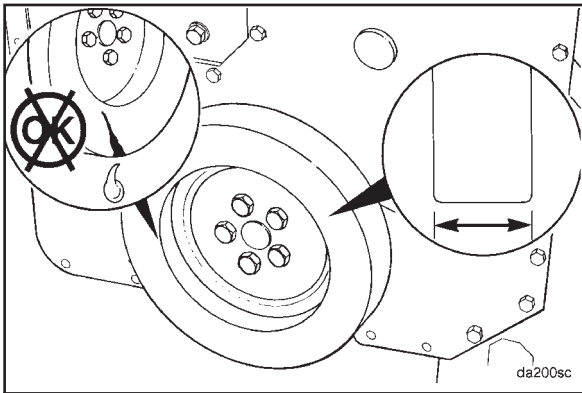


Clean (001-052-006)

⚠ WARNING ⚠

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

Use steam or solvent to clean the vibration damper. Dry with compressed air.



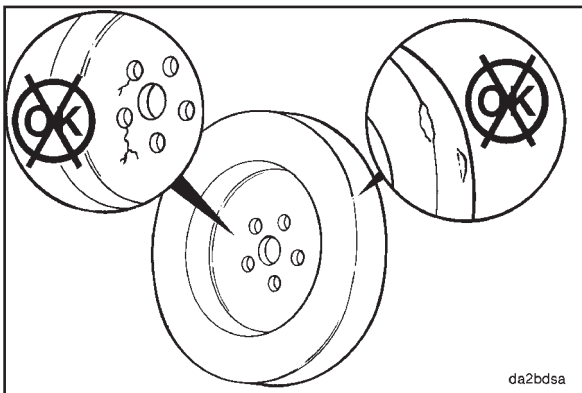
Inspect for Reuse (001-052-007)

⚠ CAUTION ⚠



The silicone fluid in the vibration damper will become solid after extended service and will make the damper inoperative. An inoperative vibration damper can cause major engine or drive line failures.

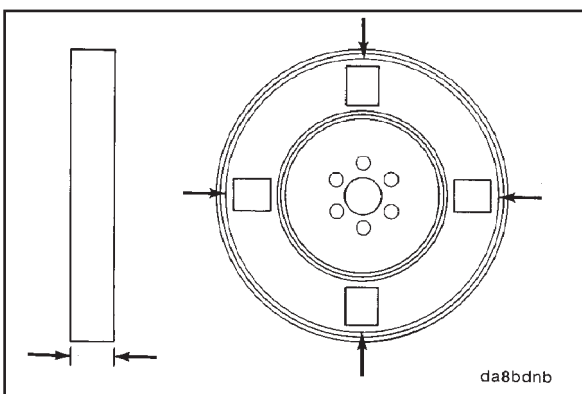
Check the vibration damper for evidence of fluid loss, dents, and wobble. Visually inspect the vibration damper thickness for any deformation or raising of the damper front cover plate.



Check the mounting web for cracks.

Check the housing for dents or raised surfaces.

Replace the damper if any of these defects are identified.



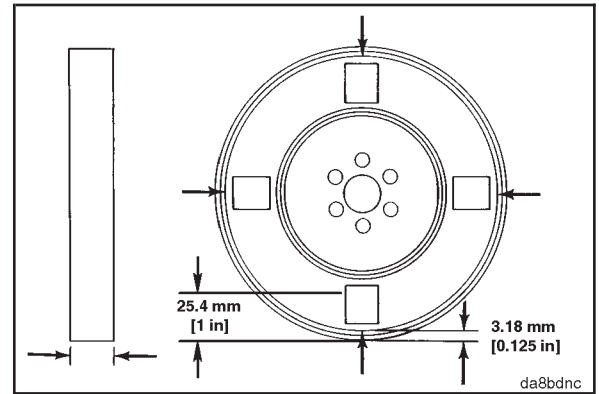
Remove the paint from four locations on either side of the damper.

Measure and record the vibration damper thickness at two points at each of the four locations.

- Measure the thickness at 3.18 mm [0.125 in] from the outer lip.
- Measure the thickness at 25.4 mm [1.0 in] from the outer lip.

NOTE: This procedure will result in a total of eight measurements.

If the variations between any of the eight measurements exceeds 0.25 mm [0.010 in], or if the thickness at any point exceeds 45 mm [1.772 in], replace the vibration damper.



To check for oil leaks, spray the damper with crack detection developer, Part No. 3375434.

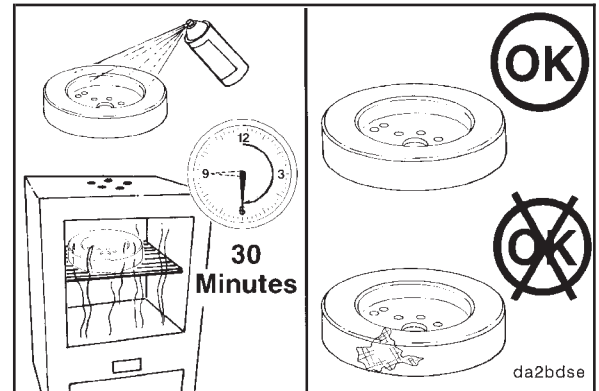


Use insulated gloves, Part No. 3823730, when handling heated parts. Hot parts can cause serious personal injury.

Heat the damper in an oven, rolled lip side down, for two hours.

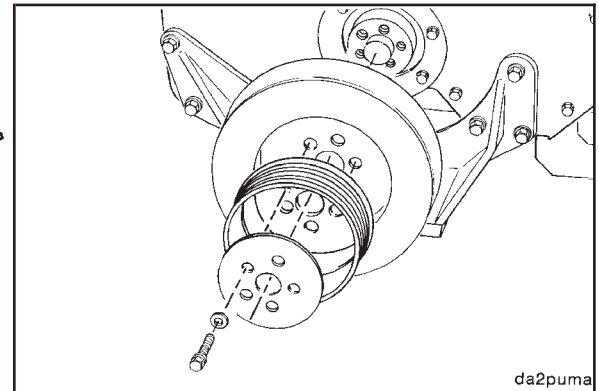
Temperature 93 °C [200 °F]

Replace the damper if oil leaks are found.

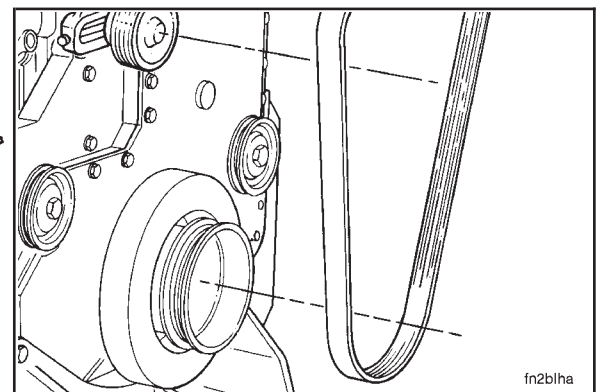


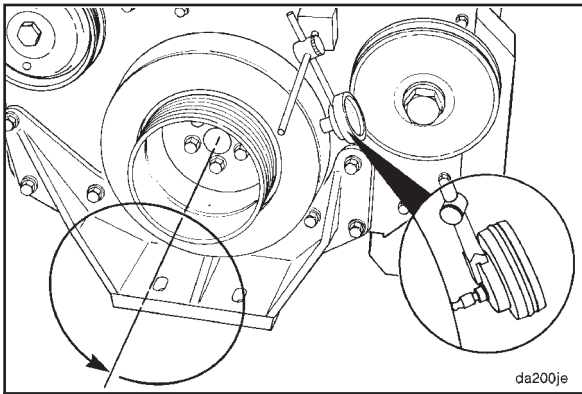
Install (001-052-026)

Install the vibration damper, crankshaft pulley and clamping plate. Refer to Procedure 001-022-026.



Install the fan drive belt. Refer to Procedure 008-002-026.





Eccentricity Check (001-052-064)

Clean the outside surface of the vibration damper.

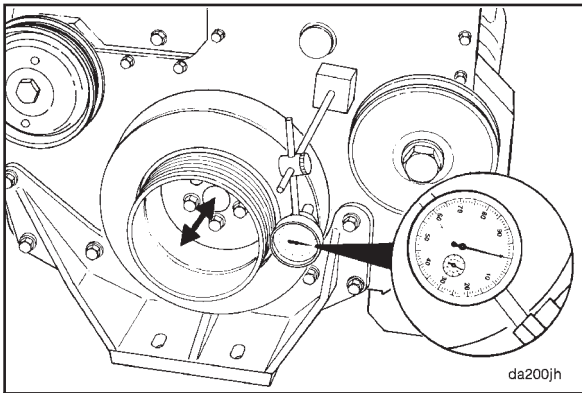


To measure damper eccentricity (out of round), install the dial indicator on the gear cover as indicated.



Rotate the crankshaft with the accessory drive shaft one complete revolution (360 degrees), and record the total indicator movement.

Replace the vibration damper if the eccentricity exceeds 0.28 mm [0.011 inch].



Wobble Check (001-052-065)

To measure wobble (face alignment), install the dial indicator as shown.

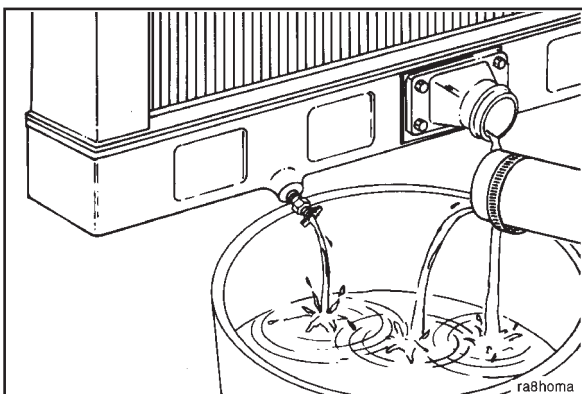
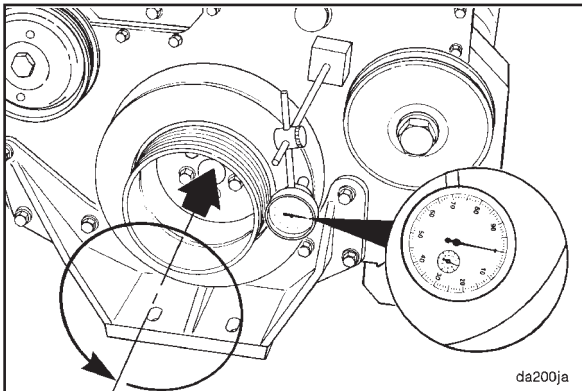
Push the crankshaft to the front or rear of the engine and "0" (zero) the indicator.



Rotate the crankshaft with the accessory drive shaft one complete revolution (360 degrees) while maintaining the position of the crankshaft either toward the front or the rear of the engine.

Record the total indicator movement.

Replace the damper if wobble exceeds 0.28 mm [0.011 inch].



Water Header Plate, Cylinder Block (001-053)



Remove (001-053-002)

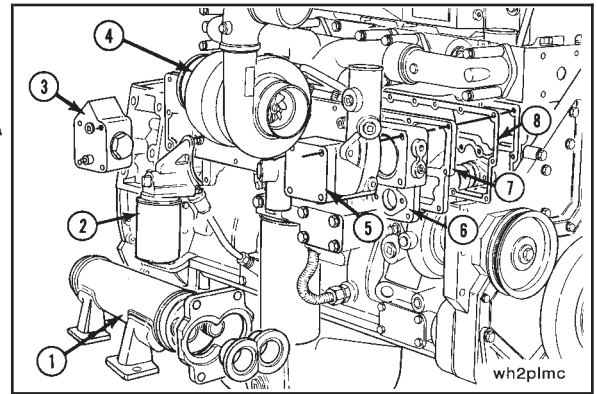
Drain the cooling system. Refer to Procedure 008-018-005.

Remove the intake piping.

Remove the alternator belt and the alternator. Refer to Procedures 013-005-002 and 013-001-002.

Remove the following components:

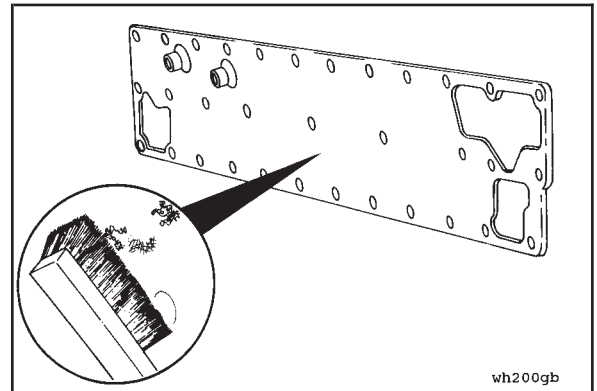
- Lubricating oil cooler (1), Procedure 007-003-002.
- Coolant filter and filter head (2), Procedure 008-007-002.
- Coolant heater housing (3), Procedure 008-011-002.
- Turbocharger (4), Procedure 010-033-002.
- Coolant thermostat housing (5), Procedure 008-014-002.
- Coolant thermostat housing support (6), Procedure 008-015-002



Remove the water header plate (7) and gasket (8).

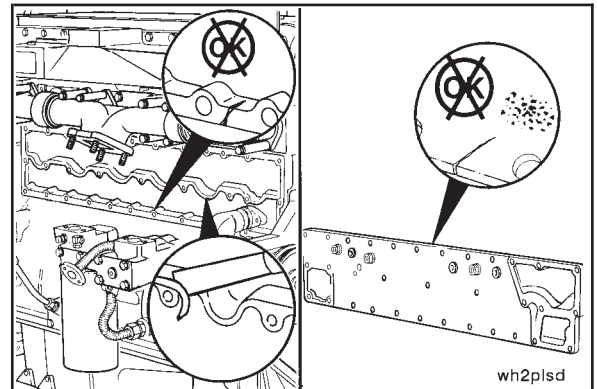
Clean (001-053-006)

Use a wire brush and a gasket scraper to clean the water header plate and the cylinder block gasket surface.



Inspect for Reuse (001-053-007)

Visually inspect the water header plate and the cylinder block gasket surface for cracks or other damage.



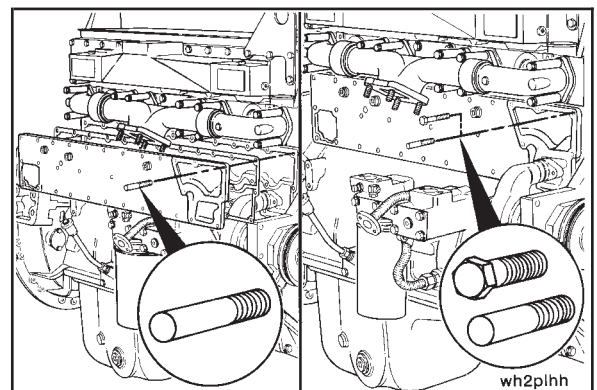
Install (001-053-026)

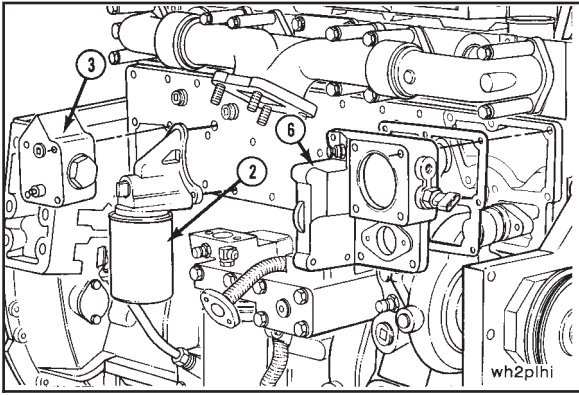
Install two guide pins, Part No. 3376488, in the top row of the water header plate mounting capscrew holes.

Use a new gasket and install the water header plate and capscrews.

Remove the two guide pins and install the other two capscrews.

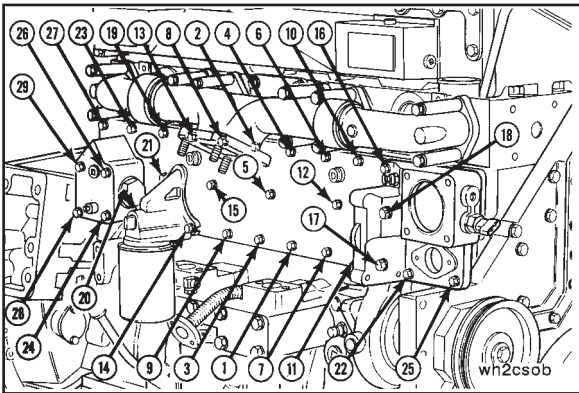
NOTE: The capscrews are **not** tightened to their final value until all related components are installed.





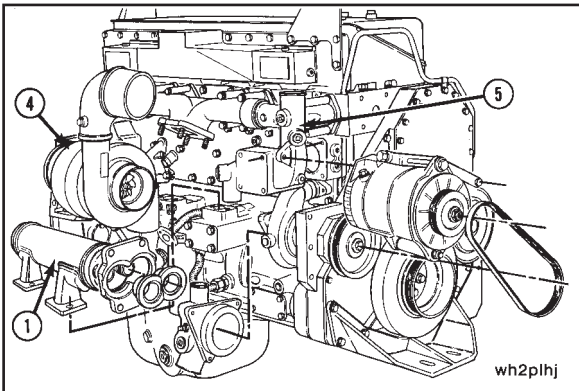
Install the following components:

- Coolant heater housing (3), Procedure 008-011-026.
- Coolant filter head and filter (2), Procedure 008-007-026.
- Coolant thermostat housing support and gasket (6), Procedure 008-015-026.



Tighten all capscrews in the sequence shown.

Torque Value: 54 N•m [40 ft-lb]

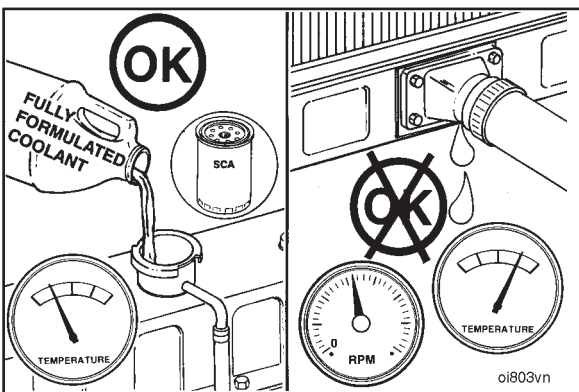


Install the following components:

- Lubricating oil cooler (1), Procedure 007-003-026.
- Turbocharger (4), Procedure 010-033-026.
- Coolant thermostat housing (5), Procedure 008-014-026.

Install the intake piping.

Install the alternator and alternator belt. Refer to Procedures 013-001-026 and 013-005-026.



Fill the cooling system. Refer to Procedure 008-018-028.

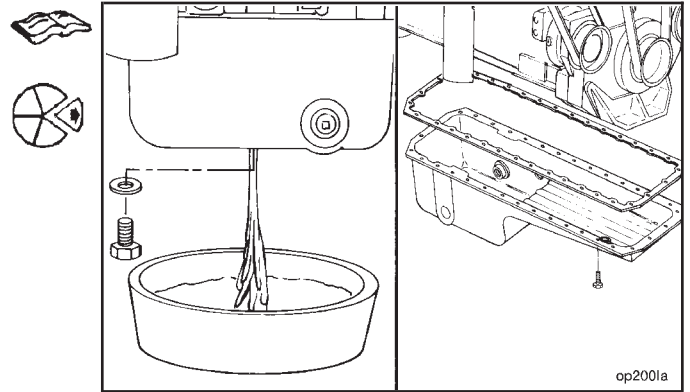
Operate the engine until it reaches a temperature of 80°C [180°F] and check for coolant leaks.

Piston and Connecting Rod Assembly (001-054)

Remove (001-054-002)

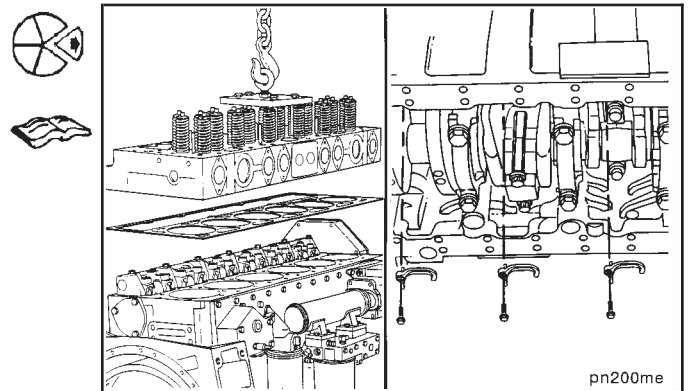
Drain the lubricating oil. Refer to Procedure 007-025-005.

Remove the lubricating oil pan. Refer to Procedure 007-025-002.



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

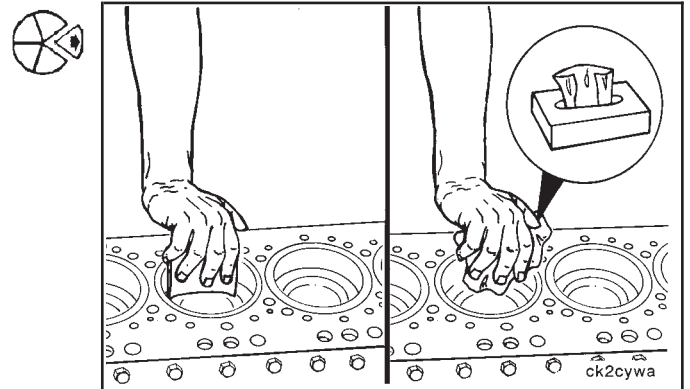
Remove the piston cooling nozzles. Refer to Procedure 001-046-002.



⚠ CAUTION ⚠

Do not use emery cloth or sandpaper to remove carbon from the cylinder liners. Aluminum oxide or silicon particles from emery cloth or sand paper can cause serious engine damage. Do not use any abrasives in the ring travel area. The cylinder liner can be damaged.

Use a fine fibrous abrasive pad such as Scotch-Brite® 7448, Part No. 3823258 or equivalent, and solvent to remove the carbon.

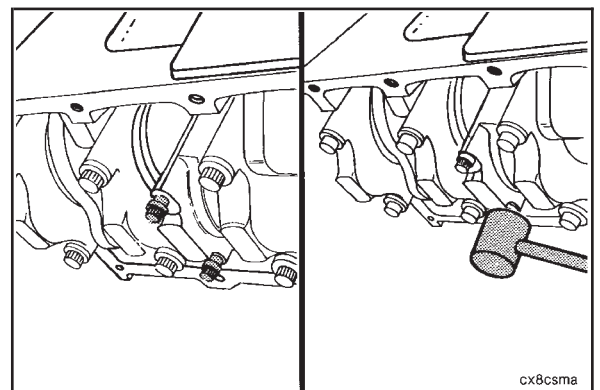


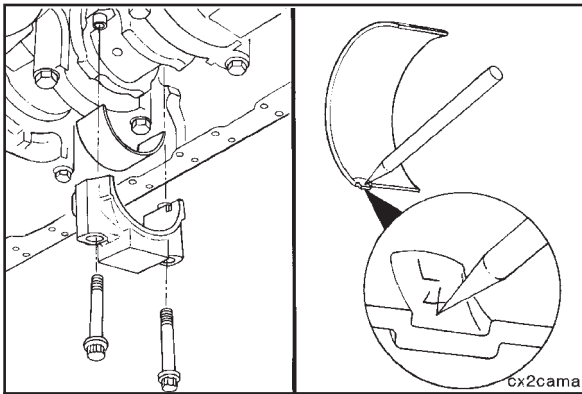
Rotate the crankshaft to position the rod caps at bottom dead center (BDC) for removal.

Loosen the connecting rod capscrews.

NOTE: Do not remove the capscrews from the rods at this time.

Use a rubber hammer to hit the connecting rod capscrews to loosen the caps from the dowel rings.





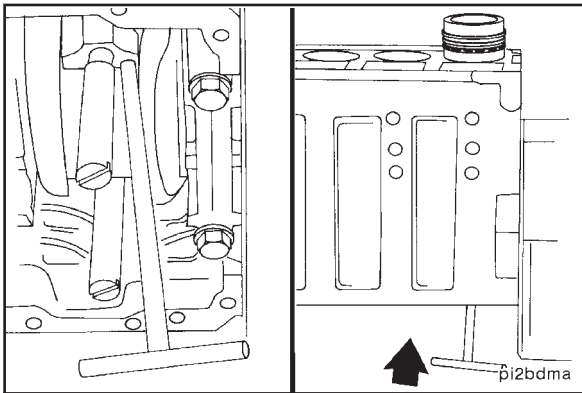
Remove the connecting rod capscrews.

Remove the rod caps.

Remove the lower rod bearings.

Mark the cylinder number and the letter "L" (lower) in the flat surface of the bearing tangs.

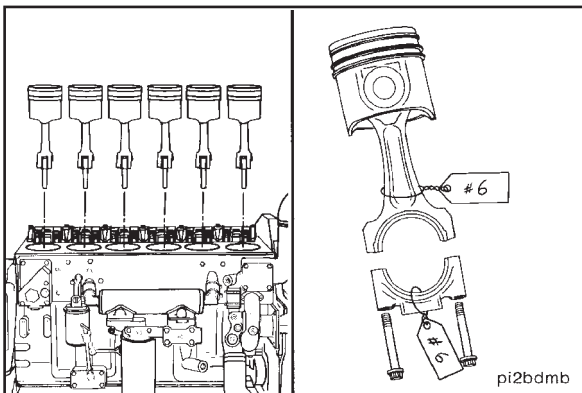
NOTE: Some M11 CELECT™ engines were built without drilled connecting rods, and without bearings with an oil hole in the upper bearing shell. Beginning in the fall of 1995, all M11 engines are built with drilled connecting rods and bearings with an oil hole in the upper bearing shell.



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

Use a "T-handle" piston pusher to push the rod away from the crankshaft.

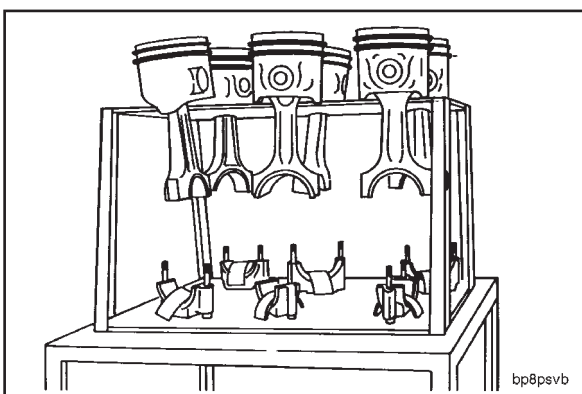
Push the rod until the piston rings are outside of the top of the cylinder liner.



Use both hands to remove the piston and rod assembly.

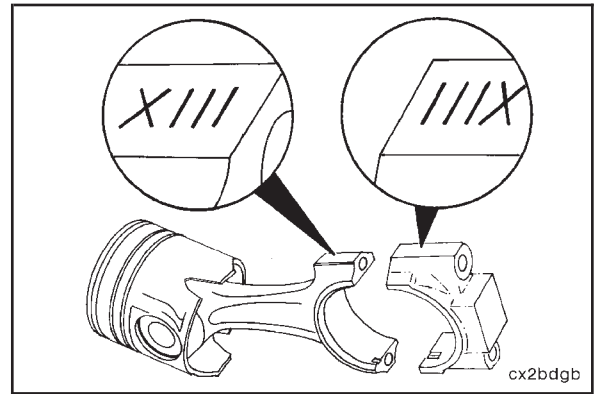
The piston and connecting rod assemblies **must** be installed in the same cylinder number they were removed from to ensure proper fit of worn mating surfaces if parts are used again.

Use a tag to mark the cylinder number each piston and rod assembly was removed from.



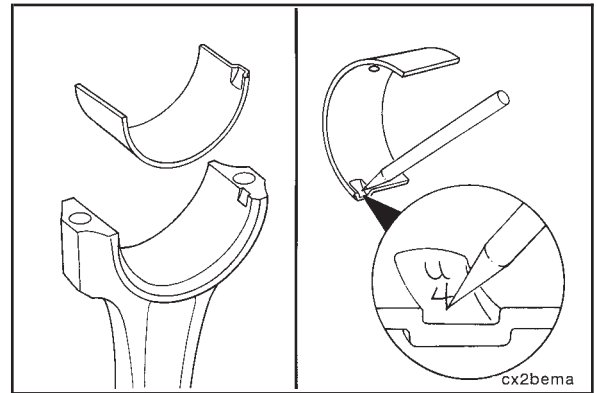
Place the rod and piston assemblies in a container to protect them from damage.

A unique number (not cylinder number) is stamped on the connecting rod and matching cap. When the rods and caps are installed in the engine, the numbers on the rods and caps **must** match and be installed on the same side of the engine.



Remove the upper rod bearing.

Mark the cylinder number and the letter "U" (upper) in the flat surface of the bearing tang.

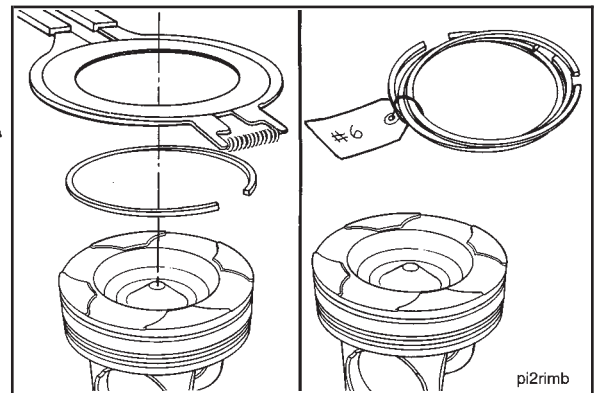


Disassemble (001-054-003)

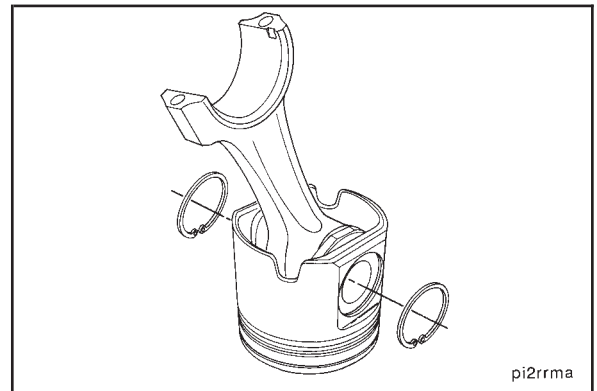
Use piston ring expander, Part No. ST-821, to remove the piston rings.

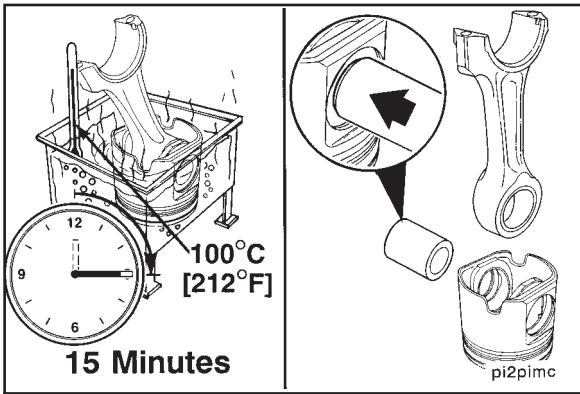
Place a tag on the rings and record the cylinder number of the piston on the tag.

NOTE: Refer to Procedure 001-047 for piston ring inspection.



Use internal snap ring pliers to remove the snap rings from both sides of the piston.



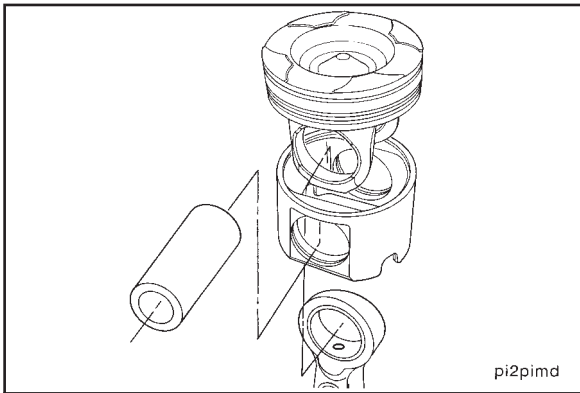


⚠ CAUTION ⚠

Do not use a hammer to remove the piston pins. The piston can distort causing it to seize in the liner.

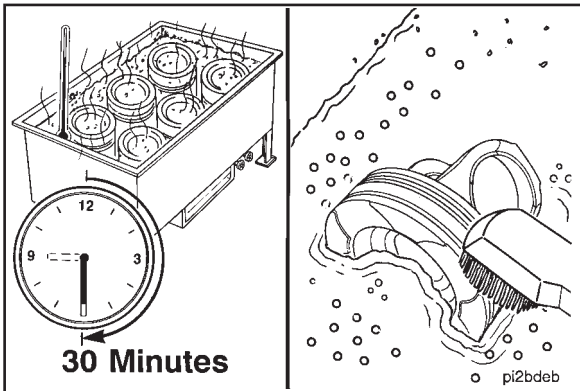
If the piston pin **cannot** be easily removed by hand:

- Install the piston and rod assembly in a container of water.
- Heat the piston in boiling water for 15 minutes.
- Use a blunt tool to push the piston pin from the piston and rod assembly.



NOTE: When the piston pin is removed from an articulated piston, the skirt will separate from the crown. Use care to prevent damage to the piston.

Mark the cylinder number the piston, crown, skirt, and pin was removed from on the parts to **make sure** they are installed in the correct cylinder if they are used again.



Clean (001-054-006)

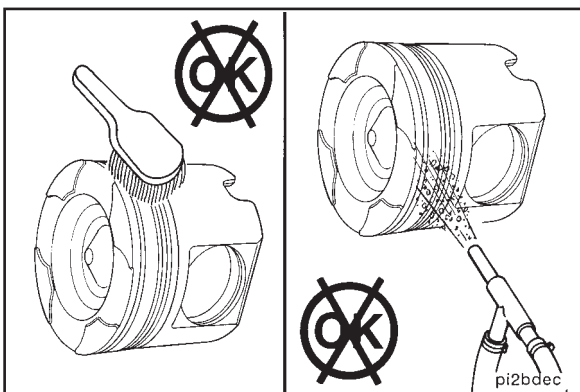
⚠ CAUTION ⚠



Be sure the cleaning solvent is approved for aluminum. Damage to the pistons can result if the wrong solution is used.

Allow the pistons to soak for a minimum of 30 minutes in a tank containing an approved cleaning solvent for aluminum.

Use a hot soapy solution and a non-metallic brush to remove carbon deposits.



⚠ CAUTION ⚠

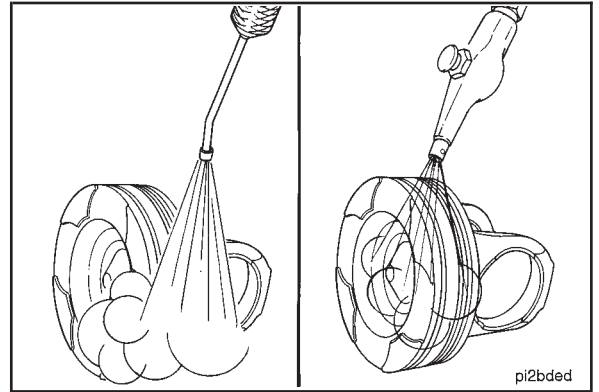
Do not use a metal brush. A metal brush will damage the piston ring grooves. Do not use glass beads to clean the grooves. Walnut shell or plastic bead, Part No. 3822735, blasting can be used on ring grooves on the dome or crown of the piston. Use the minimum effective pressure and do not concentrate the spray in one area for an extended period of time. The recommended blast pressure for plastic bead blasting is 276 kPa [40 psi]. Do not use glass beads or walnut shell blasting on the aluminum piston pin bores or articulated piston skirts. This can cause piston pin bore damage.

⚠ WARNING ⚠

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

Use steam to clean the pistons.

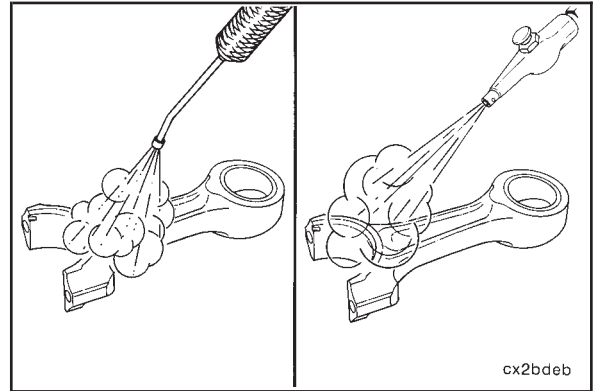
Dry with compressed air.



⚠ WARNING ⚠

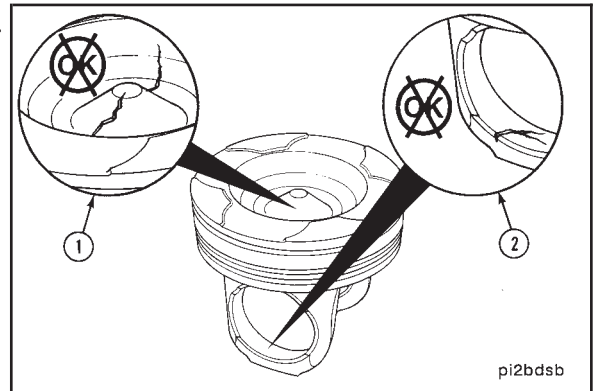
When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

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

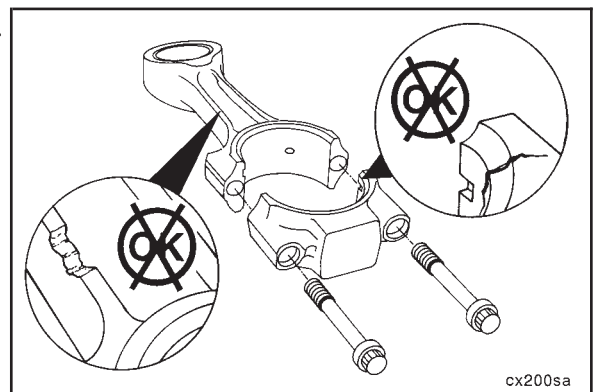


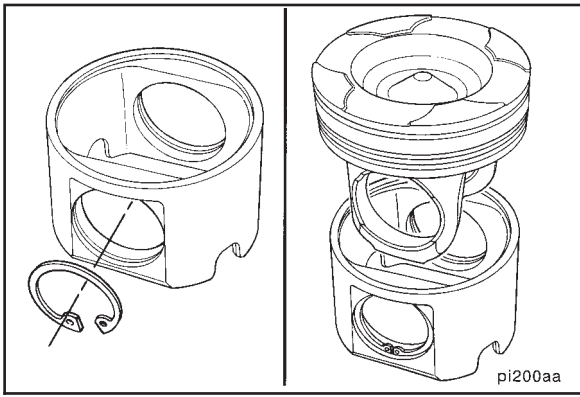
Inspect for Reuse (001-054-007)

Refer to Procedure 001-043-007 for inspection specifications for M11 pistons.



Refer to Procedure 001-014-007 for inspection specifications for M11 connecting rods.





Assemble (001-054-025)

CAUTION

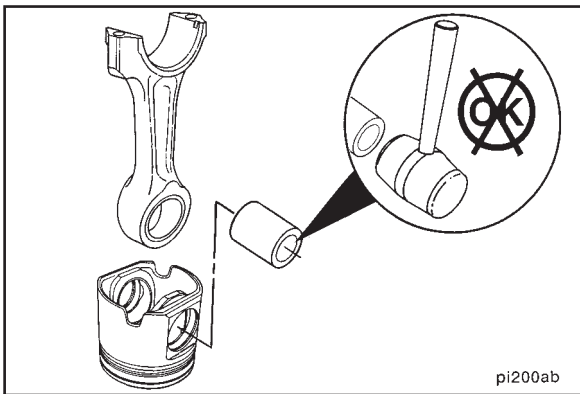
The retainer snap ring must be seated completely in the piston pin groove to prevent engine damage during engine operation.

Install a new snap ring in one piston pin bore of each piston skirt.

NOTE: If the pistons are being reused, the crown, skirt, and pin **must** be matched as they were when they were removed.

Position the skirt over the piston crown.

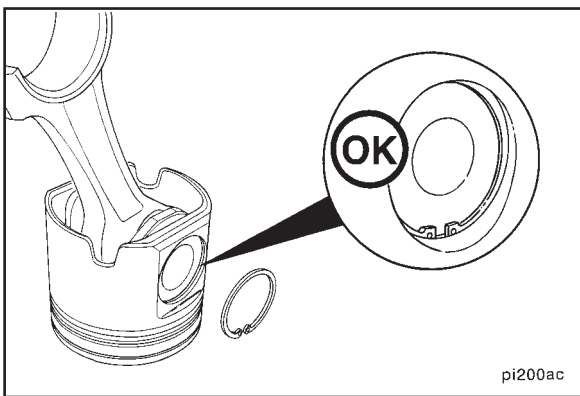
NOTE: It is **not** necessary to heat the articulated pistons before assembly. The piston pin is slip fit.



CAUTION

Do not use a hammer to install the piston pin. The piston can distort causing it to seize in the liner.

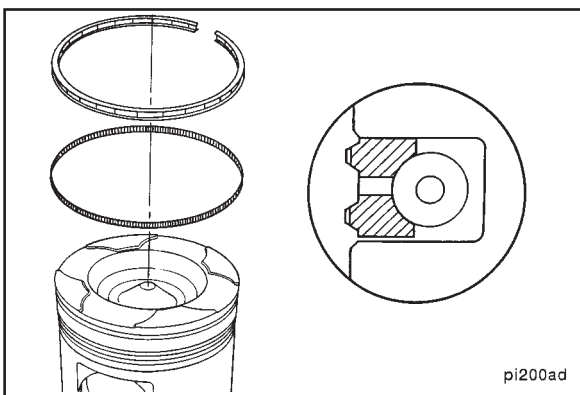
Align the pin bore of the rod with the pin bore of the piston skirt and crown, and install the piston pin.



CAUTION

The snap ring must be seated completely in the piston groove to prevent engine damage during engine operation.

Install a new snap ring in the piston pin bore.



A cross sectioned view of an oil control ring is shown.

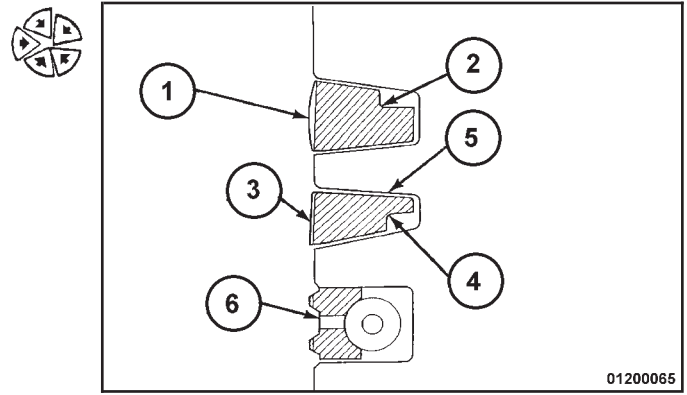
The two piece oil control ring **must** be installed with the expander ring gap 180 degrees from the gap of the oil ring. Do **not** overlap the ends of the expander ring.

Use piston ring expander, Part No. ST-821, to install the rings on the piston.

The top piston ring (1) is a positive twist design that has a cutback notch (2) on the top side of the ring.

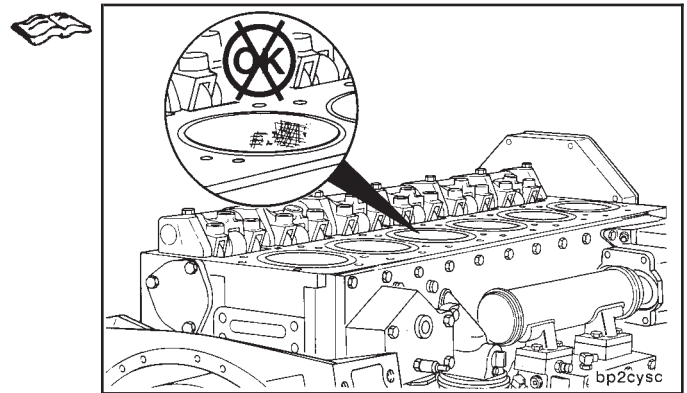
The intermediate ring (3) is a negative twist design with a cutback notch (4) on the bottom side and a two degree taper face. It also has a black phosphate coating (5) which helps to readily distinguish it from the top ring.

The oil control ring (6) is the bottom piston ring.



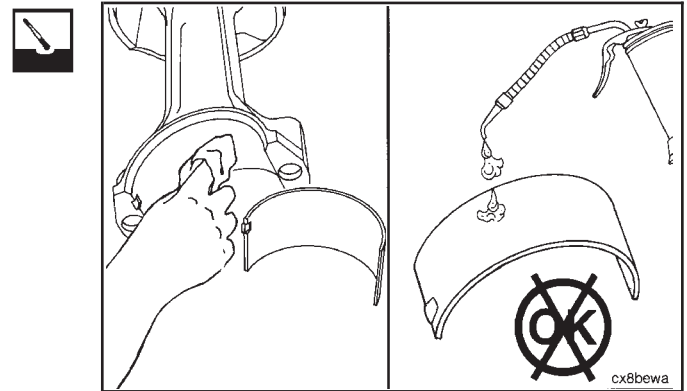
Install (001-054-026)

The cylinder block and all parts **must** be clean before assembly. Refer to Procedure 001-028-007 to inspect the cylinder liners for reuse.



Use a clean lint free cloth to clean the connecting rods and bearing shells.

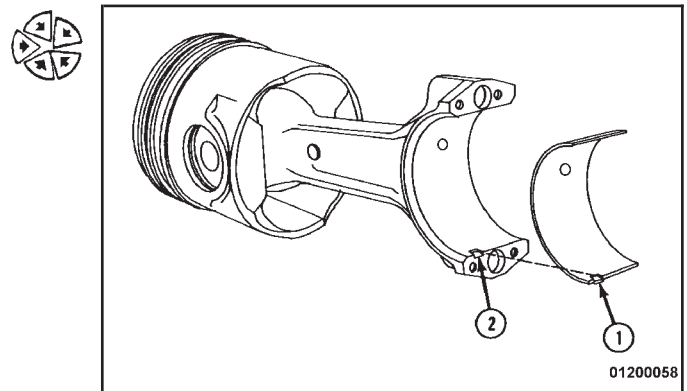
Do not lubricate the back side of the bearing shells. The operating clearance of the bearing will be reduced and the bearing can be damaged during engine operation.

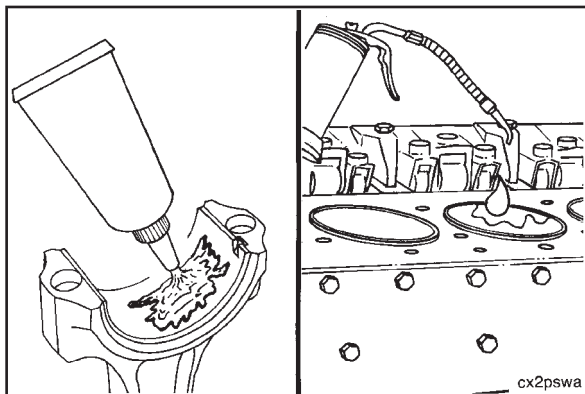


If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod from which they were removed.

Install the upper bearing shell into the connecting rod.

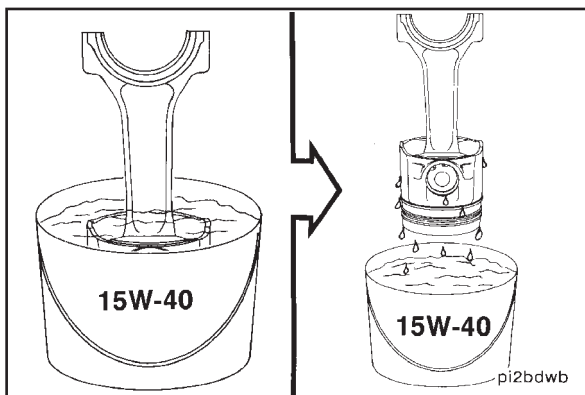
The tang of the bearing shell (1) **must** be in the slot of the rod (2). The end of the bearing shell **must** be even with the cap mounting surface.





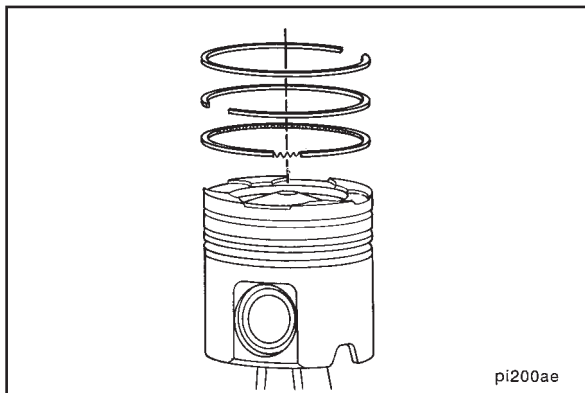
Use Lubriplate® 105, or equivalent, to coat the inside diameter of the bearing shell.

Apply a heavy film of clean 15W-40 oil to the liner.



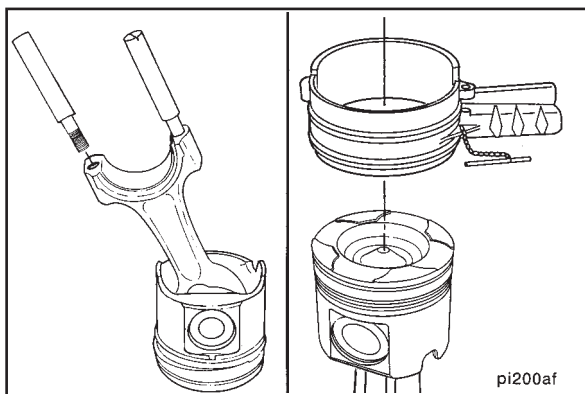
Install the piston and ring assembly in a container of clean 15W-40 oil.

Remove the piston and ring assembly from the container and let the excess oil drain from the piston.



Rotate the rings to position the ring gaps as shown.

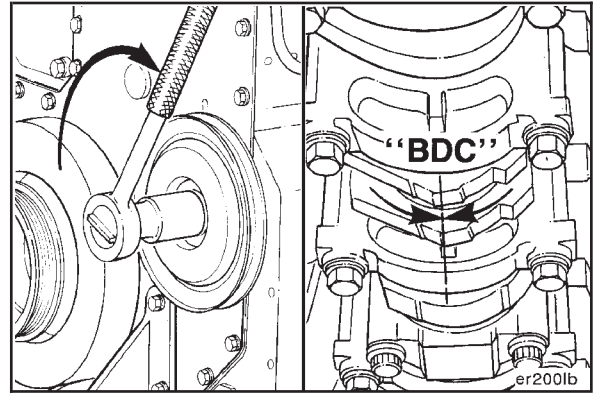
NOTE: The ring gap of each ring **must not** be aligned with the piston pin, or with any other ring. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.



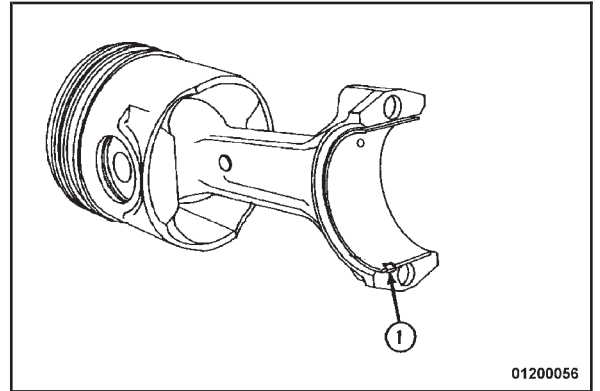
Install connecting rod guide pins, Part No. 3376038.

Use piston ring compressor, Part No. 3823309, to compress the rings.

Use the accessory drive pulley to rotate the crankshaft so the connecting rod journal of the connecting rod being installed is at bottom dead center.



Insert the connecting rod through the cylinder liner with the bearing tang (1) toward the camshaft side of the engine until the ring compressor contacts the top of the liner.

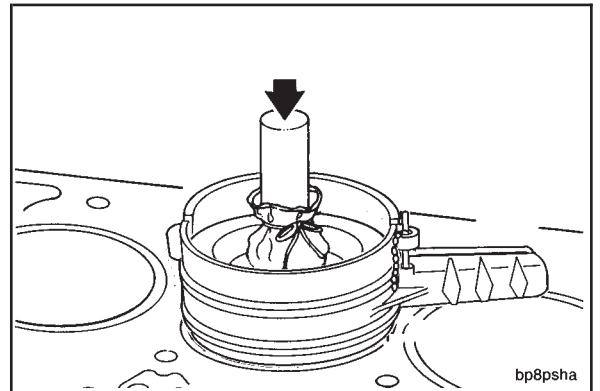


CAUTION

Do not use a metal drift to push the piston into the cylinder liner. The piston rings or cylinder liner can be damaged.

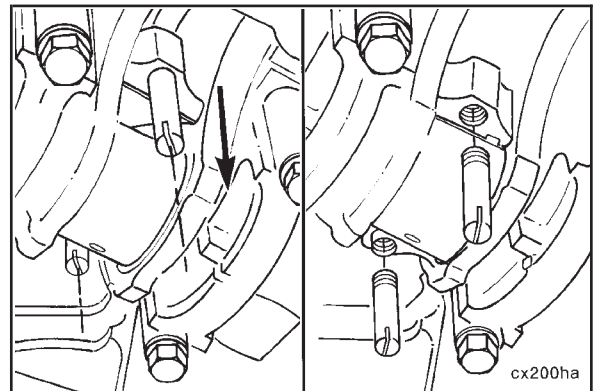
Hold the ring compressor against the cylinder liner. Push the piston through the ring compressor and into the cylinder liner. Push the piston until the top ring is completely in the cylinder liner.

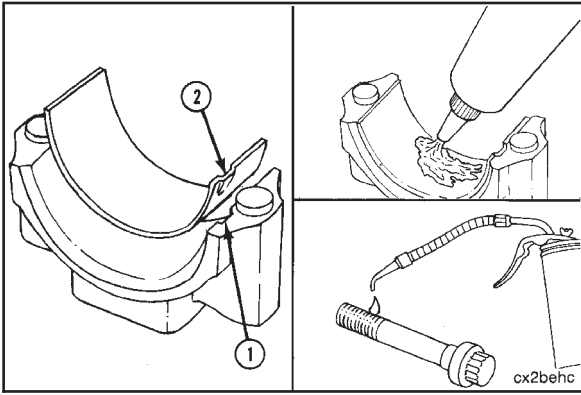
NOTE: If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.



Use the nylon guide pins to align the connecting rod with the crankshaft while pushing the piston and rod assembly in place.

Remove the nylon guide pins.





NOTE: If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod cap from which they were removed.

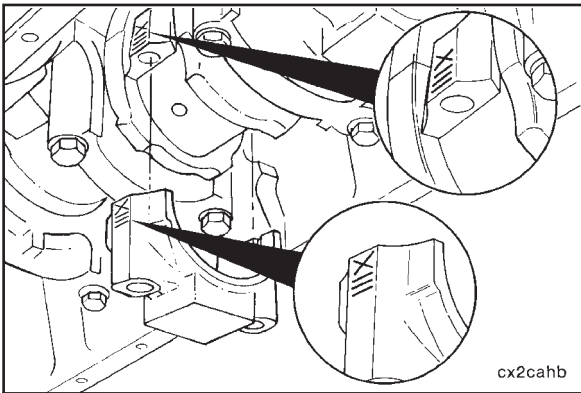


Install the bearing in the connecting rod cap.

The tang of the bearing (2) **must** be in the slot of the cap (1).

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

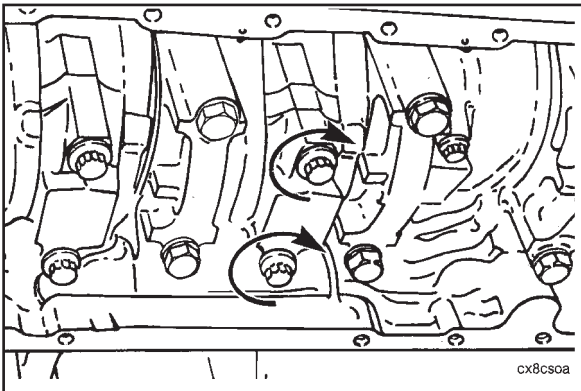
Use clean 15W-40 oil to lubricate the connecting rod capscrew threads.



The connecting rod and cap **must** have the same number and **must** be installed in the proper cylinder. The connecting rod cap number and rod number **must** be on the same side of the connecting rod to prevent engine damage during engine operation.

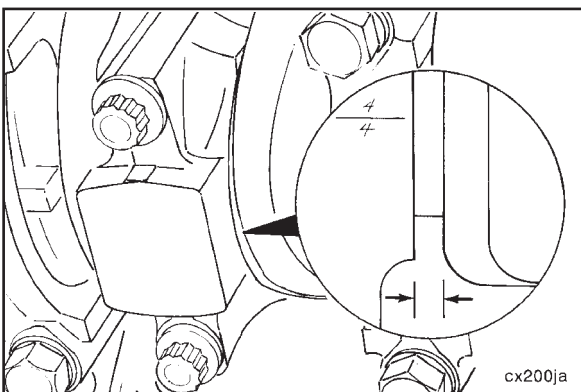


Install the connecting rod caps and capscrews.



Complete the following steps to tighten the rod capscrews in alternating sequence:

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

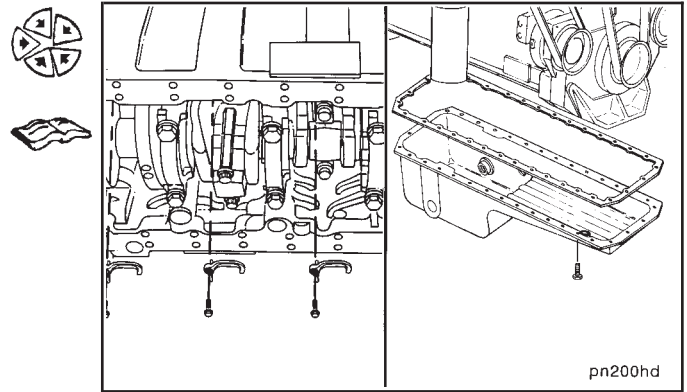


Measure the connecting rod side clearance. Refer to Procedure 001-014-026.

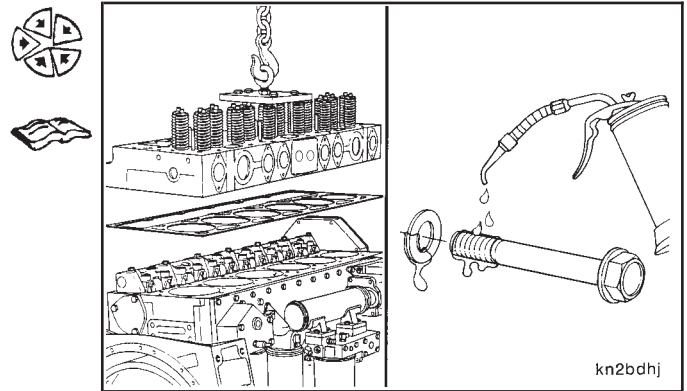


Install the piston cooling nozzles. Refer to Procedure 001-046-026.

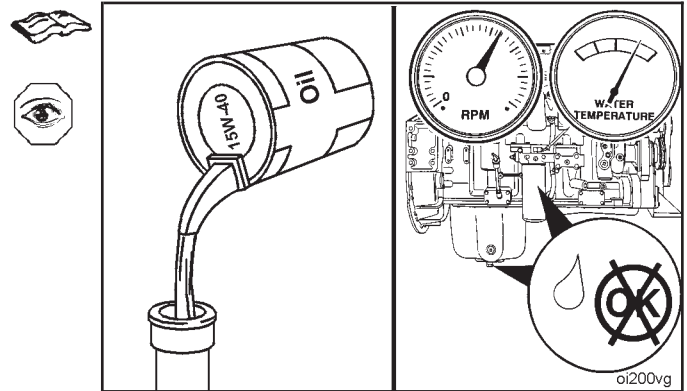
Install the lubricating oil pan. Refer to Procedure 007-025-026.



Install the cylinder head. Refer to Procedure 002-004-026.

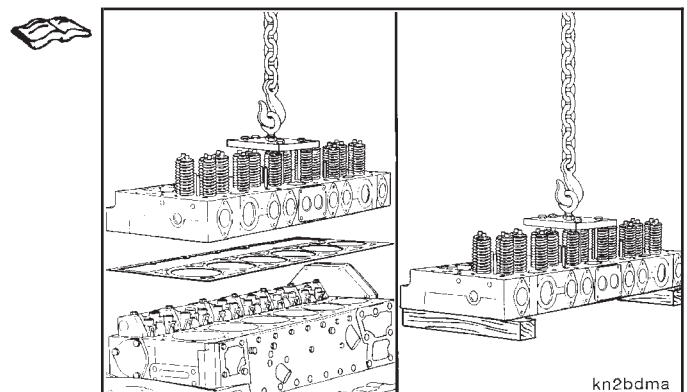


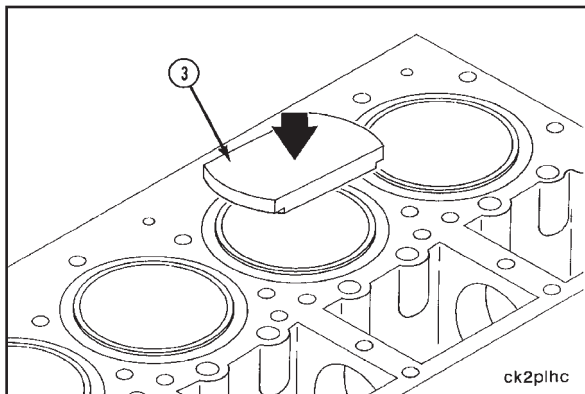
Fill the lubricating oil pan. Refer to Procedure 007-025-028.
Operate the engine to normal operating temperature and check for leaks.



Cylinder Liner Protrusion (001-064) Preparatory (001-064-000)

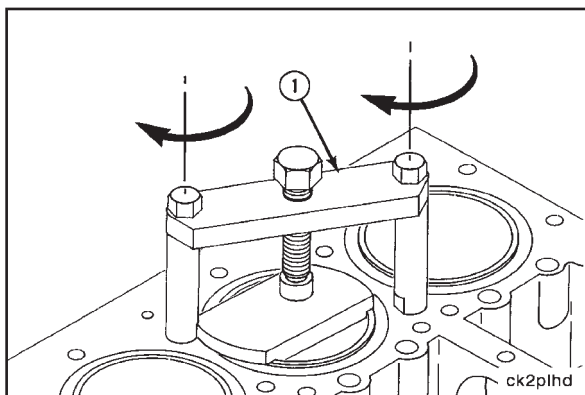
To measure the cylinder liner protrusion, the cylinder head **must** be removed. If the cylinder head is **not** removed, refer to Procedure 002-004-002 for instructions how to remove the cylinder head.



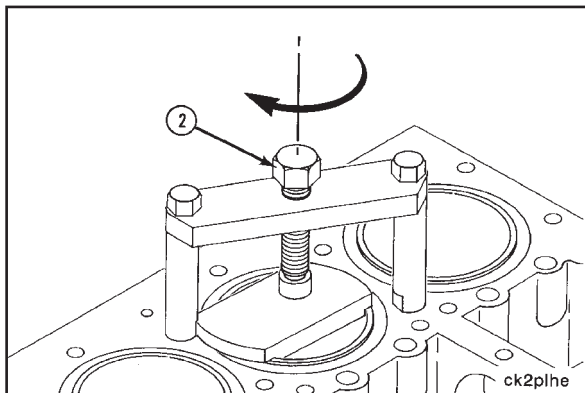


Use cylinder liner clamping tool, Part No. 3824272, to seat the liner in the cylinder block.

Place the force plate (3) across the top of the liner with the step inside the liner bore.



Put the installation tool bridge (1) across the liner and install the two cylinder head capscrews finger tight to hold the bridge down. Rotate the force plate until the areas where the protrusion measurements will be taken are exposed.



CAUTION

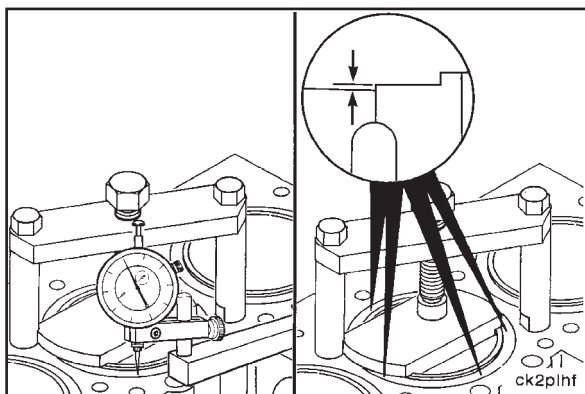
Do not use an impact wrench to tighten the liner force plate screw. Excessive torque will cause damage to the liner installation tool.



Tighten the forcing screw (2).

Torque Value: 136 N•m [100 ft-lb]

Check for correct protrusion.



Measure (001-064-010)

Use a depth gauge, Part No. 3823495, to measure the liner protrusion at four points 90 degrees apart.

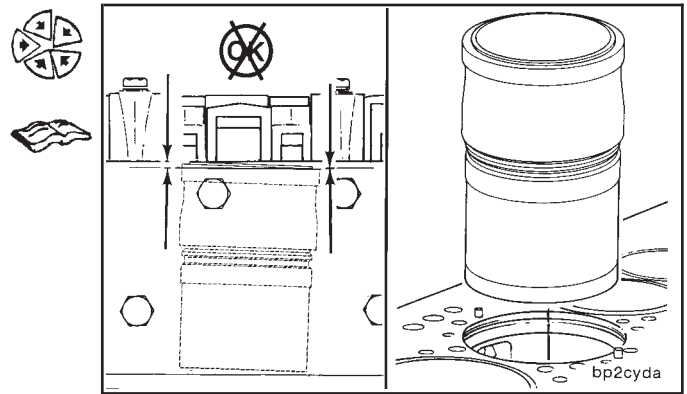
Cylinder Liner Protrusion		
mm		in
0.00	MIN	0.000
0.13	MAX	0.005

M11 Series
Section 1 - Cylinder Block - Group 01

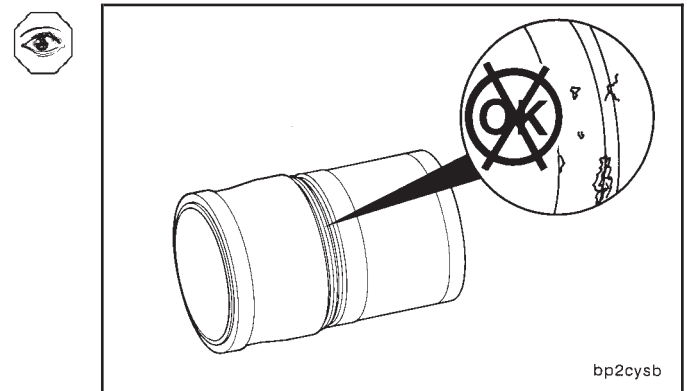
If the liner protrusion varies more than 0.025 mm [0.0010 inch] for each 180 degrees:

- Remove the liner.

NOTE: It will be necessary to remove the piston and connecting rod assembly, if this has not already been done, before removing the cylinder liner. Refer to Procedure 001-054-002.

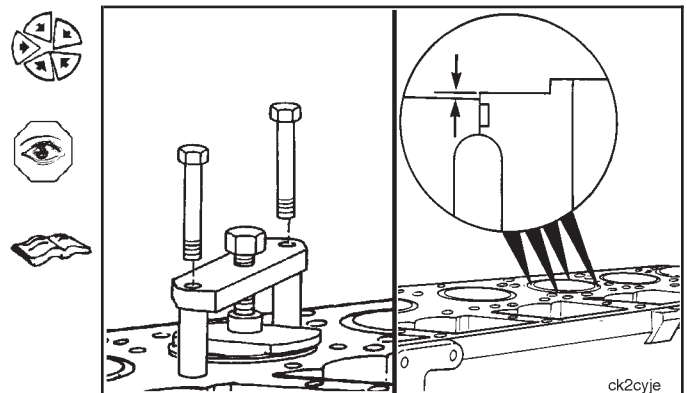


- Inspect the liner sealing edge for burrs, dirt or damage.
- Replace the liner if it is damaged.



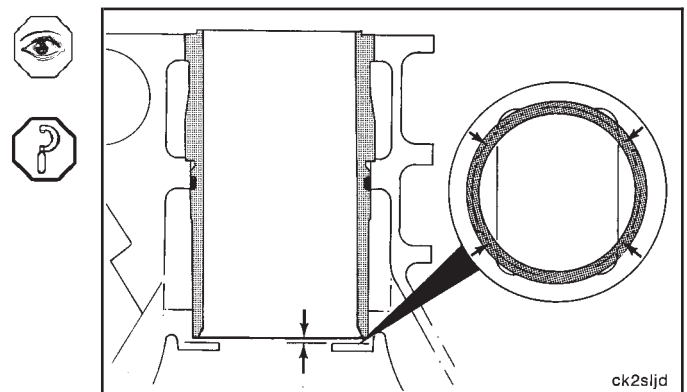
- Install the liner again.
- Inspect the liner protrusion.

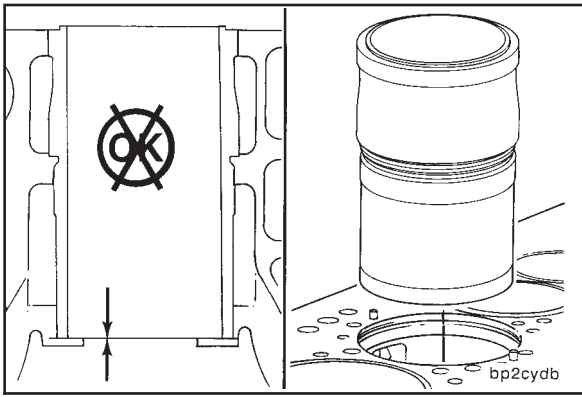
If the liner protrusion still does **not** meet the specifications, cut the cylinder block liner bore for shims. Refer to the Alternative Repair Manual, Bulletin No. 3810310, for the correct procedure.



Use a feeler gauge to inspect the liner to block clearance at the four block casting points.

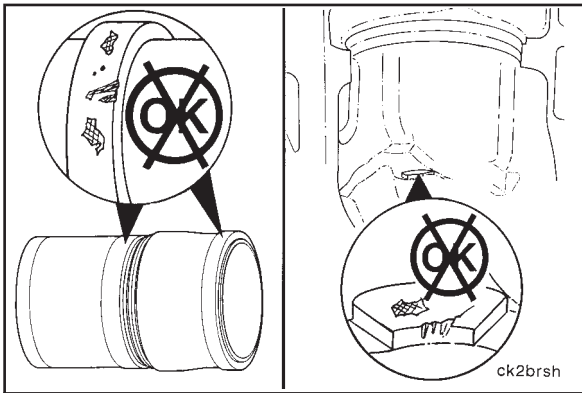
Cylinder Liner to Block Clearance		
mm		in
0.25	MIN	0.010



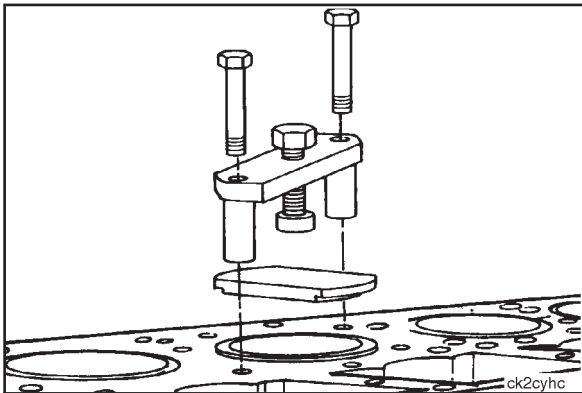


If the clearance is less than 0.25 mm [0.010 inch]:

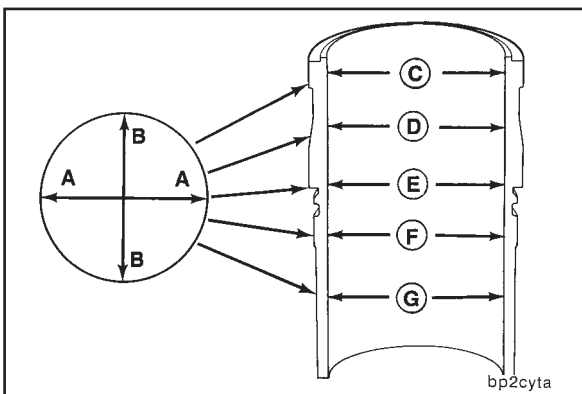
- Remove the liner.



- Inspect the liner and cylinder block for dirt or damage.



- Replace the liner if it is damaged.
- Install the liner again.



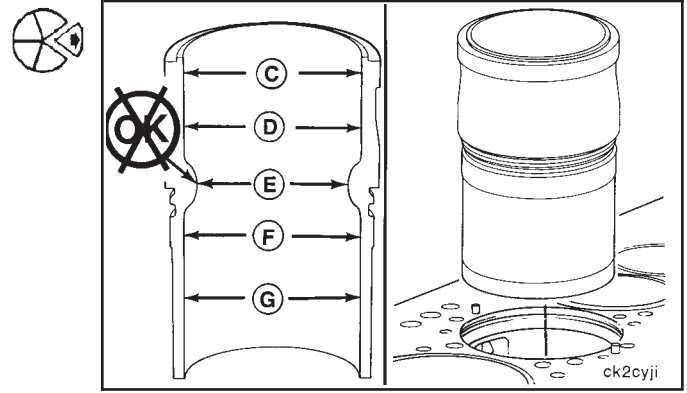
Measure the liner bore for out-of-roundness at points "C", "D", "E", "F" and "G". Measure each point in the direction "AA" and "BB". The bore **must not** be more than 0.10 mm [0.004 inch] out-of-round.

M11 Series
Section 1 - Cylinder Block - Group 01

If the liner bore is more than 0.10 mm [0.004 inch] out-of-round:

- Remove the liner so the cylinder block liner bore can be measured.

NOTE: The block counterbore diameters above and below the cylinder block counterbore area are **not** critical dimensions, and do **not** need to be measured.

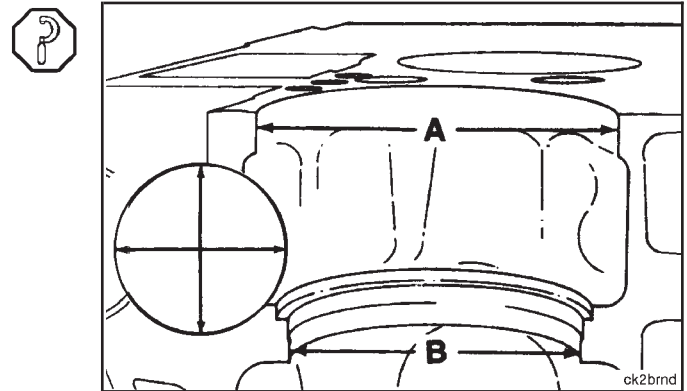


Measure the cylinder block upper liner bore (A).

Cylinder Block Upper Liner Bore ID (A)		
mm		in
145.900	MIN	5.7441
146.027	MAX	5.7491

Measure the cylinder block liner seal seat bore (B) 8.0 to 13.5 mm [0.32 to 0.53 inch] below the counterbore.

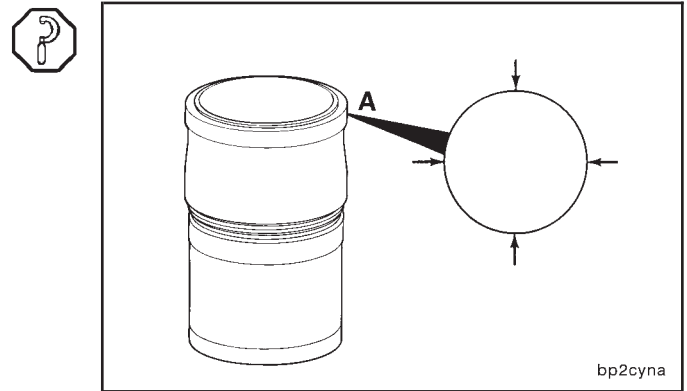
Cylinder Block Liner Seal Seat Bore ID (B)		
mm		in
138.063	MIN	5.4355
138.113	MAX	5.4375



Measure the liner outside diameter (A).

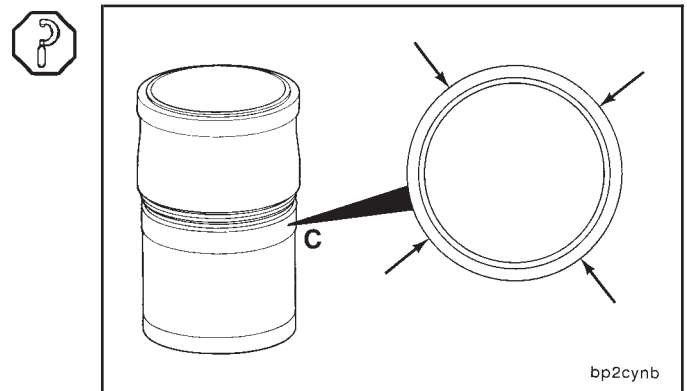
Cylinder Liner Top Press Fit OD (A)		
mm		in
145.938	MIN	5.7456
145.976	MAX	5.7471

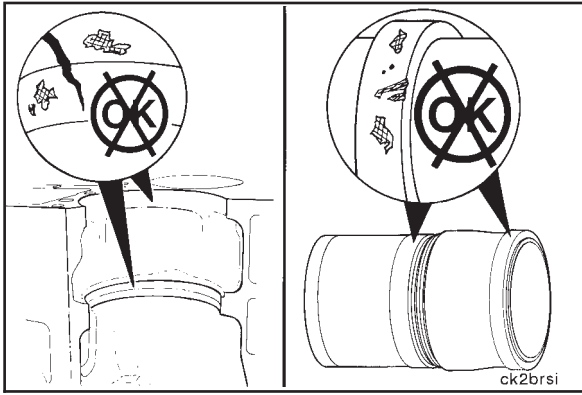
NOTE: The cylinder block liner counterbore flange diameter is **not** a critical dimension and does **not** need to be measured.



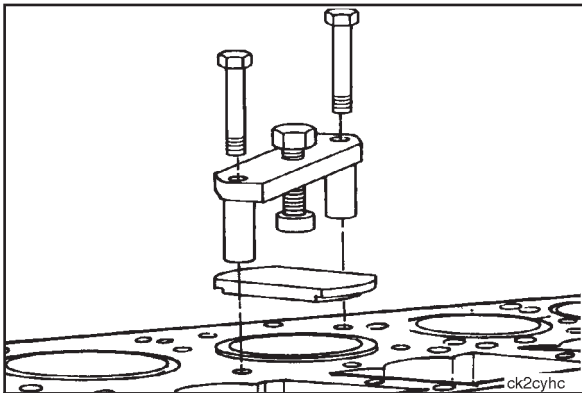
Measure the cylinder liner seal seat outside diameter (C).

Cylinder Liner Seal Seat O.D. (C)		
mm		in
137.937	MIN	5.4306
138.013	MAX	5.4336

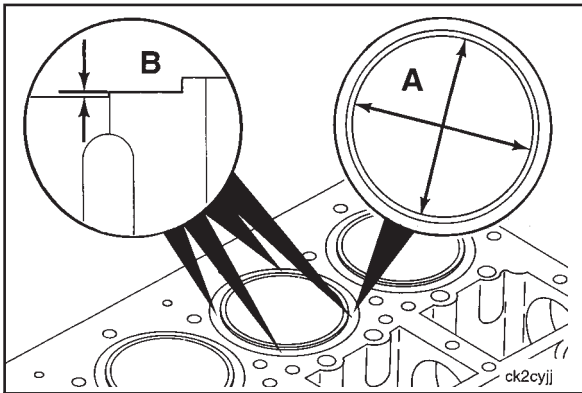




Inspect the cylinder block liner bore and liner for burrs, dirt or damage.



Replace the liner if it is damaged.



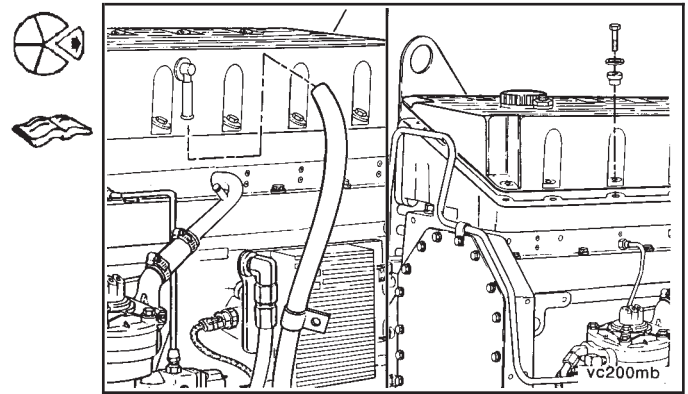
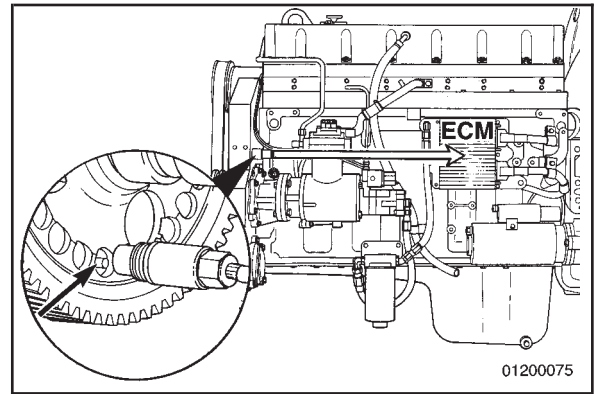
Inspect the liner bore (A) and protrusion again (B).
Replace the liner if it does **not** meet the specifications.

Camshaft End Clearance (001-065)

Measure (001-065-010)

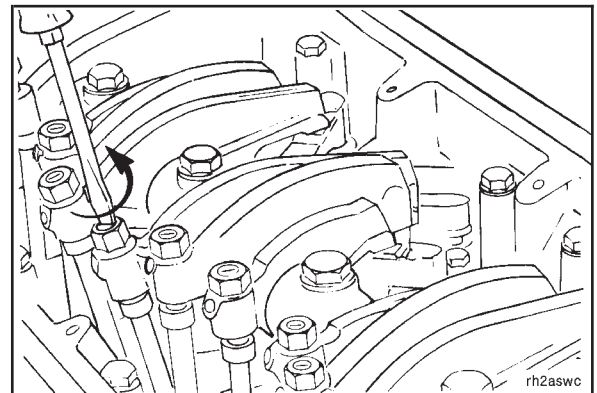
A condition on CELECT™ and CELECT™ Plus engines where the engine will not start or is difficult to start can be caused by excessive clearance between the engine position sensor and the pickup on the back of the camshaft gear. This condition prevents the engine position sensor from sending the necessary signal to the electronic control module. The excessive clearance can be caused by a failed thrust bearing on the camshaft. Use this procedure to measure the camshaft end clearance in-chassis on CELECT™ and CELECT™ Plus engines without removing the front gear cover. If the end clearance is **not** within the specifications given, the gear cover **must** be removed and the cause of the excessive end clearance repaired.

To measure the camshaft end clearance without removing the front gear cover, first remove the rocker lever cover. Refer to Procedure 003-011-002.



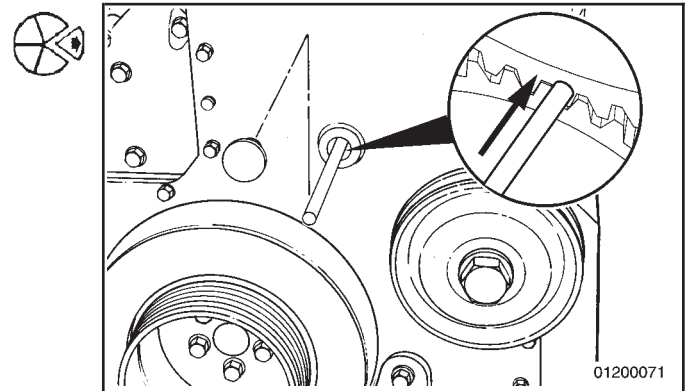
Loosen the locknut and turn out the adjusting screw on each injector and valve rocker lever. The overhead load on the camshaft **must** be released to allow free movement of the camshaft.

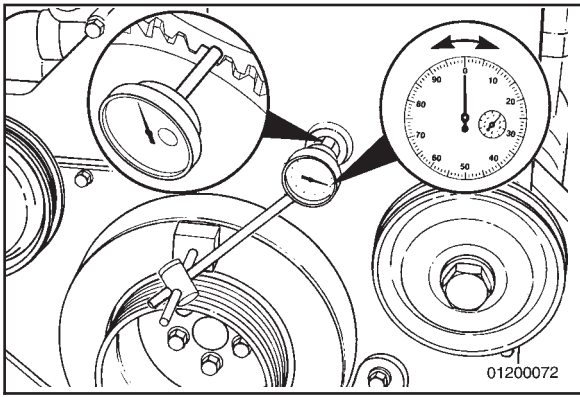
NOTE: It is **not** necessary to remove the push rods or push tubes.



Remove the inspection plug in the front of the gear cover.

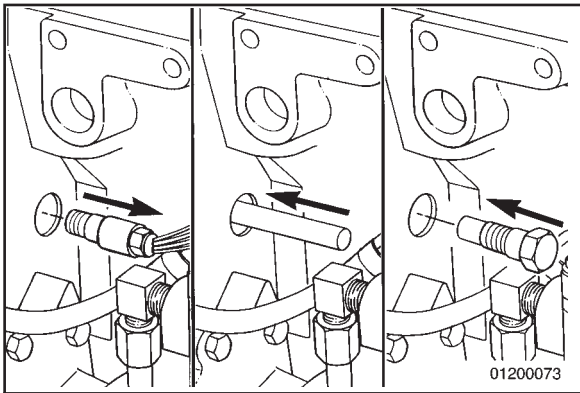
Use a rod against the camshaft gear to push the camshaft as far as possible towards the rear of the engine.





Setup a dial indicator gauge, Part No. 3376050, and extension, Part No. ST-537-4, with a magnetic base on the front of the cylinder head or vibration damper. Place the tip of the indicator on the face of the camshaft gear through the gear cover inspection hole.

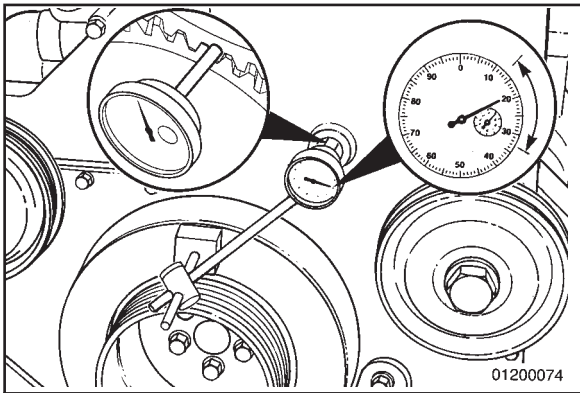
Set the dial indicator to zero.



Remove the engine position sensor from the rear of the gear housing.

Use a rod to reach inside the gear housing through the engine position sensor mounting hole and push the camshaft gear as far as possible toward the front of the engine.

NOTE: If access limits make it difficult to push the camshaft by hand, a threaded bolt (3/4 x 16) can be threaded into the hole and used as a pushing device against the back of the cam gear. The capscrew needs to have the threads ground off, approximately 25.4 mm [1 inch] back from the end. Although the hole is threaded clear through the gear housing, this will make sure the capscrew does **not** contact anything but the camshaft gear.

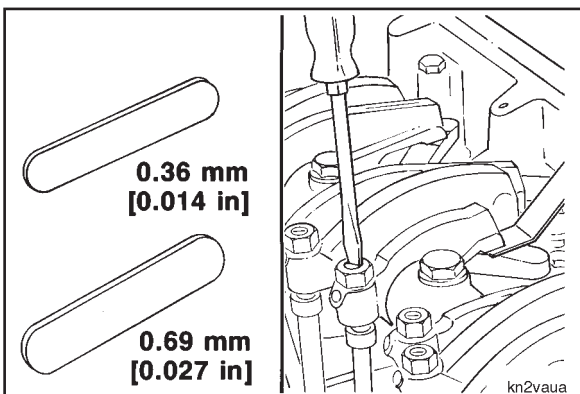


Record the measurement on the dial indicator.



Camshaft End Clearance		
mm		in
0.13	MIN	0.005
0.33	MAX	0.013

If the camshaft end clearance does **not** meet the above specifications, the front cover **must** be removed and the camshaft thrust plate inspected. Refer to Procedure 001-008.



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

Install the camshaft inspection plug in the gear cover.

Install the engine position sensor.

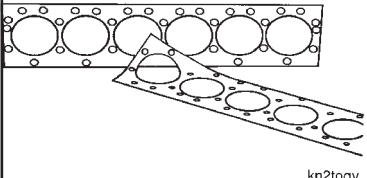
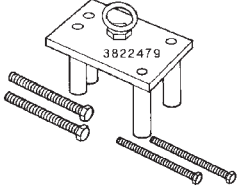
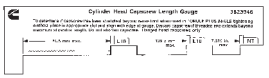
Section 2 - Cylinder Head - Group 02

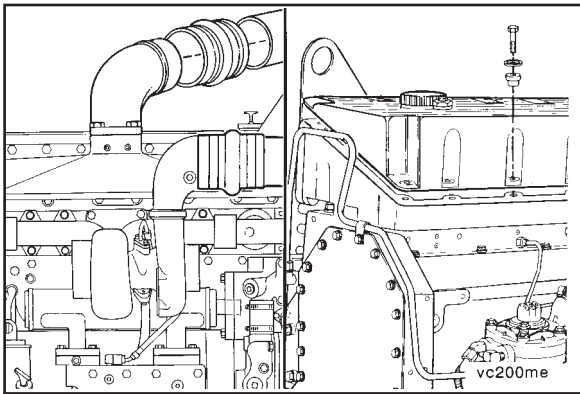
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Service Tools Cylinder Head

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

Tool No.	Tool Description	Tool Illustration
3376082	Cylinder Head Water Test Fixture Used to pressure test the cylinder head injector sleeves for leakage.	 <p style="text-align: right;">kn2togv</p>
3822479	Cylinder Head Lifting Bracket Used for lifting the cylinder head on and off the engine.	
3823546	Cylinder Head Capscrew Length Gauge Used to measure the length of the cylinder head mounting capscrews.	 <p style="text-align: right;">3823546</p>



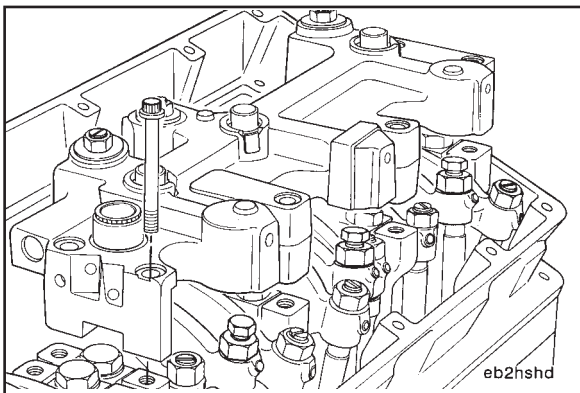
Cylinder Head (002-004)

Remove (002-004-002)

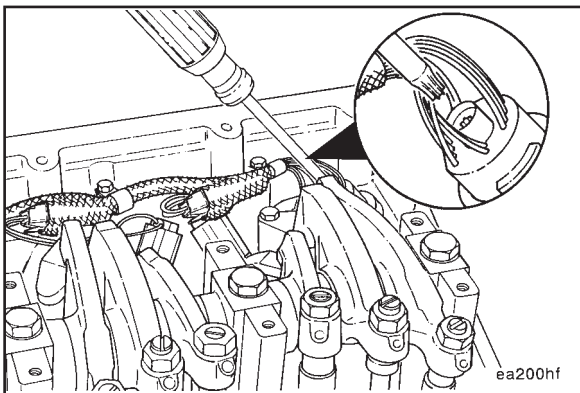


Remove the air piping from the intake manifold and the turbocharger.

Remove the rocker lever cover. Refer to Procedure 003-011-002.



Remove the engine brakes, if applicable. Refer to Procedure 020-001-002.

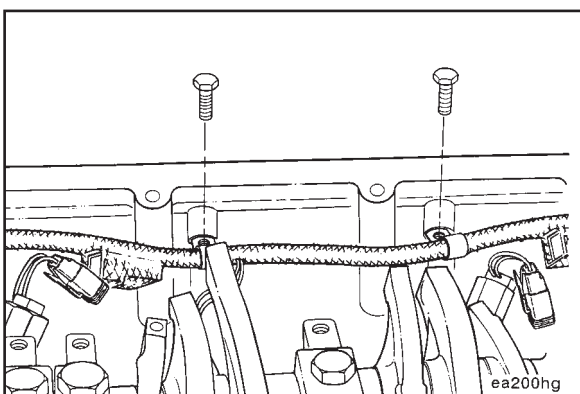


NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

The internal engine wiring harness is located under the rocker lever cover.

Remove the locking capscrew from the Metri-Pack 12-pin connector at the rear end of the rocker lever housing and separate the connector.

NOTE: The connector is held together with a Torx® (six pointed star) screw. Use a Torx® (size T-25) screwdriver to disconnect this connector.

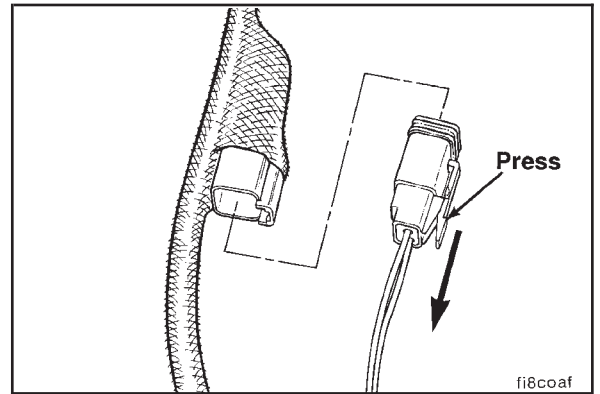


NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Remove the internal engine wiring harness holding clamp cap screws.

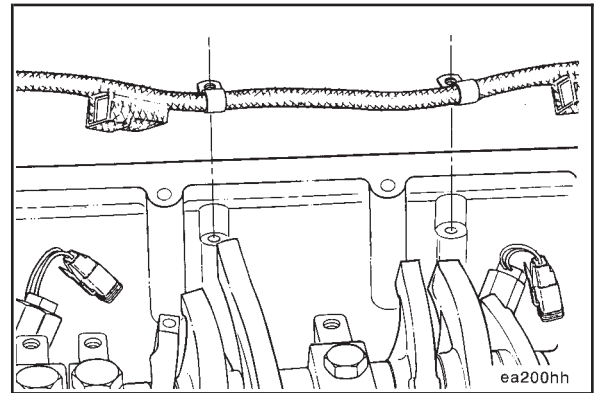
NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Separate the Deutsch 2-pin connectors from the internal engine wiring harness to the fuel injectors.



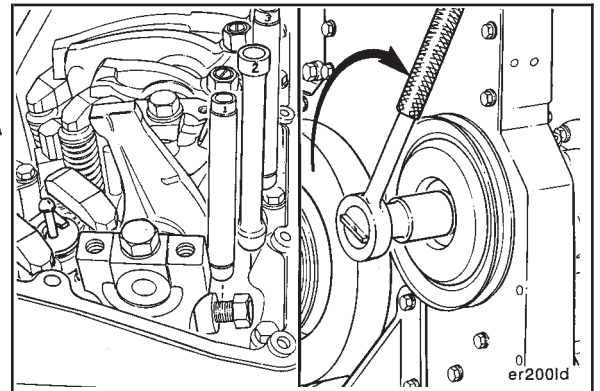
NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Remove the internal engine wiring harness from the engine.

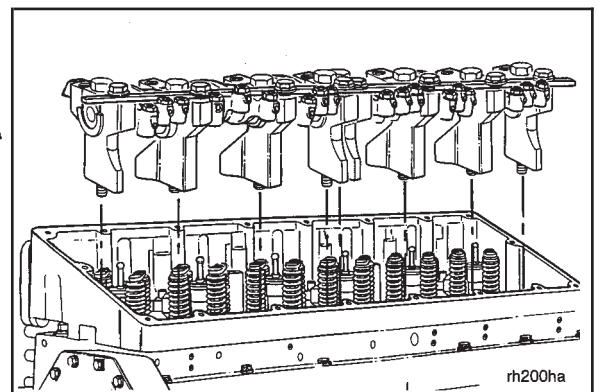


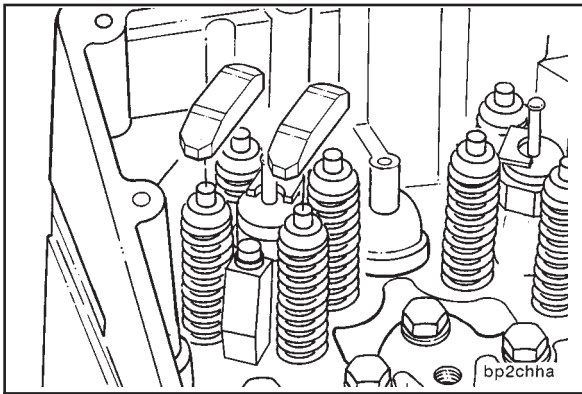
Remove the push tubes and push rods. Refer to Procedure 004-014-002.

NOTE: Mark the position of the crossheads as they are removed. The crossheads **must** be installed in the same position when the engine is assembled.



Remove the rocker lever assemblies. Refer to Procedure 003-009-002.

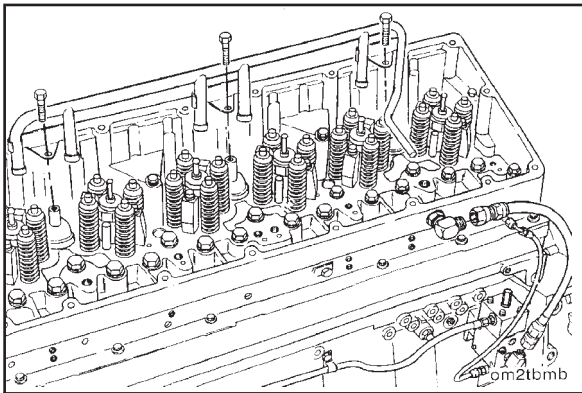




Remove the crossheads.

Number each crosshead with the cylinder number and position as it is removed.

NOTE: Each crosshead **must** be installed in the same position as it was removed when the engine is assembled.



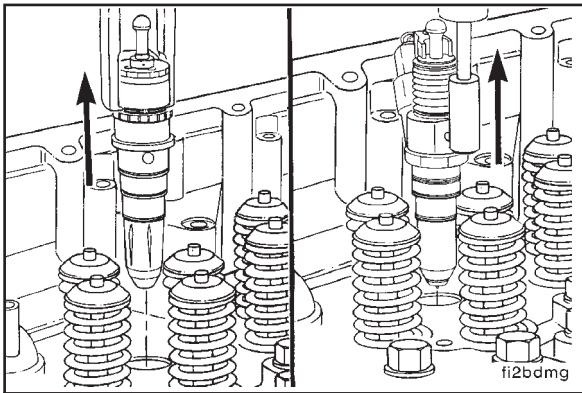
NOTE: This action applies to STC engines only.

Remove the oil supply line from the STC control valve to the STC oil manifold connection on the side of the rocker housing.

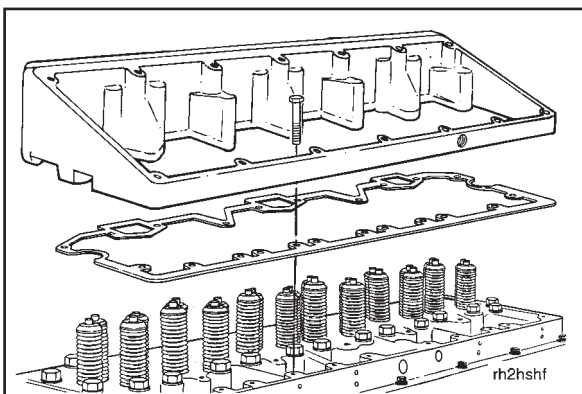
Remove the elbow from the rocker lever housing.

Remove the three STC oil manifold mounting capscrews from inside the rocker lever housing.

Remove the STC oil manifold.



Remove the injectors. Refer to Procedure 006-026-002.

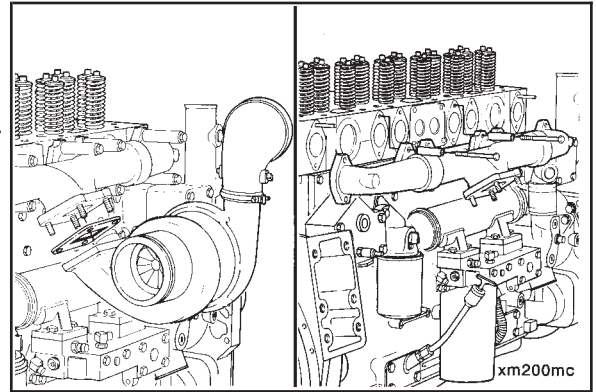


Remove the rocker lever housing. Refer to Procedure 003-013-002.



M11 Series
Section 2 - Cylinder Head - Group 02

Remove the turbocharger. Refer to Procedure 010-033-002.

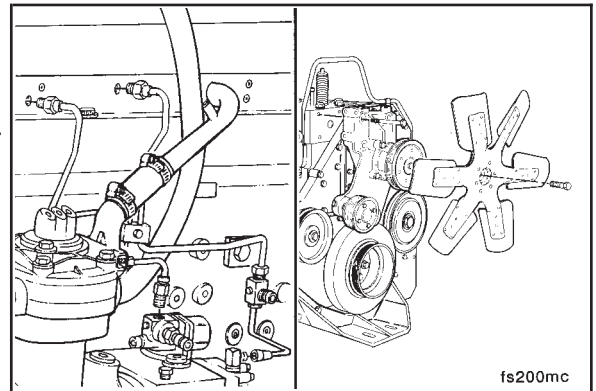


Remove the exhaust manifold. Refer to Procedure 011-007-002.

Disconnect the fuel lines and air compressor tube from the cylinder head.

Remove the fan and fan hub. Refer to Procedure 008-037-002.

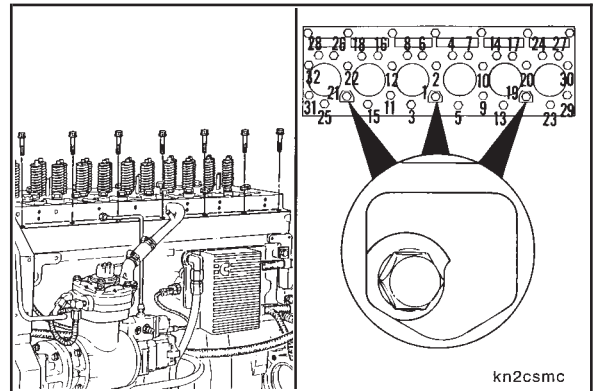
Remove all the necessary brackets and clamps.



Remove the seven 12-point cylinder head capscrews on the fuel pump side of the engine.

Remove the remaining 32 cylinder head capscrews in the sequence shown.

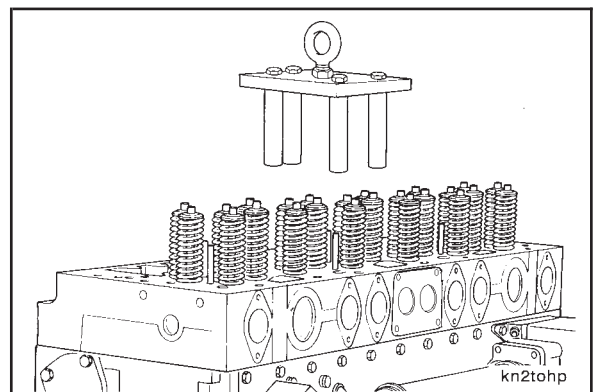
NOTE: Three capscrews are located inside the intake ports.

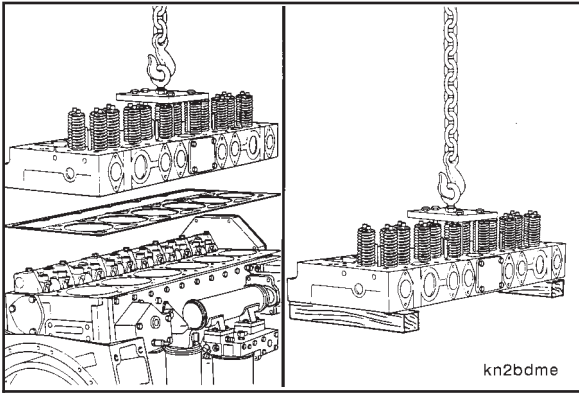


Install cylinder head lifting bracket, Part No. 3822479, with two rocker lever support mounting capscrews and two of the long rocker housing mounting capscrews.

Tighten the capscrews.

Torque Value: 47 N•m [35 ft-lb]





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

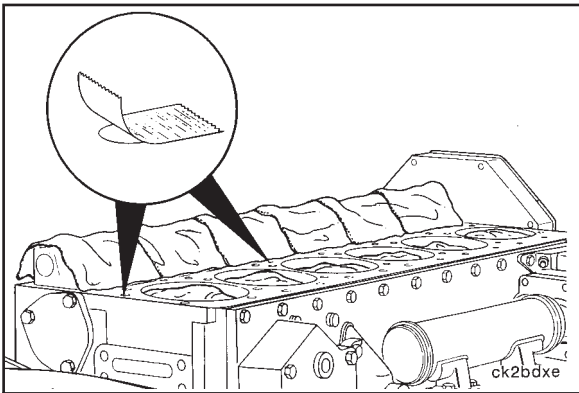


CAUTION

Place the cylinder head on wood blocks to prevent damage to the combustion face.

Use a hoist or hydraulic arm and remove the cylinder head.

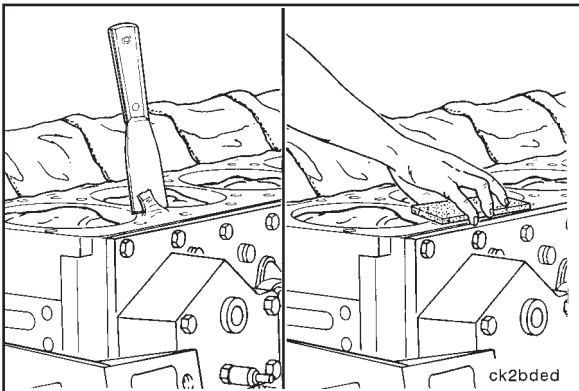
Remove the cylinder head gasket.



Clean (002-004-006)

Place clean lint-free rags over the cam followers and above the pistons to prevent dirt from falling into the engine.

Plug or cover the coolant and oil passages in the cylinder block deck.



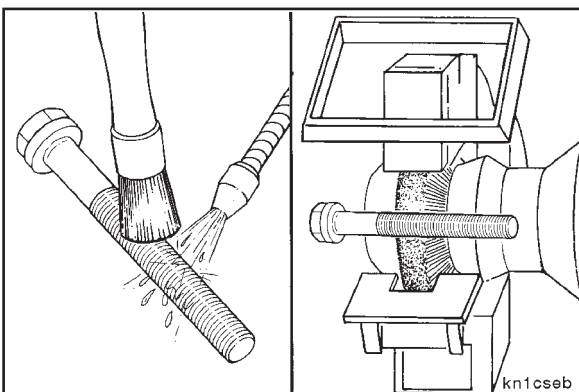
Use a gasket scraper to clean the cylinder block deck surface.

Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, and solvent to remove any residual gasket material from the cylinder block deck surface.

CAUTION

When using compressed air to clean capscrew holes, always wear safety glasses or a face shield to protect the eyes. Personal injury can result.

Make sure the cylinder head capscrew holes are clean and free of debris, oil or coolant.



CAUTION

Do not use caustic or acid solutions to clean the cylinder head capscrews.

Clean the cylinder head capscrews with a petroleum based solvent.

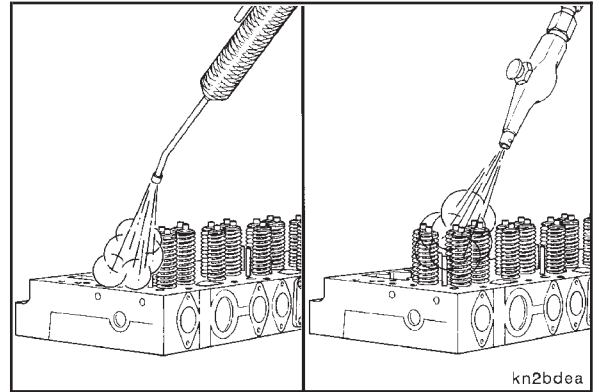
Clean the capscrews thoroughly with a wire brush, with a wire wheel (soft), or use a non-abrasive bead blast to remove deposits from the shank and the threads.

⚠ WARNING ⚠

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

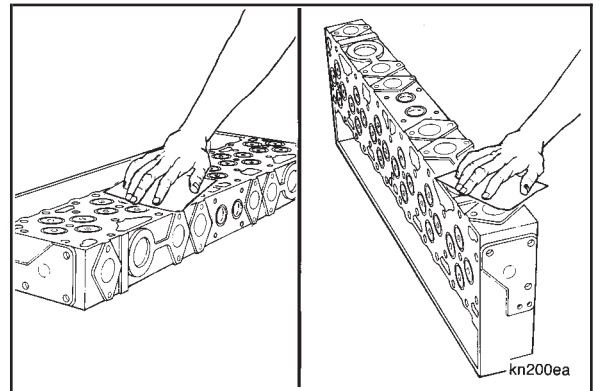
Steam clean the cylinder head and dry with compressed air.

Use compressed air to blow out all capscrew holes.

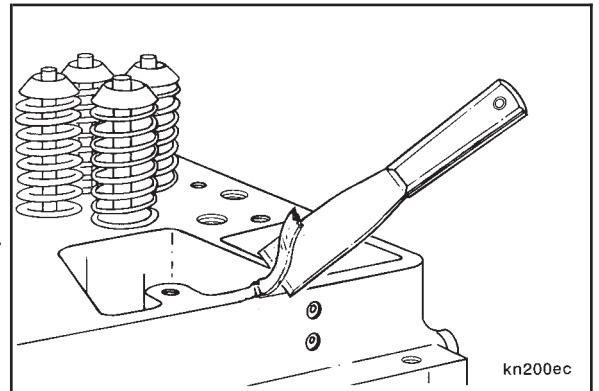


Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, and solvent to clean the cylinder head combustion face.

Clean the exhaust manifold gasket surface.



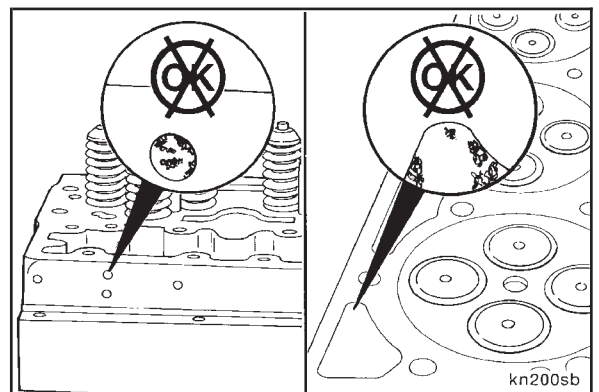
Clean the rocker housing gasket surface.

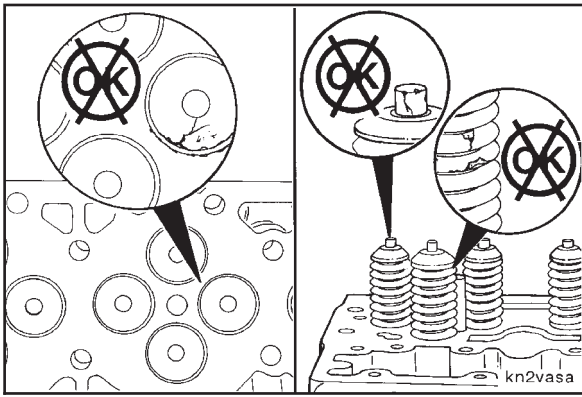


Inspect for Reuse (002-004-007)

Visually inspect the fuel drillings and water passages for restrictions or foreign material.

Remove any obstructions.



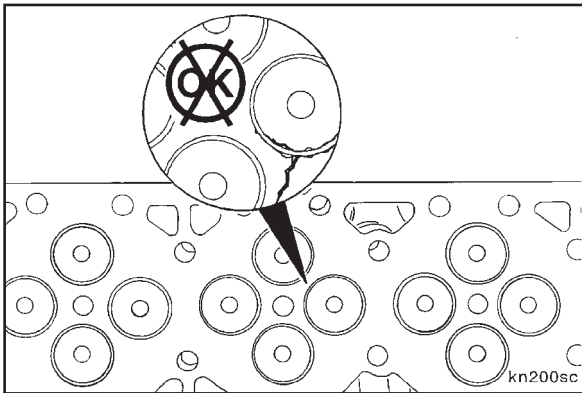


Visually inspect the valves and valve springs for cracks, bent or broken valve stems, broken valve spring collets, or other damage.



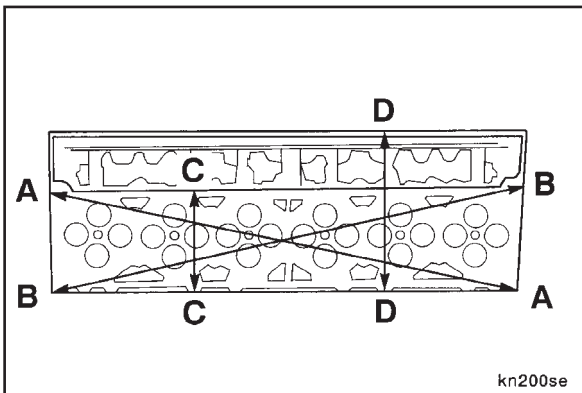
Visually inspect the valves for indications of leakage or burning.

If cracked or damaged parts, or indication of leakage or burning is found, the cylinder head **must** be rebuilt. Refer to the M11 Shop Manual, Bulletin No. 3666075.



Visually inspect the cylinder head and valves for cracks or damage.

If a crack in the cylinder head is suspected, pressure test the cylinder head. Refer to Procedure 002-004-013.



Measure the flatness of the cylinder head combustion face surface as follows:

- AA and BB (corner to corner)
- CC (across combustion face)
- DD (across entire head surface)

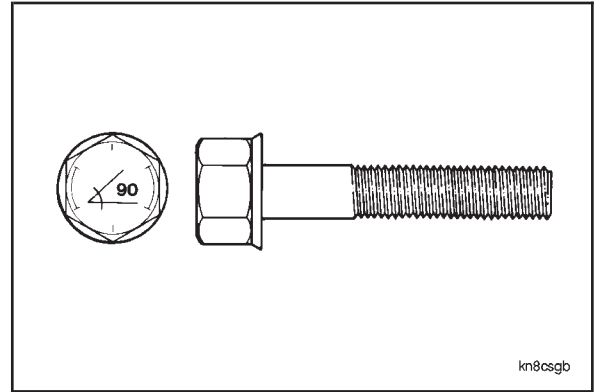
NOTE: Dimensions CC and DD **must** be checked from front to rear of cylinder head.

Cylinder Head Flatness			
	mm		in
AA and BB	0.200	MAX	0.008
CC	0.076	MAX	0.003
DD	0.127	MAX	0.005

If the cylinder head is pitted, has grooves or wear greater than the maximum specified, the cylinder head surface **must** be machined or cut. Refer to the Alternative Repair Manual, Bulletin No. 3810310.

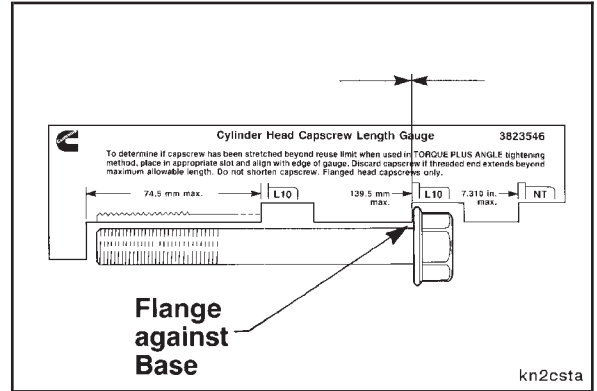
Using flange head capscrews with the torque plus angle method of installation places the capscrew beyond the yield point and permanently stretches the capscrew. These capscrews can be reused throughout the life of the engine unless the capscrew exceeds the specified free length. The free length **must** be checked to avoid bottoming in the block during installation.

Cylinder head capscrew length gauge, Part No. 3823546, has been developed to check capscrew free length.

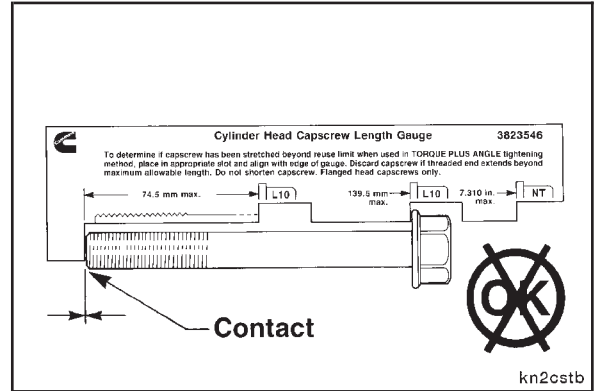


To check the capscrew free length, place the head of the capscrew in the appropriate slot, long or short, with the flange against the base of the slot.

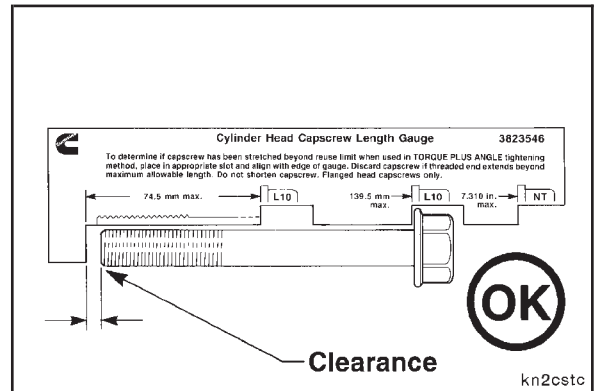
NOTE: Use the slot marked for L10 cylinder head capscrews when checking M11 cylinder head capscrews.

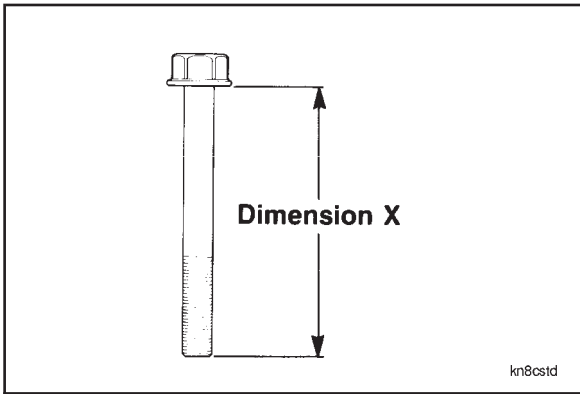


If the end of the capscrew touches the foot of the gauge, the capscrew is too long and **must** be discarded.



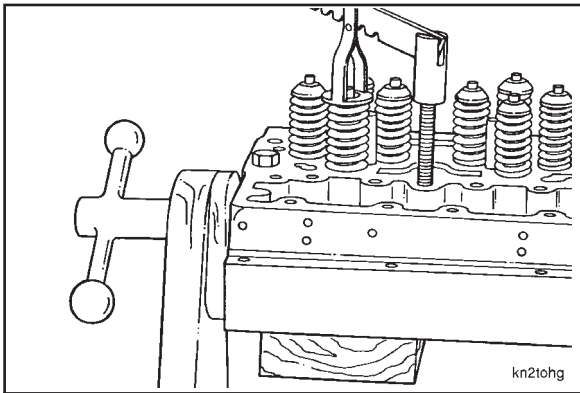
If there is clearance between the end of the capscrew and the bottom base of the tool, the capscrew is OK for reuse.





The cap screw can also be checked using a set of calipers. The maximum allowable free length is measured (from the bottom of the flange to the end of the cap screw (Dimension X)).

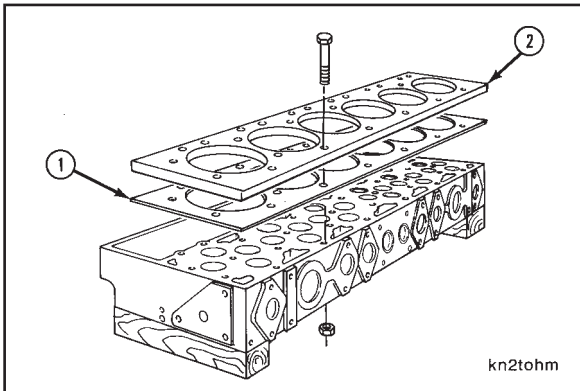
Cylinder Head Cap screw Free Length			
	mm		in
3045849	74.5	MAX	2.933
3045850	139.5	MAX	5.492



Pressure Test (002-004-013)



Do not pressure test the cylinder head with the valves and valve springs installed. Water entering the cylinder head cannot be dried thoroughly, and will damage the valve guides and valve stems. Refer to Engine Shop Manual, Bulletin No. 3810476, for cylinder head disassembly procedures.



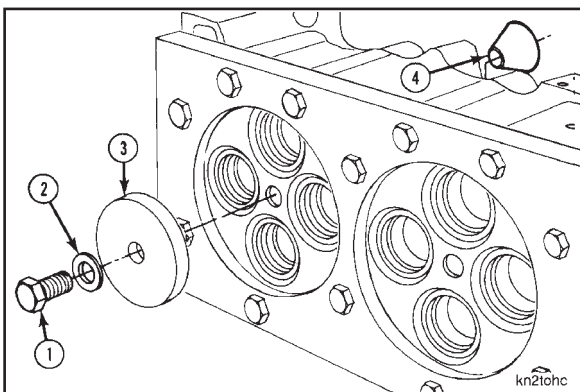
Install cylinder head water test fixture, Part No. 3376082:

- Install gasket, Part No. 3376084 (1)
- Install test plate, Part No. 3376658 (2)
- Install the 32 cylinder head cap screws and 32 (M14 x 1.50) nuts.



Tighten the nuts.

Torque Value: 47 N•m [35 ft-lb]

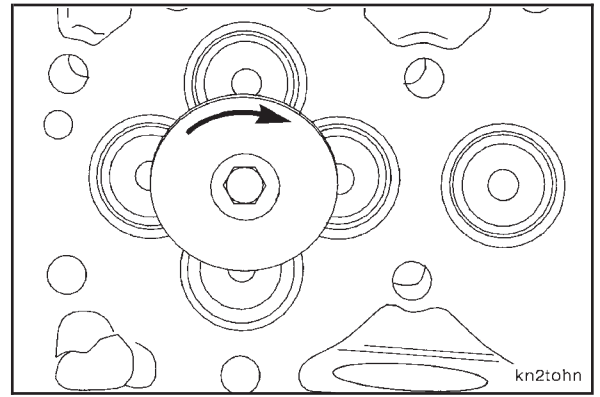


Use six injector sleeve holding tools, Part No. ST-1179.

Install the cap screw (1), flat washer (2), anvil (3) Part No. ST-179-4, and mandrel (4) Part No. ST-1179-2 in each injector bore as shown.

Tighten the six injector sleeve holding tool capscrews.

Torque Value: 75 N•m [55 ft-lb]



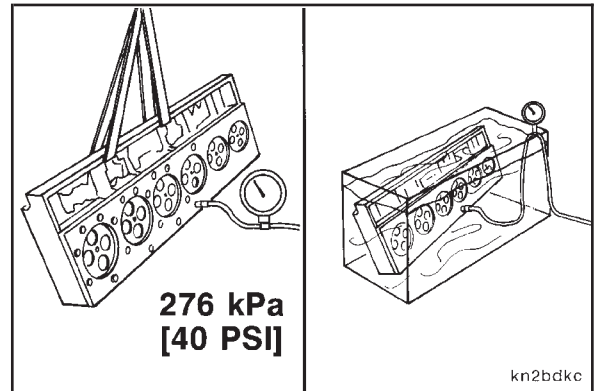
Connect a regulated air supply hose to the test fixture plate. Apply air pressure.

Air Pressure 276 kPa [40 psi]

Use a nylon lifting strap and a hoist to place the cylinder head in a tank of heated water.

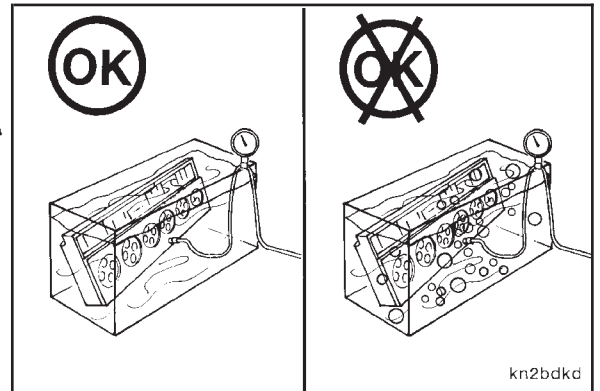
Completely submerge the cylinder head in the water.

Water Temperature 60 °C [140 °F]



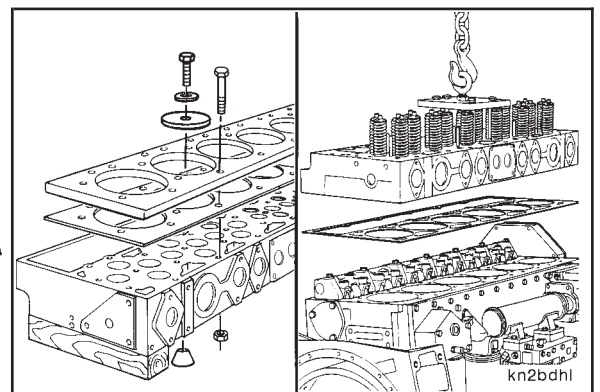
Visually inspect for air bubbles rising from the water.

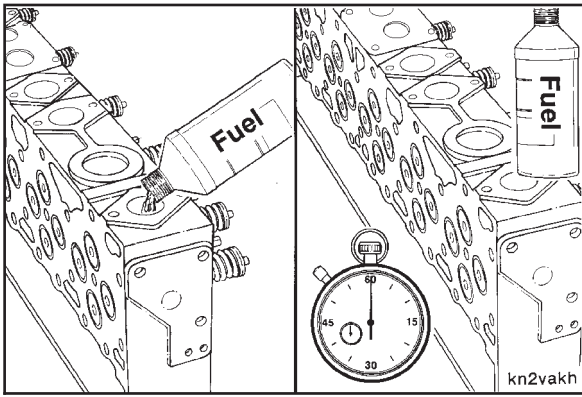
If air bubbles are seen, replace or rebuild the cylinder head. Refer to the M11 Shop Manual, Bulletin No. 3666075, for rebuild procedures.



Remove the test equipment.

Assemble the cylinder head. Refer to the M11 Shop Manual, Bulletin No. 3666075.

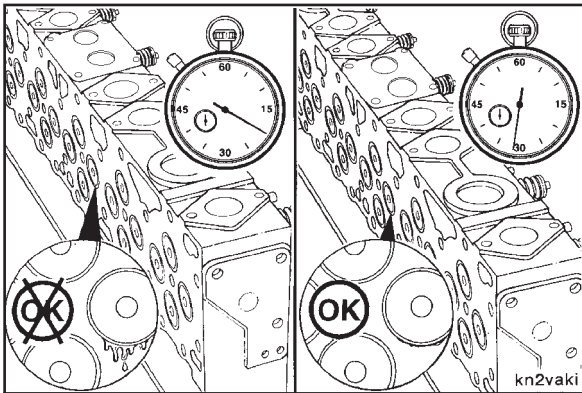




Leak Test (002-004-014)

Visually inspect the valves for indications of leakage or burning. If indications of leakage or burning are found, the valves and the seats **must** be resurfaced. Refer to the M11 Shop Manual, Bulletin No. 3666075.

Test the cylinder head for damage. Set the head down with the exhaust ports facing up. Pour fuel into one of the exhaust ports until it is full. Set the container of fuel down and start a timer.

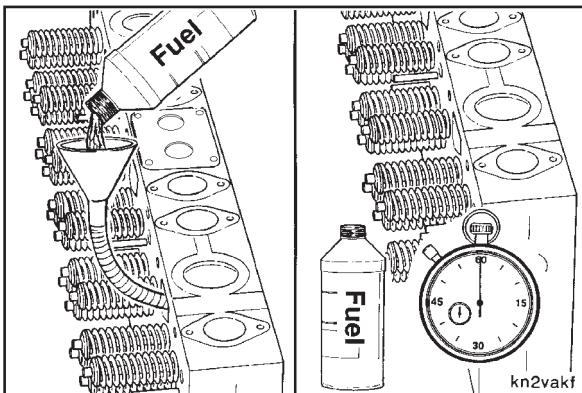


If a drop of fuel drips or runs down the face of the head within 30 seconds, the exhaust valves and the seats **must** be resurfaced. Refer to the M11 Shop Manual, Bulletin No. 3666075.



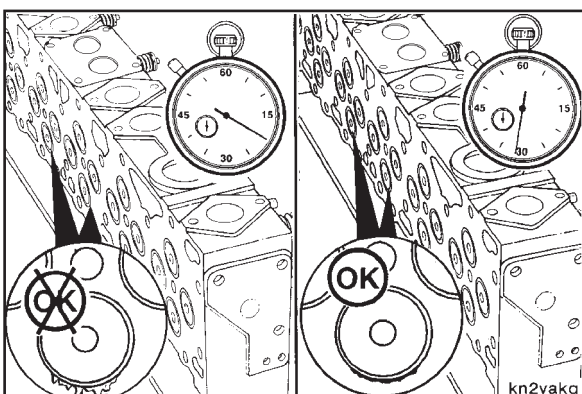
If a drop of fuel has **not** run down the face of the head in 30 seconds, the exhaust valves are okay.

Repeat the process for all six cylinders.



Pour fuel into one of the intake ports until it is full. Set the container of fuel down and start the timer.

NOTE: Each intake port supplies fuel to four intake valves (two cylinders) on M11 cylinder heads.



If a drop of fuel drips or runs down the face of the head within 30 seconds, the intake valves and the seats **must** be resurfaced. Refer to the M11 Shop Manual, Bulletin No. 3666075.



If a drop of fuel has **not** run down the face of the head in 30 seconds, the intake valves are okay.

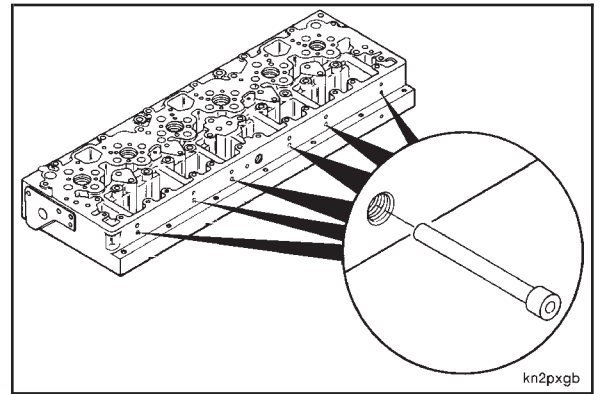
Repeat the process for all six cylinders.

NOTE: If any of the intake or exhaust valves fail the test, all the valves and valve seats **must** be resurfaced.

Install (002-004-026)

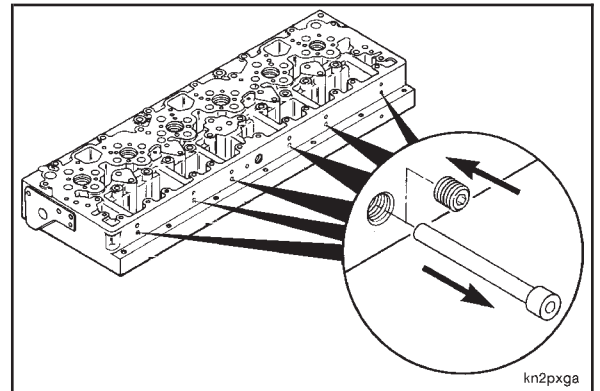
A plastic insert is installed in all fuel inlet passages on new and Recon® cylinder heads.

NOTE: The fuel inlet passages are the lower row of drillings.



Dependent upon the fuel plumbing option, one fuel inlet passage insert **must** be removed to allow fuel flow to the injectors. If the insert is **not** removed, the engine will **not** start.

Remove the pipe plug and use a sharp object to pull the insert from the hole.



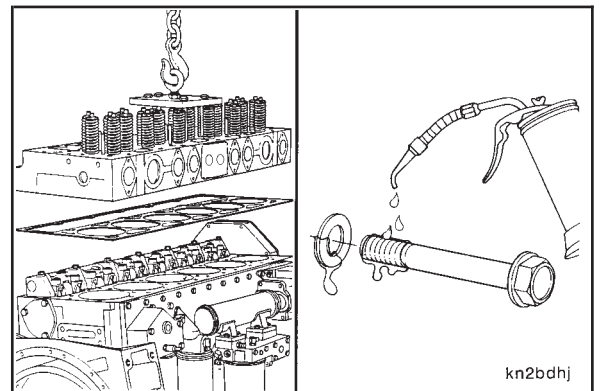
⚠ CAUTION ⚠

Do not drop the cylinder head on the cylinder head gasket. The gasket material can be damaged.

Use a new gasket and install the cylinder head.

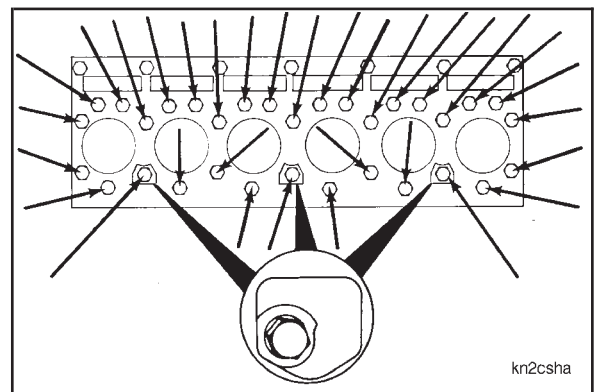
Use clean 15W-40 oil to lightly coat the cylinder head capscrew threads and bottom of the flange.

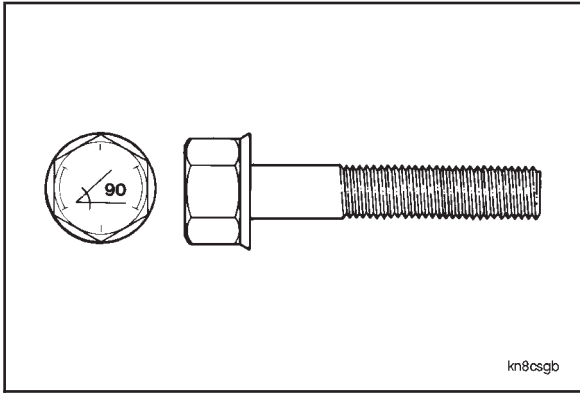
Allow the excess oil to drain from the capscrew threads.



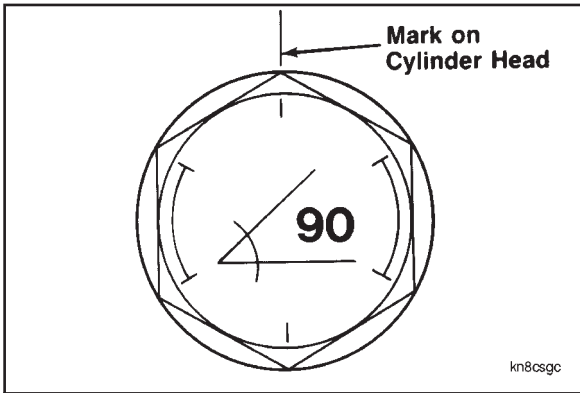
Install the cylinder head capscrews.

NOTE: Be sure to install the three capscrews inside the intake ports.

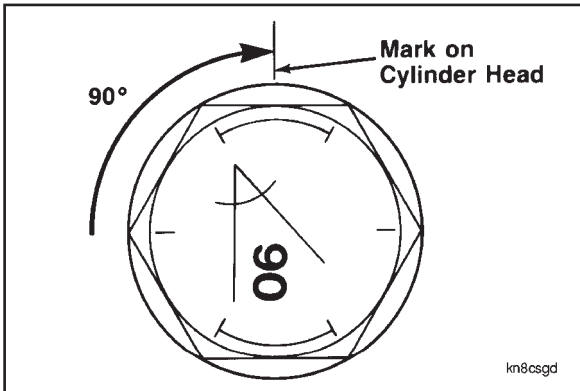




The markings on the head of the flange head capscrews serve as an aid during installation.

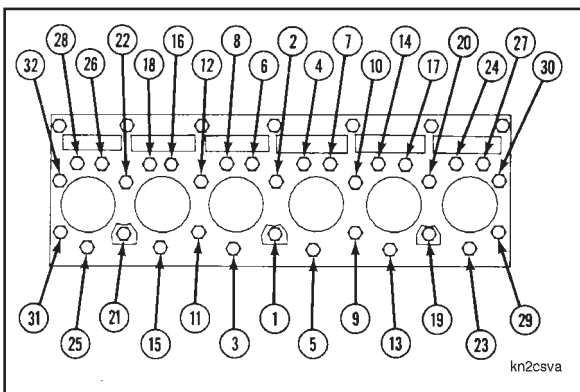


After torquing to Step 2, mark the cylinder head adjacent to one of the two single marks on the capscrew head.



All 32 capscrews **must** be rotated 90 degrees after they have been torqued to Step 2. Rotate the capscrew until the mark on the cylinder head is between the next two marks joined by an arc (more than one flat and less than two flats).

NOTE: When using torque plus angle, the tolerance on the 90 degree angle of rotation is between one and two flats. If the capscrew is unintentionally rotated beyond two flats, do **not** loosen the capscrew. The clamp load is still acceptable. However, rotating the capscrew beyond two flats reduces the number of reuses.



Tighten the capscrews in the sequence shown to the specified values:

- Torque Value:**
- | | | |
|--------|-------------------|-------------|
| Step 1 | 136 N•m | [100 ft-lb] |
| 2 | 217 N•m | [160 ft-lb] |
| 3 | Rotate 90 Degrees | |

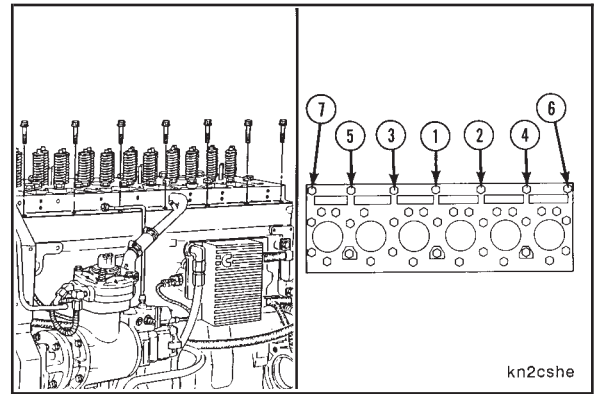
NOTE: Rotate at least one flat, but **not** more than two.

M11 Series
Section 2 - Cylinder Head - Group 02

Use new sealing washers and install the seven capscrews on the fuel pump side of the cylinder head.

Tighten the capscrews in the sequence shown.

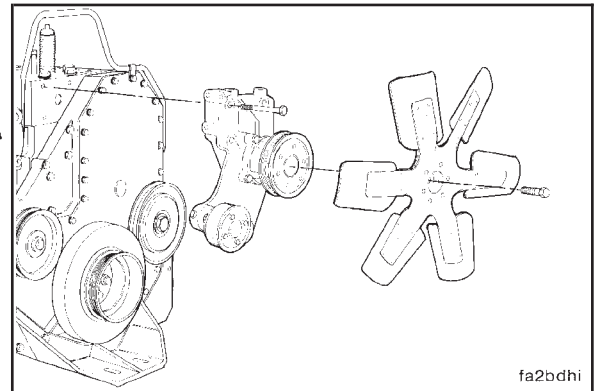
Torque Value: 68 N•m [50 ft-lb]



kn2cshe

Install the fan hub and fan. Refer to Procedure 008-037-026.

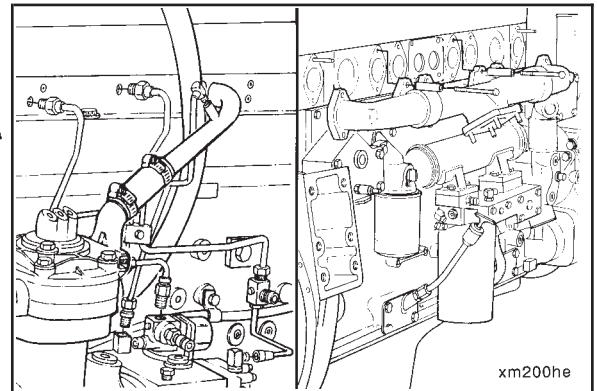
Install all brackets and clamps that were removed.



fa2bdhi

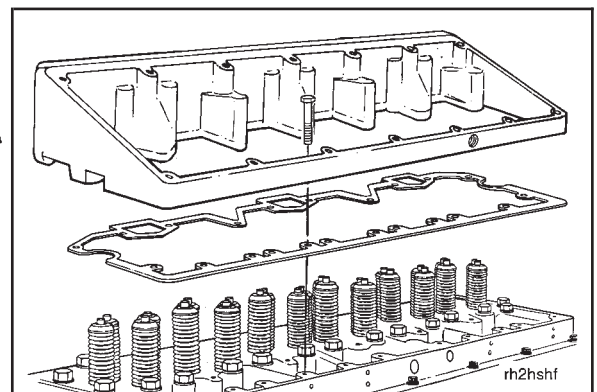
Install the fuel lines and air compressor tube to the cylinder head.

Install the exhaust manifold. Refer to Procedure 011-007-026.

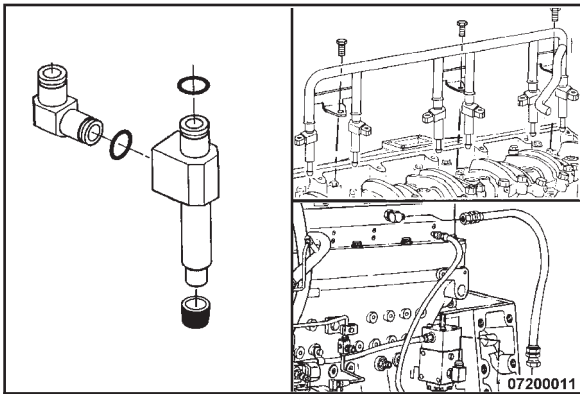


xm200he

Install the rocker lever housing. Refer to Procedure 003-013-026.

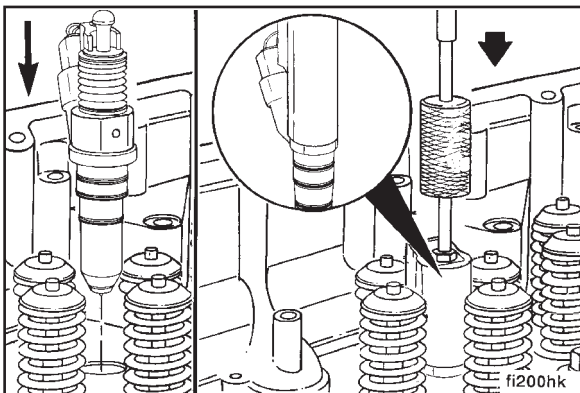


rh2hshf

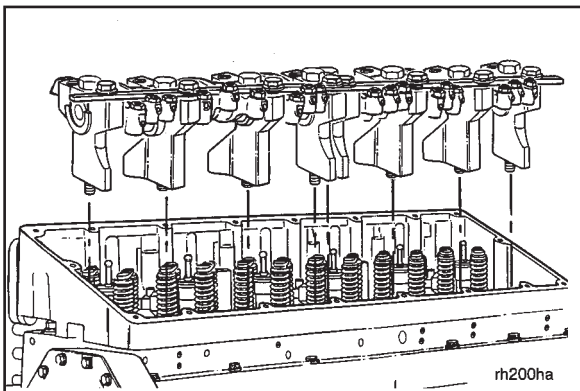


NOTE: This action applies to STC engines only.

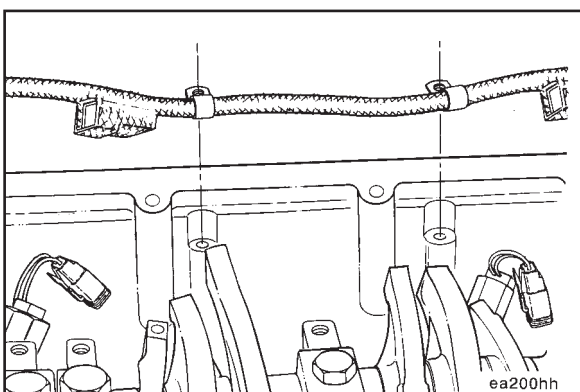
Install the STC oil manifold connection blocks and manifold. Refer to Procedure 006-038-026.



Install the injectors. Refer to Procedure 006-026-026.



Install the rocker lever assemblies. Refer to Procedure 003-009-026.



NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Install the internal engine wiring harness on the engine. The harness and connectors **must** be clear of any moving parts, so the wires will **not** be damaged during engine operation.

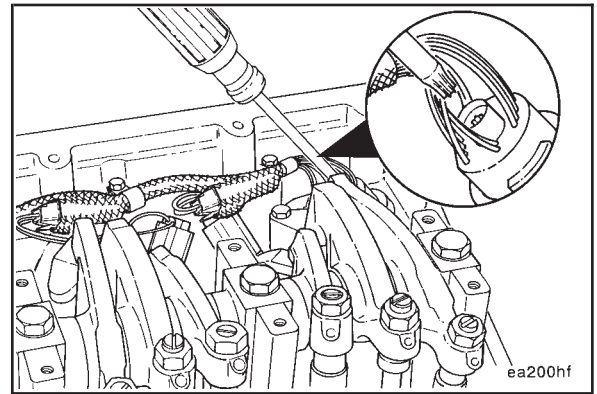
NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Connect the 12-pin connector of the internal engine harness to the 12-pin connector of the external engine harness.

NOTE: The internal and external Metri-Pack connectors are “keyed”. Make sure both connectors are correctly aligned when they are joined together.

Install the locking capscrew (Torx® Size T-25). Tighten the capscrew.

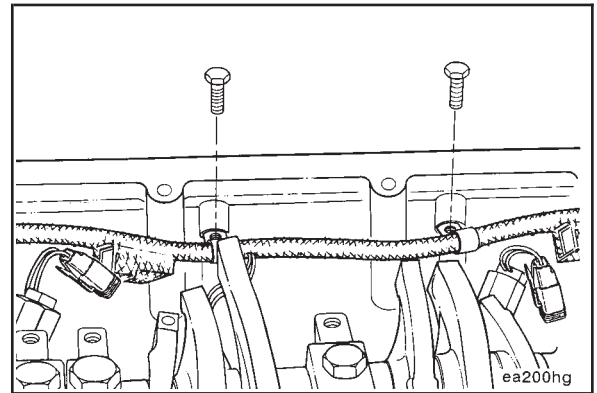
Torque Value: 1 N•m [11 in-lb]



NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Install the holding clamps for the internal engine harness. Tighten the capscrews.

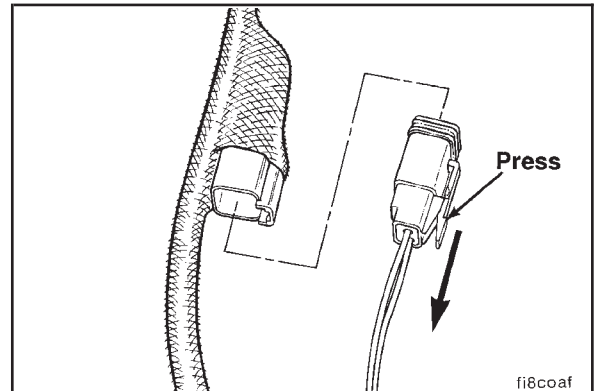
Torque Value: 20 N•m [15 ft-lb]



NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Lubricate the connector ends with lubricant, Part No. 3822934.

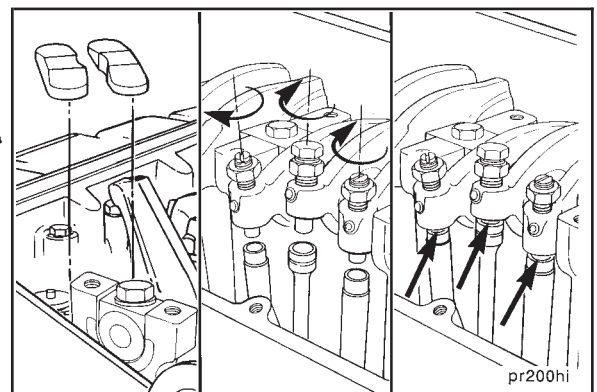
Connect the Deutsch 2-pin connectors from the internal engine harness to the fuel injectors.

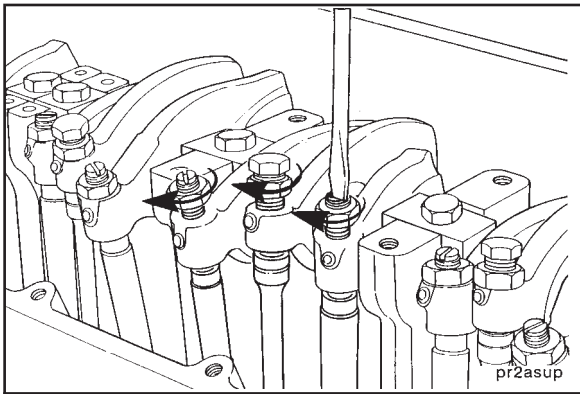


NOTE: The crossheads **must** be installed in the same position as they were removed.

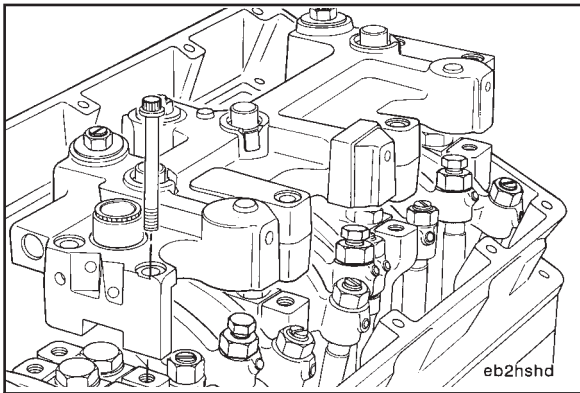
Install the crossheads.

Rotate the rocker levers up and install the push tubes and push rods. Refer to Procedure 004-014-026.

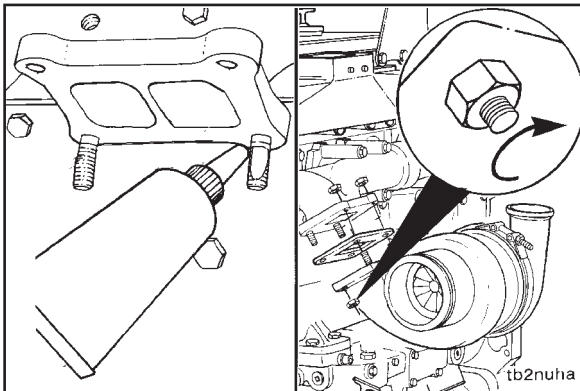




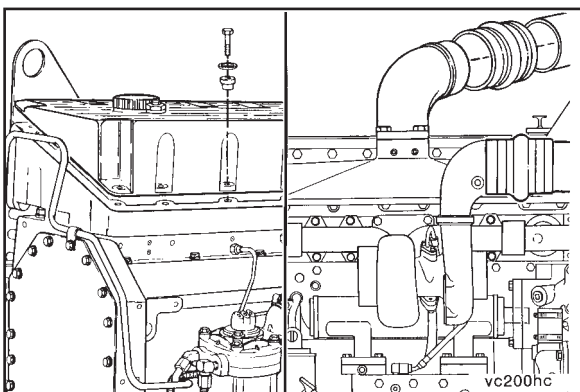
Adjust the valves and injectors. Refer to Procedure 003-004-029.



Install the engine brakes, if equipped. Refer to Procedure 020-001-026.



Install the turbocharger. Refer to Procedure 010-033-026.



Install the rocker lever cover. Refer to Procedure 003-011-026.

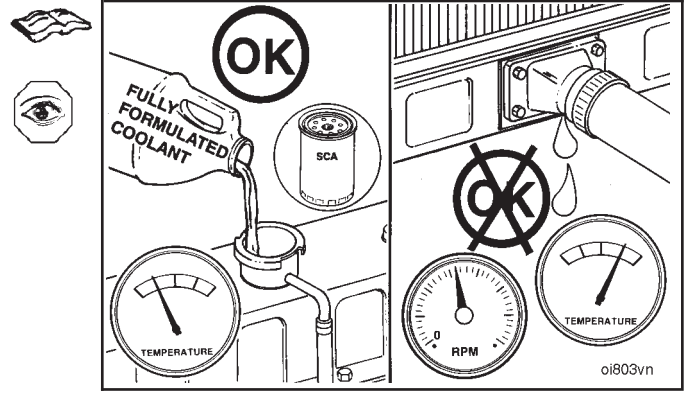


Install the air piping to the turbocharger and the intake manifold. Refer to the manufacturer's specifications for the correct torque value.

M11 Series
Section 2 - Cylinder Head - Group 02

Fill the cooling system. Refer to Procedure 008-018-028.

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



Section 3 - Rocker Levers - Group 03

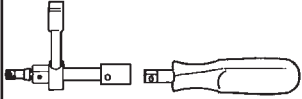
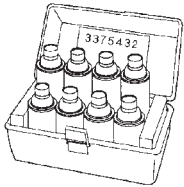
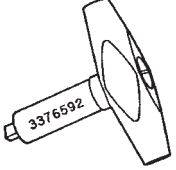

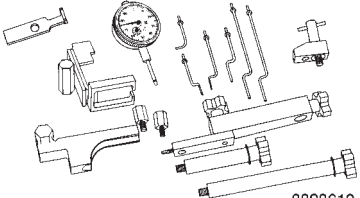
Section Contents

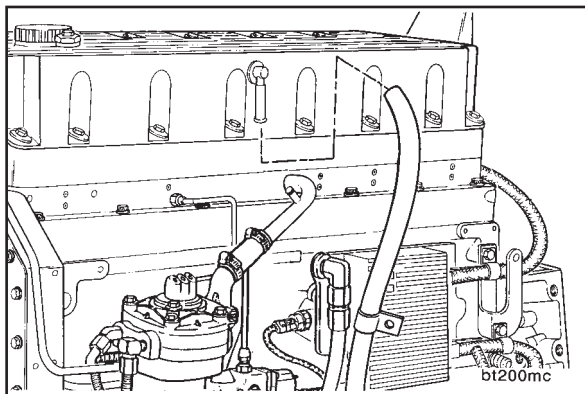
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Service Tools

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.

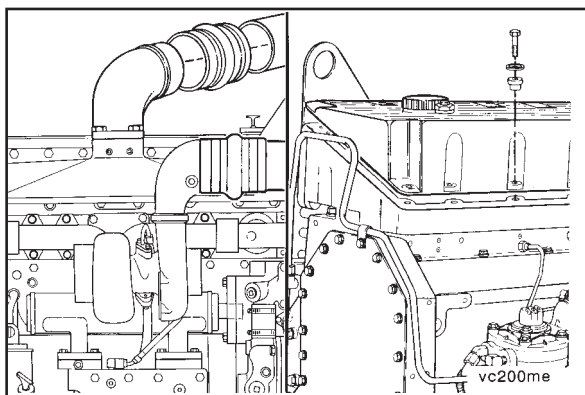
Tool No.	Tool Description	Tool Illustration
ST-669	<p>Torque Wrench Adapter Tighten rocker lever adjusting screws.</p>	 <p style="text-align: right;">rh8togb</p>
3375432	<p>Crack Detection Kit Used to clean and inspect components for cracks.</p>	 <p style="text-align: right;">3375432</p>
3376592	<p>Inch Pound Torque Wrench Can be used as an optional valve set. Screwdriver socket, Part No. ST-669-13, must be used with this tool.</p>	 <p style="text-align: right;">fi8togi</p>
3823348	<p>STC Tappet Adjusting Tool Used to set overhead on STC engines.</p>	 <p style="text-align: right;">3823348</p>
3823610	<p>Injector Travel Measurement Kit Used to measure injector travel lash.</p>	 <p style="text-align: right;">3823610</p>



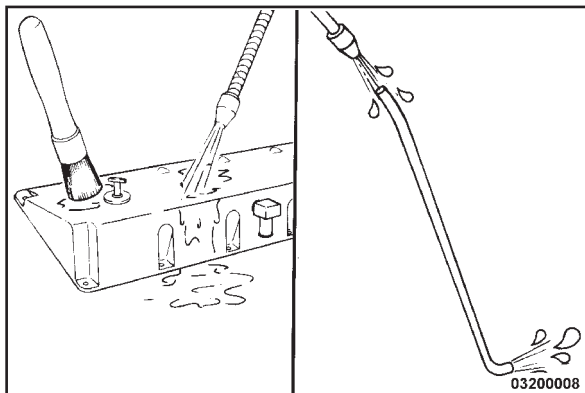
Crankcase Breather (Internal) (003-002)

Remove (003-002-002)

Remove the tube support bracket capscrew and bracket.
Remove the tube from the engine.

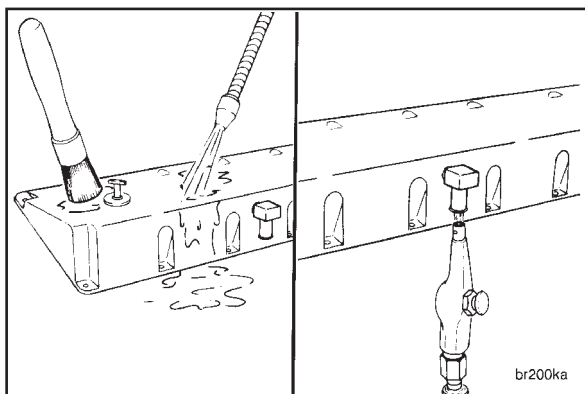


Remove the rocker lever housing cover. Refer to Procedure
003-011-002.



Clean (003-002-006)

Use solvent to clean the cover, breather cavity, and breather
tube. Dry with compressed air.

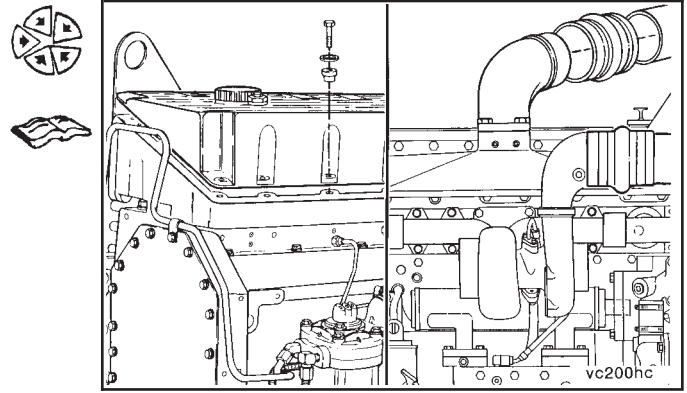


Inspect for Reuse (003-002-007)

Use compressed air to blow through the breather cavity.
If the breather cavity is clogged and the restriction **cannot**
be removed by cleaning, the cover **must** be replaced.
Use air pressure to blow through the tube.
Replace the tube if it is clogged.

Install (003-002-026)

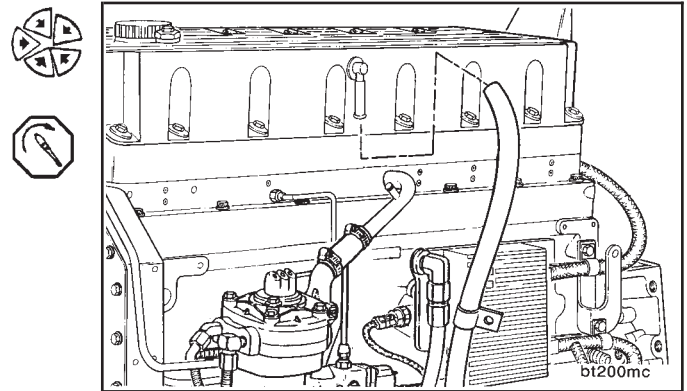
Install the rocker lever housing cover. Refer to Procedure 003-011-026.



Install the breather tube, bracket and capscrew on the engine.

Tighten the bracket capscrew.

Torque Value: 27 N•m [20 ft-lb]

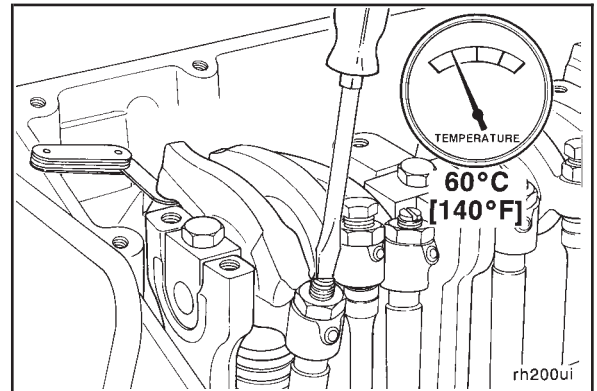


Overhead Set (003-004)

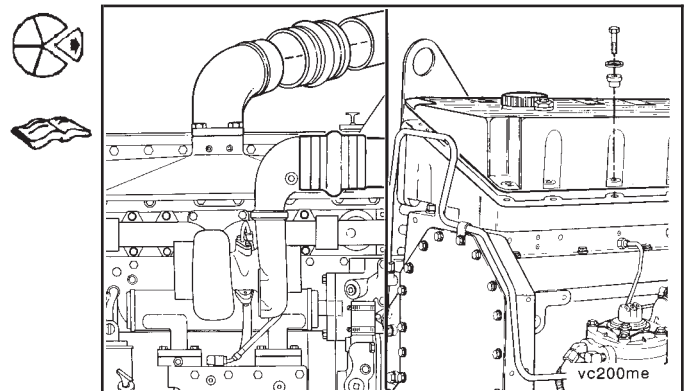
Measure (003-004-010)

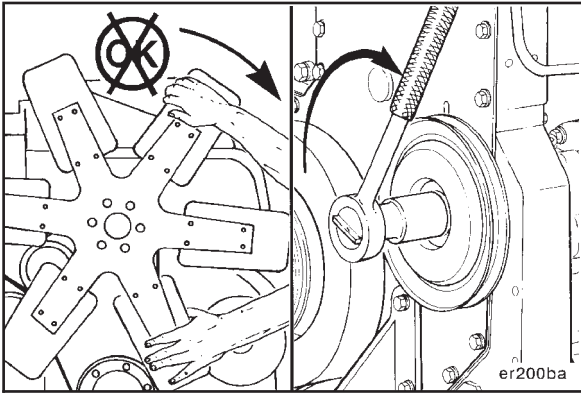
General Information

All overhead lash measurements **must** be made when the engine is cold, any stabilized coolant temperature at 60°C [140°F] or below.



Remove the rocker lever cover. Refer to Procedure 003-011-002.

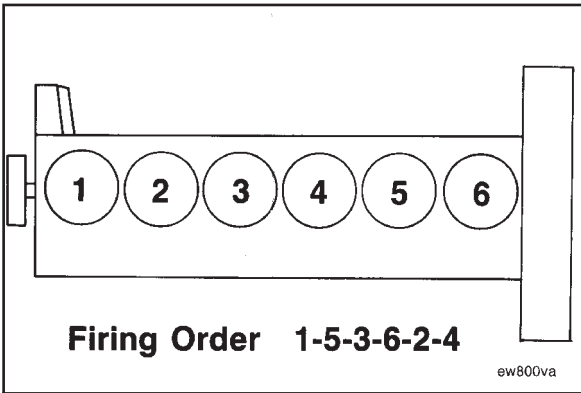




▲ WARNING ▲

Do not pull or pry on the fan blades to manually rotate the crankshaft. To do so can damage the fan blades. Damaged fan blades can cause premature fan failures which can result in serious personal injury or property damage.

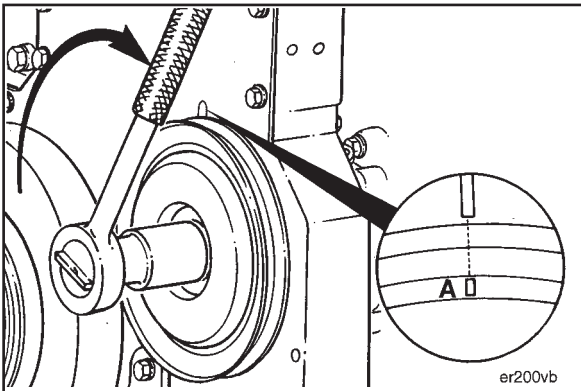
The valve set marks are located on the accessory drive pulley. The marks align with a pointer on the gear housing. Use the accessory drive shaft to rotate the crankshaft.



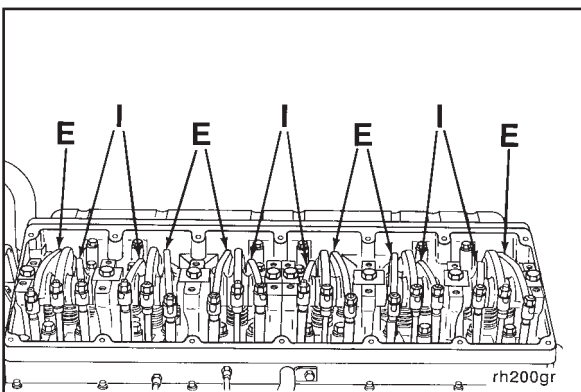
The crankshaft rotation is **clockwise** when viewed from the front of the engine.

The cylinders are numbered from the front end of the engine.

The engine firing order is 1-5-3-6-2-4.



Rotate the accessory drive **clockwise** until the "A" valve set mark on the accessory drive pulley is aligned with the pointer on the gear cover.



Each cylinder has three rocker levers:

- The long rocker lever (E) is the exhaust lever.
- The center rocker lever is the injector lever.
- The short rocker lever (I) is the intake lever.

Refer to the accompanying chart for valve rocker lever locations.

Valve and Injector Lash — CELECT™ and CELECT™ Plus Engines

When the “A” mark is aligned with the pointer, the intake and exhaust valves for cylinder No. 1 **must** be closed. The injector plunger for cylinder No. 1 **must** be at the bottom of its stroke. If these conditions are **not** correct, cylinder No. 6 **must** be ready to check. Check the injector and valves on the cylinder that both the intake and exhaust valve rocker levers can be “rattled” by hand or the push tubes can be freely rotated.

CELECT™ Injector and Valve Measurement Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder Injector	Set Cylinder Valve
Start	A	1	1
Advance to	B	5	5
Advance to	C	3	3
Advance to	A	6	6
Advance to	B	2	2
Advance to	C	4	4

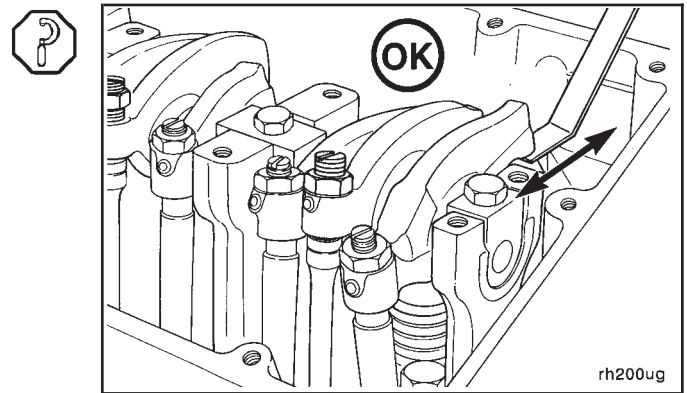
Firing Order: 1-5-3-6-2-4

oi200vh

Valve Lash

Using a set of feeler gauges, measure the amount of clearance (lash) between the crosshead and rocker lever nose. Measure and record the intake and exhaust valve lash. If the valve lash is **not** within the specifications listed below, the valves **must** be adjusted. Refer to Procedure 003-004-029.

M11 Valve Lash Recheck Limits			
	mm		in
Intake	0.10	MIN	0.004
	0.41	MAX	0.016
Exhaust	0.46	MIN	0.018
	0.76	MAX	0.030

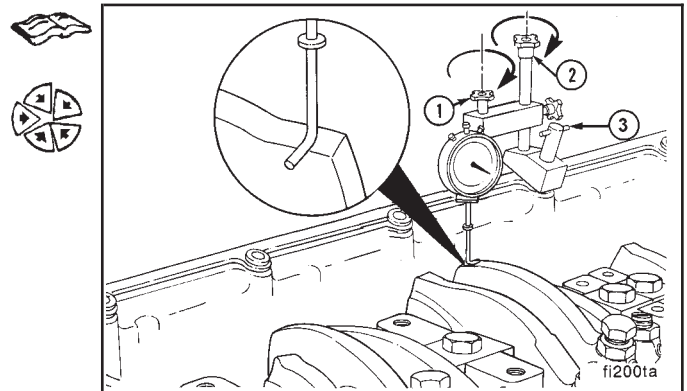


Injector Lash

Install the dial indicator and the support from injector travel measurement kit, Part No. 3823610, so the extension, Part No. 3823595, for the dial indicator is on top of the injector rocker lever directly over the socket on the cylinder being checked.

Securely tighten the thumb screw (1) and the hold down capscrews (2 and 3) in place.

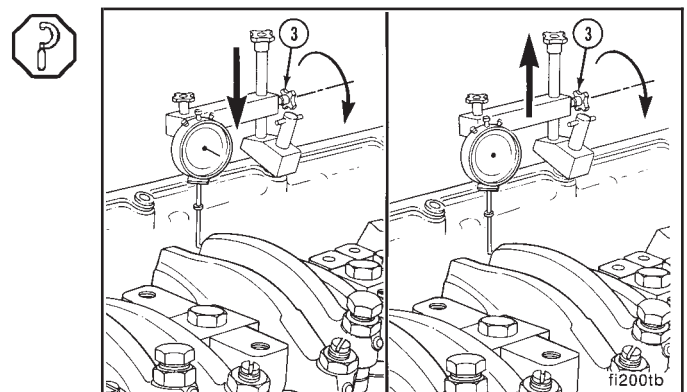
NOTE: All adjusting screws **must** be tight to get an accurate measurement.

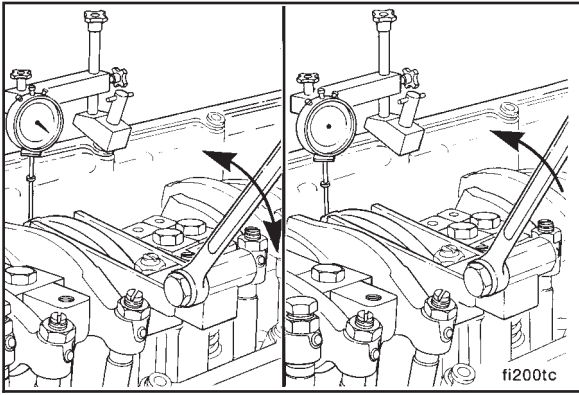


The tip of the dial indicator extension **must** rest on the rocker lever directly above the socket. If it does **not**, incorrect readings can result.

Loosen the thumb screw (3) and lower the indicator against the injector rocker lever until the stem is fully compressed.

Raise the indicator approximately 12.7 mm [0.500 inch] and tighten the thumb screw (3) to hold the indicator in position.



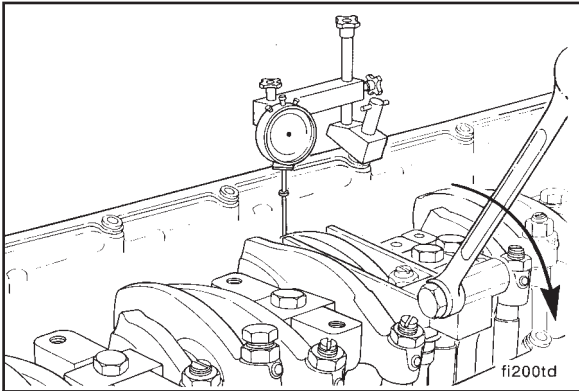


⚠ WARNING ⚠

The injector plunger is under spring tension. Do not allow the tool to slip. Serious personal injury can result.

Actuate the injector plunger three or four times to make sure the fuel has been removed from the injector assembly. Allow the lever to return slowly to prevent damage to the dial indicator.

Actuate the lever again; set the dial indicator at zero "0" while holding the injector plunger to the bottom of its travel.



Slowly release the actuator and check the dial indicator travel. Record the measured value.

If the injector lash setting is **not** within the specifications listed below, the injector **must** be adjusted. Refer to Procedure 003-004-029.

M11 Injector Lash Recheck Limits		
mm		in
0.51	MIN	0.020
2.04	MAX	0.080

STC Injector and Valve Adjustment Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder	
		Injector	Valve
Start	A	3	5
Advance to	B	6	3
Advance to	C	2	6
Advance to	A	4	2
Advance to	B	1	4
Advance to	C	5	1

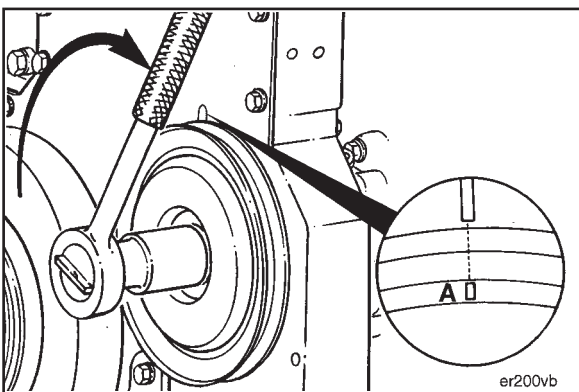
Firing Order: 1-5-3-6-2-4

oi200vi

Valve Lash — STC Engines

One pair of valves are measured at each pulley index mark before rotating the accessory drive to the next index mark.

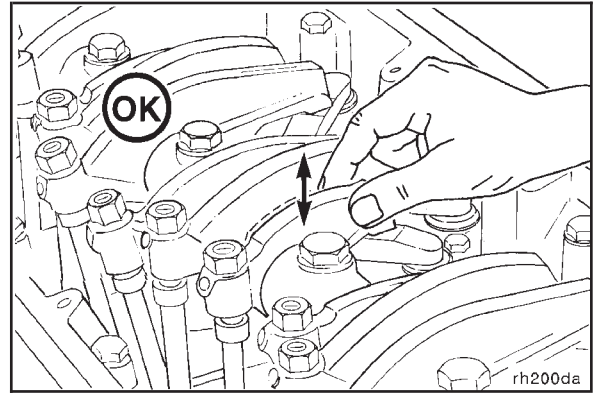
Two crankshaft revolutions are required to measure the lash of all the valves.



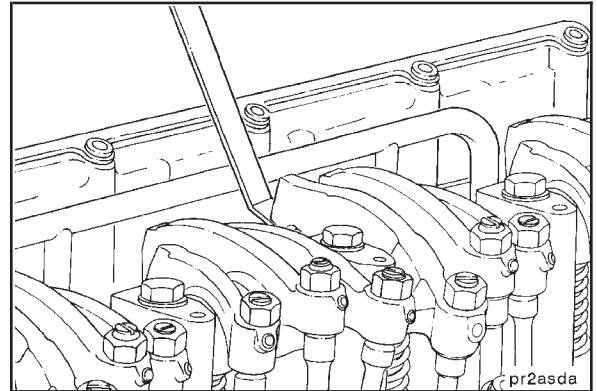
Rotate the accessory drive **clockwise** until the "A" valve set mark on the accessory drive pulley is aligned with the pointer.

Check the valve rocker levers on cylinder No. 5 to see if both valves are closed.

Both valves are closed when both rocker levers are loose and can be moved from side to side. If both valves are **not** closed, start with cylinder No. 2.



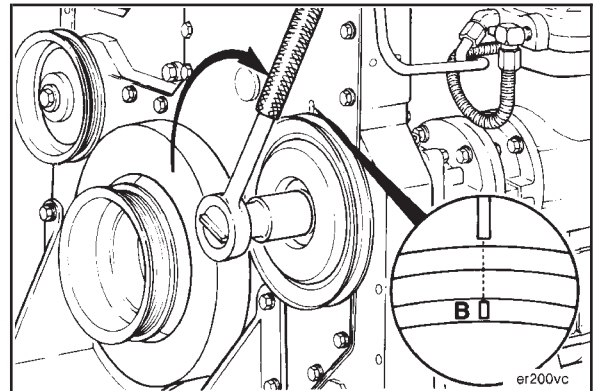
Using a set of feeler gauges, measure the amount of clearance (lash) between the crosshead and rocker lever nose for the cylinder being measured. Measure and record both the intake and exhaust rocker lever lash.



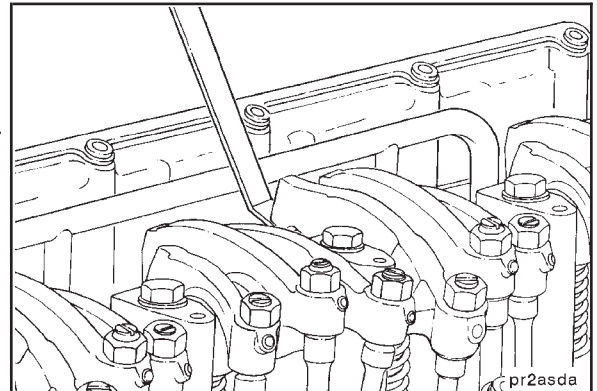
After taking the valve lash measurements, rotate the accessory drive and align the next valve set mark.

Measure the appropriate valve lash.

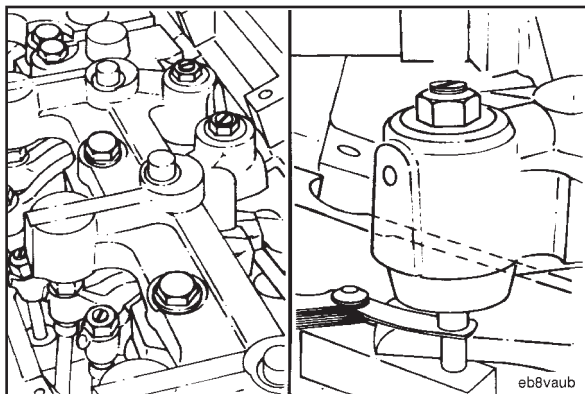
Repeat the process until all of the lash measurements have been taken.



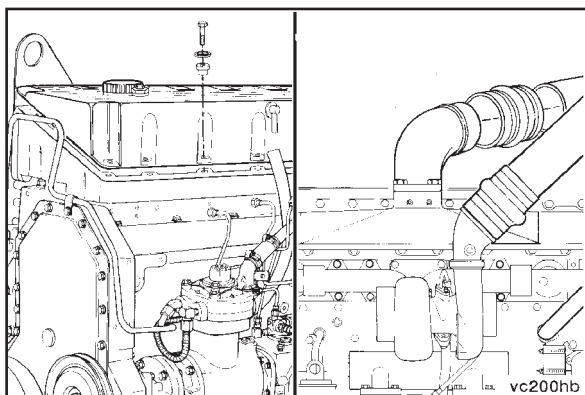
M11 Valve Lash Recheck Limits			
	mm		in
Intake	0.10	MIN	0.004
	0.41	MAX	0.016
Exhaust	0.46	MIN	0.018
	0.76	MAX	0.030



Compare valve lash measurements to the recheck limits. If the measurements are **not** within the recheck limits, the overhead **must** be reset. Refer to Overhead Adjust in this procedure.



If the engine is equipped with engine brakes, check the brake piston clearance. Refer to Procedure 020-001.



Install the rocker lever cover. Refer to Procedure 003-011-026.



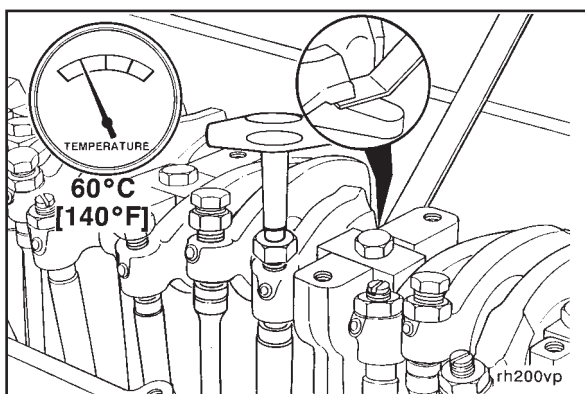
CELECT™ Plus		
Valve, Injector, and Brake Adjustment Specifications		
	mm	in
Intake Valve	0.35	0.014
Exhaust Valve	0.68	0.027
Engine Brake	0.38	0.015

03200007

Adjust (003-004-029)

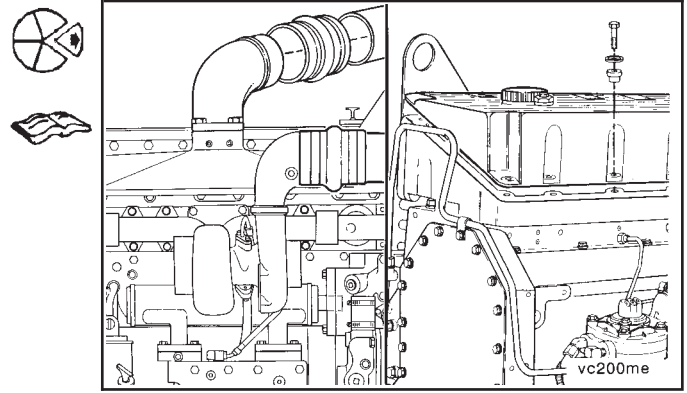
General Information

Valves, injectors, and engine brakes **must** be correctly adjusted for the engine to operate efficiently. Valve, injector, and engine brake adjustment **must** be performed using the values listed in this section. The accompanying table gives the adjustment specifications for CELECT™ Plus engines.



All valve and injector adjustments **must** be made when the engine is cold, any stabilized coolant temperature at 60°C [140°F] or below.

Remove the rocker lever cover and gasket. Refer to Procedure 003-011-002.

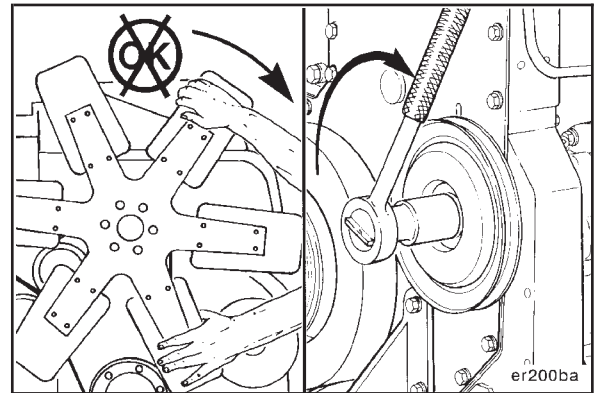


⚠ WARNING ⚠

Do not pull or pry on the fan to manually rotate the crankshaft. To do so can damage the fan blades. Damaged fan blades can cause premature fan failures which can result in serious personal injury or property damage.

The valve set marks are located on the accessory drive pulley. The marks align with a pointer on the gear cover.

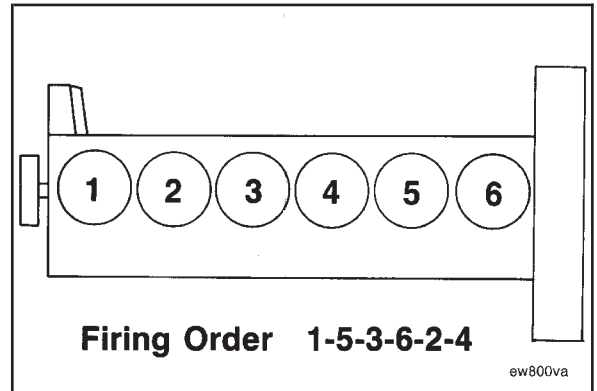
Use the accessory drive shaft to rotate the crankshaft.



The crankshaft rotation is **clockwise** when viewed from the front of the engine.

The cylinders are numbered from the front gear housing end of the engine.

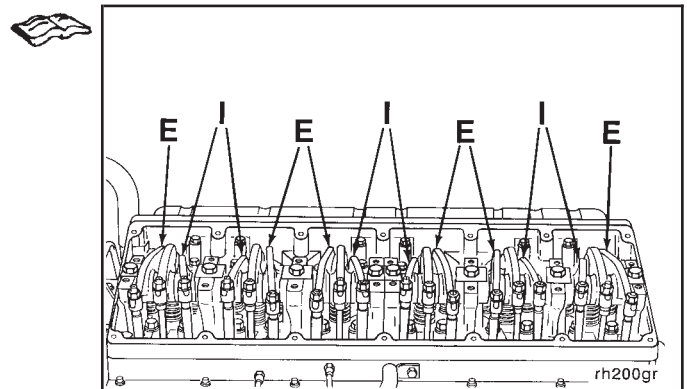
The engine firing order is 1-5-3-6-2-4.



Each cylinder has three rocker levers:

- The long rocker lever (E) is the exhaust lever.
- The center rocker lever is the injector lever.
- The short rocker lever (I) is the intake lever.

Refer to the accompanying chart for valve rocker lever locations.



CELECT™ Injector and Valve Measurement Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder	
		Injector	Valve
Start	A	1	1
Advance to	B	5	5
Advance to	C	3	3
Advance to	A	6	6
Advance to	B	2	2
Advance to	C	4	4

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

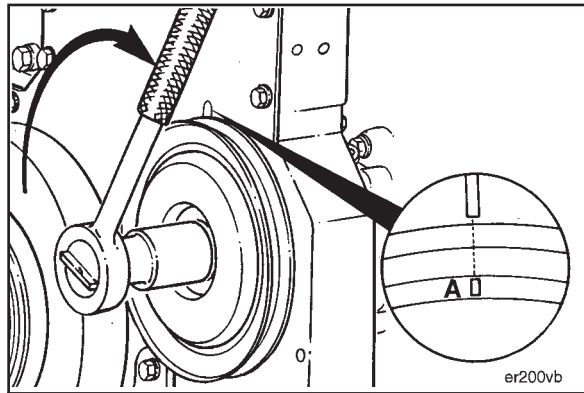
oi200vh

The valves and injectors on the same cylinders are adjusted at the same index mark on the accessory drive pulley on CELECT™ and CELECT™ Plus engines.

One pair of valves and one injector are adjusted at each pulley index mark before rotating the accessory drive to the next index mark.

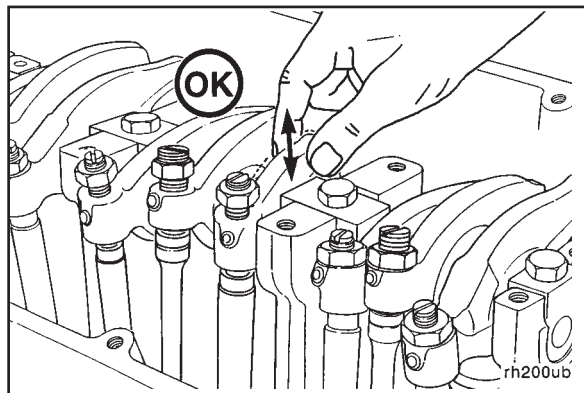
Two crankshaft revolutions are required to adjust all the valves and injectors.

NOTE: See the example before attempting to begin the adjusting procedure.



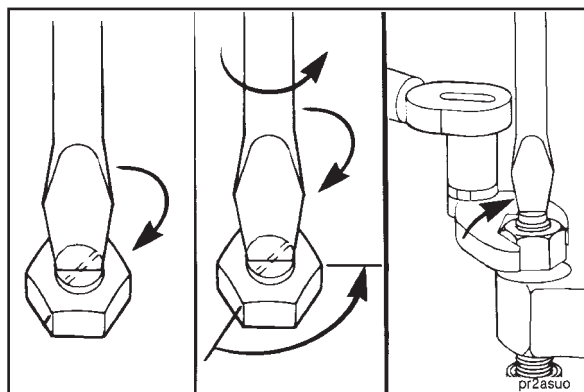
The adjustment can begin on any valve set mark. In the following example, the adjustment will begin on the "A" valve set mark with cylinder number one valves closed and ready for adjustment.

Rotate the accessory drive **clockwise** until the "A" valve set mark on the accessory drive pulley is aligned with the pointer on the gear cover.



When the "A" mark is aligned with the pointer, the intake and exhaust valves for cylinder number one **must** be closed. If these conditions are **not** correct, cylinder number six injector and valves **must** be ready to set. Set the injector and valves on the cylinder that both the intake and exhaust valve rocker lever arms are loose and can be moved from side to side.

Both valves are closed when both rocker levers are loose and can be moved from side to side.



Injector Adjustment — CELECT™ and CELECT™ Plus Engines



Loosen the injector adjusting screw locknut. Using a screwdriver (box end wrench if equipped with engine brakes) and the adjusting screw, bottom the injector plunger three or four times to remove the fuel.

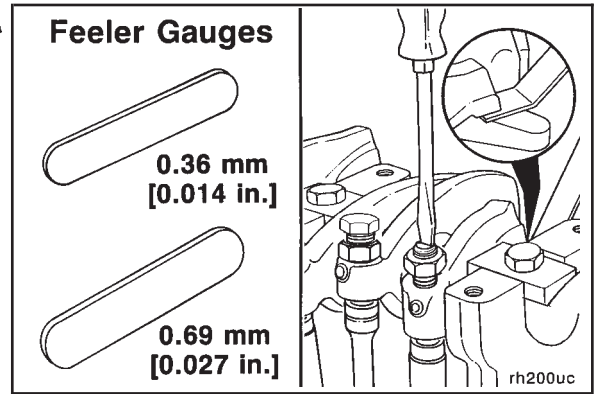
Turn the adjusting screw in until you can feel it just bottom the plunger.

NOTE: Do not use excess force when bottoming the plunger.

Back out the adjusting screw two flats, 120 degrees. Hold the adjusting screw and torque the locknut.

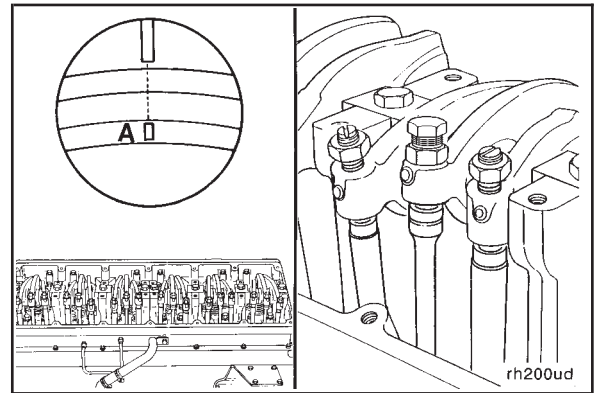
Torque Value: 61 N•m [45 ft-lb]

After setting the injector, set the valves on the same cylinder.



Valve Adjustment — CELECT™ and CELECT™ Plus Engines

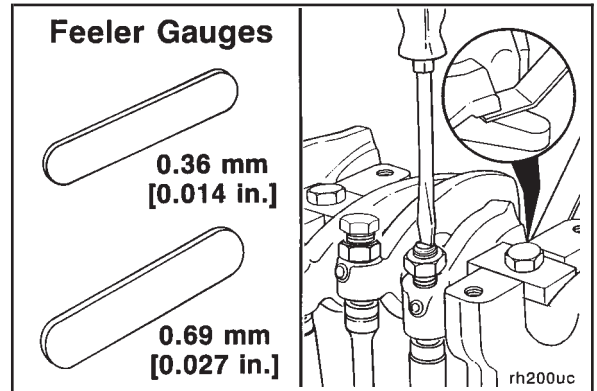
With the ‘A’ valve set mark aligned with the pointer on the gear cover and both valves closed on the cylinder to be adjusted, loosen the adjusting screw locknuts on the intake and exhaust valves.



Select a feeler gauge for the correct valve lash specification.

	Valve Lash Specification	
	mm	in
Intake	0.36	0.014
Exhaust	0.69	0.027

Insert the feeler gauge between the top of the crosshead and the rocker lever pad.

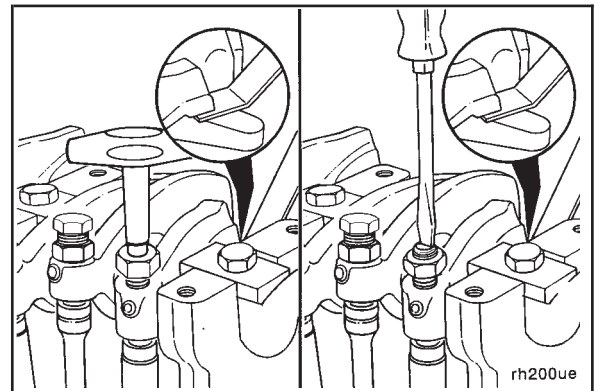


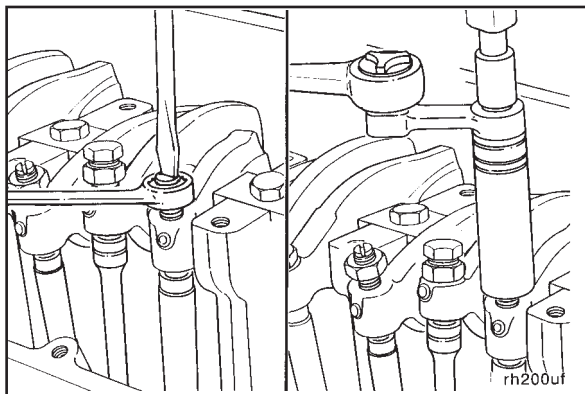
Two different methods for establishing valve lash clearance are described below. Either method can be used; however, the torque wrench method has proven to be the most consistent. It eliminates the need to feel the drag on the feeler gauge.

- **Torque Wrench Method:** Use the inch pound torque wrench, Part No. 3376592, normally used to set preload on top stop injectors, and tighten the adjusting screw.

Torque Value: 0.7 N•m [6 in-lb]

- **Touch Method:** Tighten the adjusting screw until a slight drag is felt on the feeler gauge.

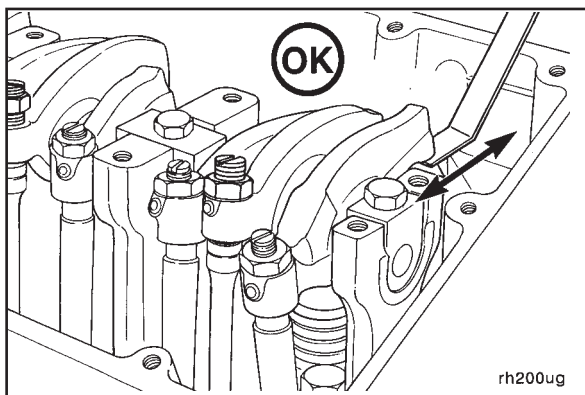




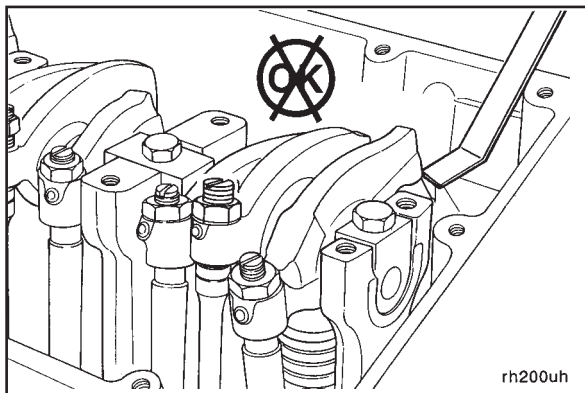
Hold the adjusting screw in this position. The adjusting screw **must not** turn when the locknut is tightened.

Torque Value:

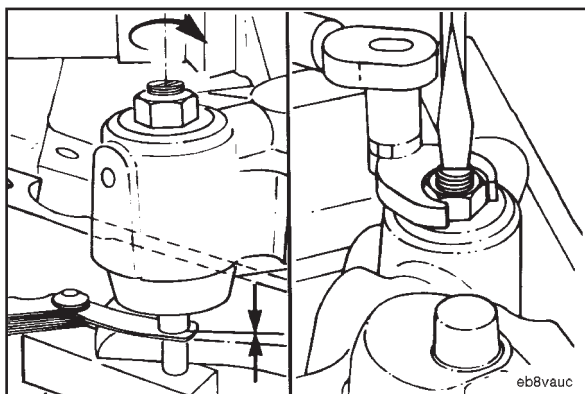
- **Without** Torque Wrench Adapter
61 N•m [45 ft-lb]
- **With** Torque Wrench Adapter, Part No. ST-669:
47 N•m [35 ft-lb]



After tightening the locknut to the correct torque value, check to make sure the feeler gauge will slide backward and forward between the crosshead and the rocker lever with only a slight drag.



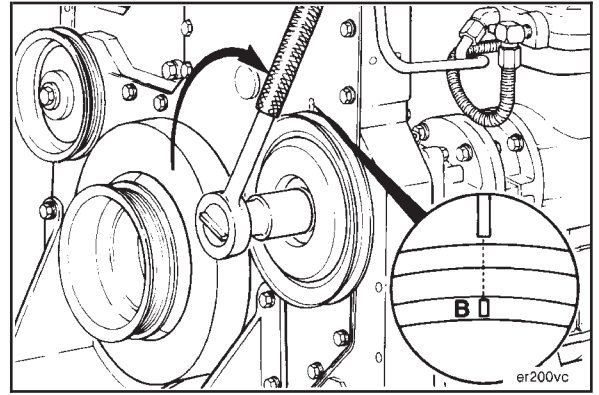
If using the touch method, attempt to insert a feeler gauge that is 0.03 mm [0.001 inch] thicker between the crosshead and the rocker lever pad. The valve lash is **not** correct when a thicker feeler gauge will fit.



If the engine is equipped with an engine brake, refer to "Engine Brake — Adjust" following in this procedure.



After adjusting the injector, valves, and engine brakes (if equipped) on the appropriate cylinder, rotate the accessory drive pulley and align the next valve set mark with the pointer on the gear cover.



Adjust all of the injectors, valves, and brakes (if equipped) following the injector and valve adjustment sequence chart.

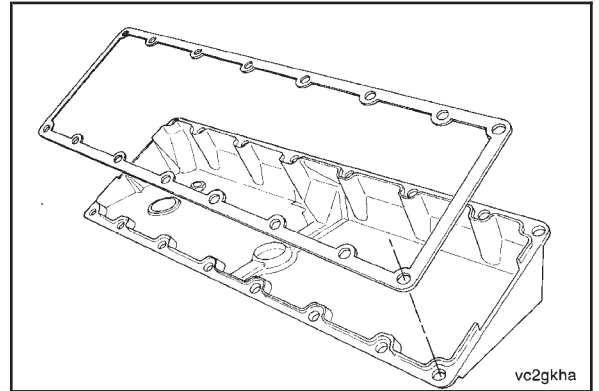
CELECT™ Injector and Valve Measurement Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder	
		Injector	Valve
Start	A	1	1
Advance to	B	5	5
Advance to	C	3	3
Advance to	A	6	6
Advance to	B	2	2
Advance to	C	4	4

Firing Order: 1-5-3-6-2-4 oi200vh

If the valve cover gasket was **not** damaged, it can be used again. If the gasket was damaged, it **must** be discarded and a new one used.

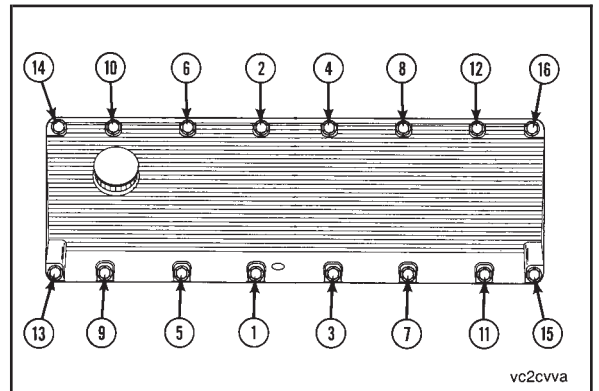


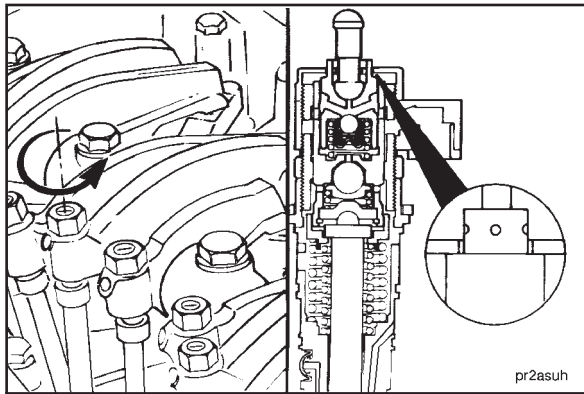
Install the gasket on the cover.



Install the cover on the rocker lever housing.
 Install the 16 isolators, spacers and capscrews in the cover.
 Tighten the capscrews in the sequence shown.

Torque Value: 15 N•m [130 in-lb]

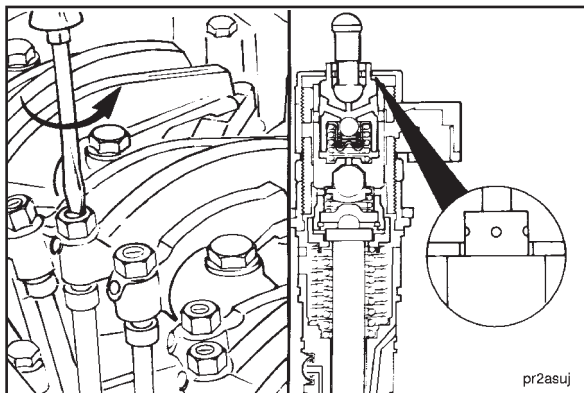




Injector Adjustment — STC Engines

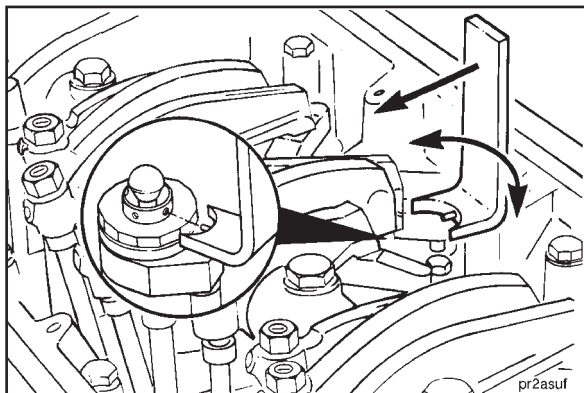
Loosen the injector adjusting screw locknut on cylinder number three. Tighten the adjusting screw until all the clearance is removed from the injector train.

Tighten the adjusting screw one additional turn to correctly seat the link.

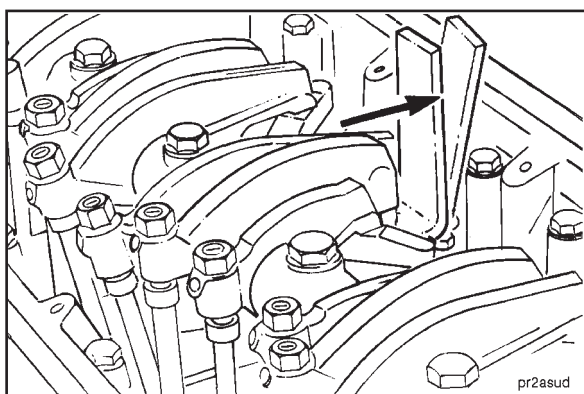


Loosen the injector adjusting screw until the STC tappet touches the top-cap of the injector.

Be sure to loosen the adjusting screw enough, so there is no preload on the injector. This will be accomplished when the rocker lever is loose enough to move.



Place the STC tappet adjusting tool, Part No. 3823348, on the upper surface of the STC injector top-cap. Rotate the tool around the tappet until the tool's locating pin is inserted into one of the four holes in the top of the tappet.



Apply thumb pressure to the tool handle to hold the tappet in the maximum upward position.

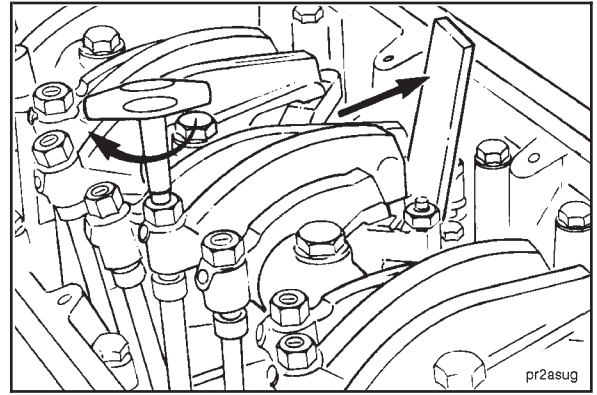
NOTE: Apply only enough force to the tool to hold the tappet in the maximum upward position. Excess force will cause the tool to break.

CAUTION

An overtightened setting on the injector adjusting screw will produce increased stress on the injector train and the camshaft injector lobe which can result in engine damage.

Use torque wrench, Part No. 3376592, to tighten the adjusting screw while holding the tappet in the maximum upward position.

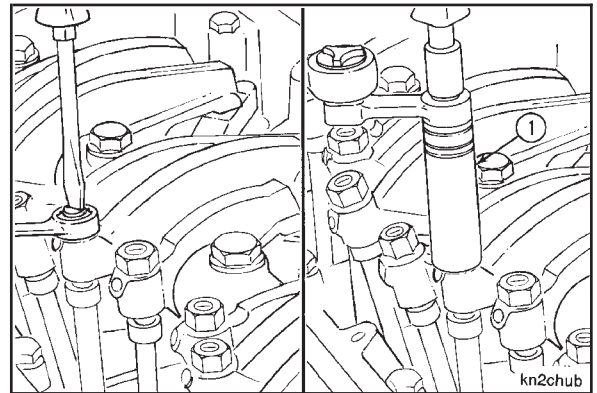
Torque Value: 0.6 to 0.7 N•m [5 to 6 in-lb]



Hold the adjusting screw in this position. The adjusting screw **must not** turn when the locknut is tightened.

Torque Value:

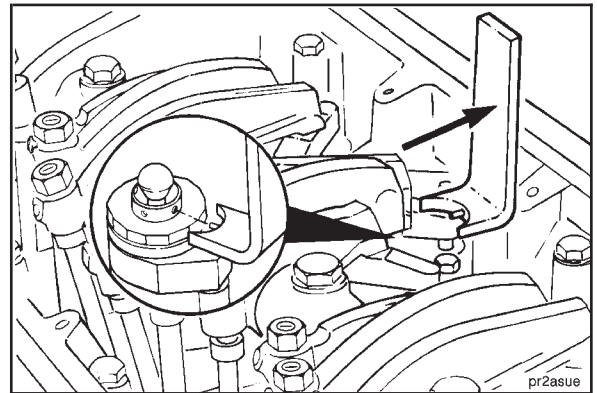
- **Without** Torque Wrench Adapter:
61 N•m [45 ft-lb]
- **With** Torque Wrench Adapter (1):
47 N•m [35 ft-lb]



The tappet tool **must** be removed before rotating the crankshaft to prevent damage to the tappet.

Remove the tappet adjusting tool.

Check to make sure the injector push rod can be rotated by hand. If it can't, the setting is too tight.



Valve Adjustment — STC Engines

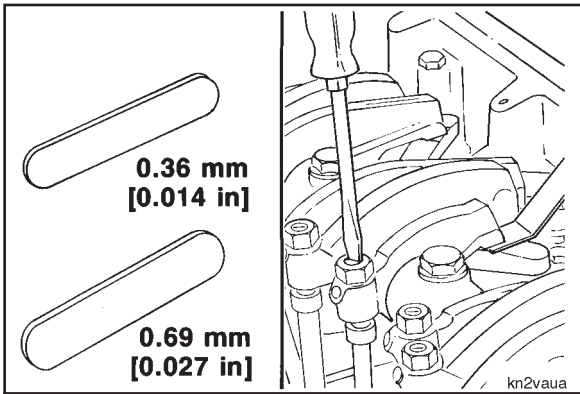
Adjust the valves on the appropriate cylinder according to the sequence chart before rotating the accessory drive to the next valve set mark.



STC Injector and Valve Adjustment Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder Injector	Set Cylinder Valve
Start	A	3	5
Advance to	B	6	3
Advance to	C	2	6
Advance to	A	4	2
Advance to	B	1	4
Advance to	C	5	1

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

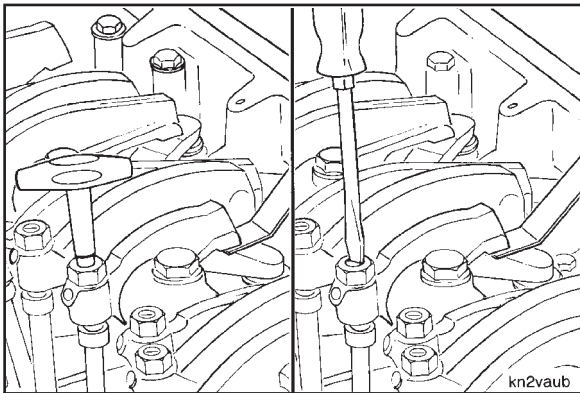
oi200vi



Select a feeler gauge for the correct valve lash specification.

	Valve Lash Specification	
	mm	in
Intake	0.36	0.014
Exhaust	0.69	0.027

Insert the feeler gauge between the top of the crosshead and the rocker lever pad.



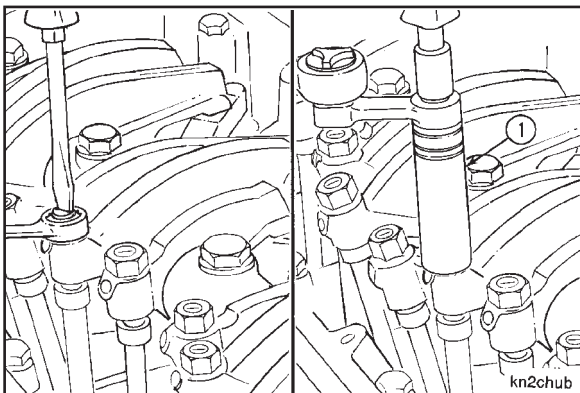
Two different methods for establishing valve lash clearance are described below. Either method can be used; however, the torque wrench method has proven to be the most consistent. It eliminates the need to feel the drag on the feeler gauge.



- **Torque Wrench Method:** Use the inch pound torque wrench. Part No. 3376592, (normally used to set preload on top stop injectors), and tighten the adjusting screw.

Torque Value: 0.7 N•m [6 in-lb]

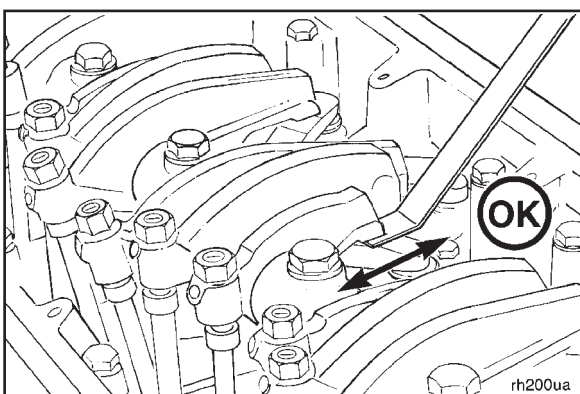
- **Touch Method:** Tighten the adjusting screw until a light drag is felt on the feeler gauge.



Hold the adjusting screw in this position. The adjusting screw **must not** turn when the locknut is tightened. Tighten the locknut.

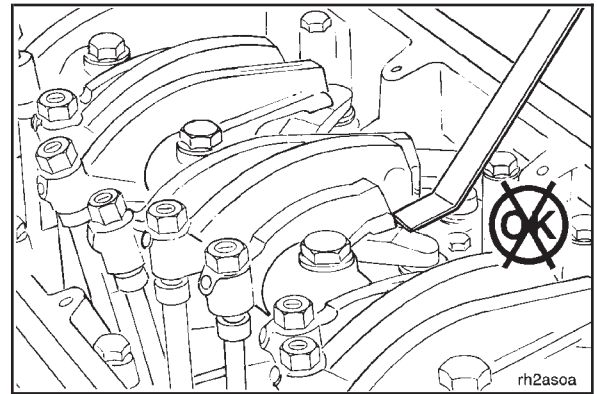
Torque Value:

- **Without Torque Wrench Adapter:**
61 N•m [45 ft-lb]
- **With Torque Wrench Adapter (1):**
47 N•m [35 ft-lb]

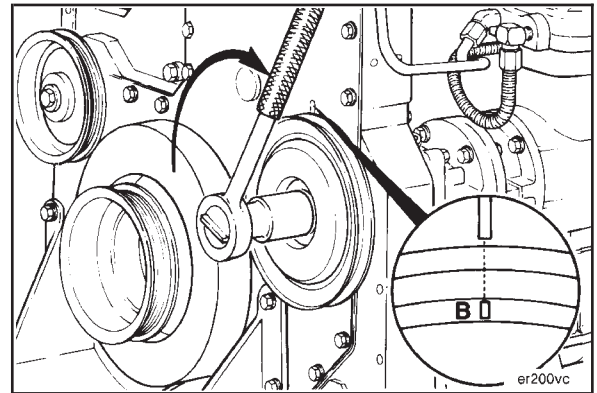


After tightening the locknut to the correct torque value, check to make sure the feeler gauge will slide backward and forward between the crosshead and the rocker lever with only a slight drag.

If using the touch method, attempt to insert a feeler gauge that is 0.03 mm [0.001 inch] thicker between the crosshead and the rocker lever pad. The valve lash is **not** correct when a thicker feeler gauge will fit.



After adjusting the valves, rotate the accessory drive and align the next valve set mark on the accessory drive pulley with the pointer on the gear cover.



Adjust the appropriate injector and valves following the Injector and Valve Adjustment Sequence Chart.



Repeat the process to adjust all injectors and valves.

After adjusting all the injectors and valves, check the torque on the adjusting screw locknuts to make sure none were overlooked.

STC			
Injector and Valve Adjustment Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder	
		Injector	Valve
Start	A	3	5
Advance to	B	6	3
Advance to	C	2	6
Advance to	A	4	2
Advance to	B	1	4
Advance to	C	5	1

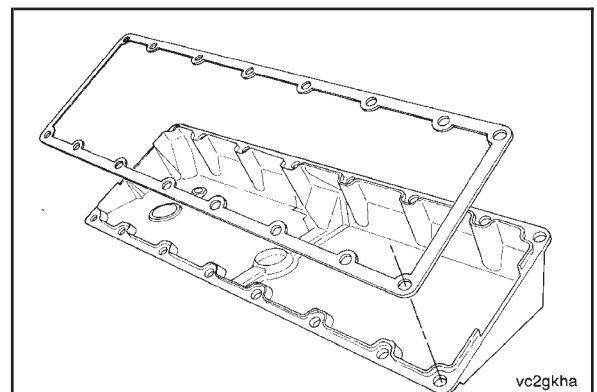
Firing Order: 1-5-3-6-2-4

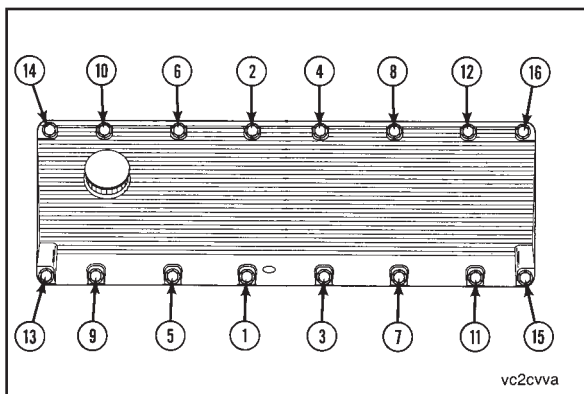
oi200vi

If the valve cover gasket was **not** damaged, it can be used again. If the gasket was damaged, it **must** be discarded and a new one used.



Install the gasket on the cover.





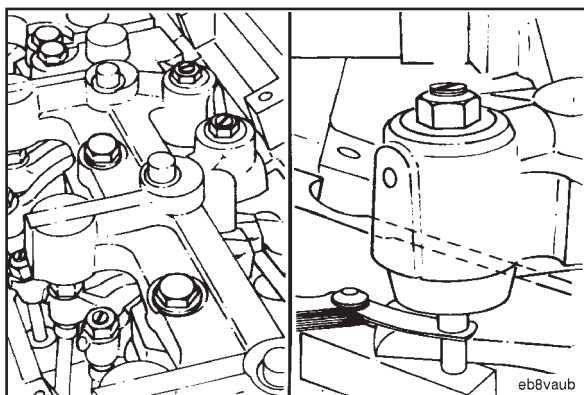
Install the cover on the rocker lever housing.

Install the 16 isolators, spacers and capscrews in the cover.

Tighten the capscrews in the sequence shown.



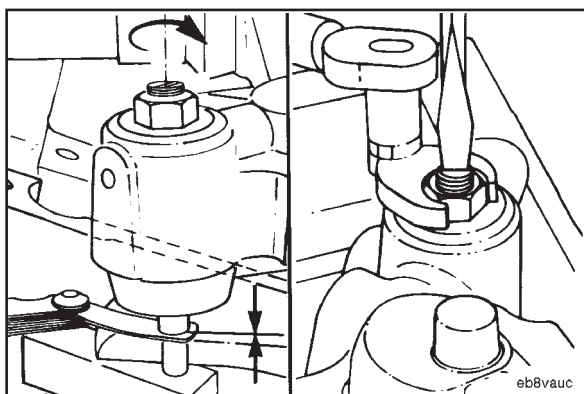
Torque Value: 15 N•m [130 in-lb]



Engine Brake — Adjust

NOTE: To obtain maximum brake operating efficiency and prevent engine damage by piston-to-valve contact, complete the following instructions carefully.

After adjusting the exhaust valves on the appropriate cylinder, insert a feeler gauge 0.38 mm [0.015 in] between the slave piston and the actuating pin in the crosshead.

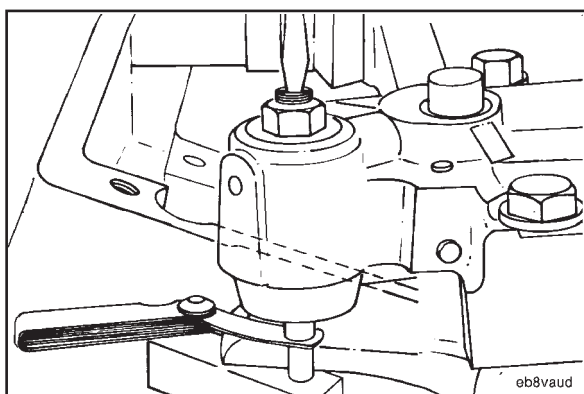


Turn the slave piston adjusting screw down until it touches the feeler gauge.

Hold the screw in position and tighten the locknut.

Torque Value:

- **Without** Torque Wrench Adapter:
34 N•m [25 ft-lb]
- **With** Torque Wrench Adapter:
30 N•m [22 ft-lb]



⚠ CAUTION ⚠

After the slave piston adjusting screw locknut is tightened to the correct torque value, check the clearance with the feeler gauge again. Do not tighten the adjusting screws too tight. The engine can be damaged.

Rocker Lever Assembly (003-009)

General Information

The M11 engine is built with one of two different types of rocker lever supports. Engines with the STC fuel system are built with aluminum supports (1). Engines built with the CELECT™ or CELECT™ Plus fuel system are built with a cast iron support (2) and retaining clamp (3).

The removal and installation of the rocker lever assemblies in the engine are the same. However, on engines with the cast iron supports a piece of 1/4 inch key stock and four M10 – 1.50 x 25 capscrews are used to lift the assemblies in and out of the engine. All other removal, inspection, and installation procedures are the same.

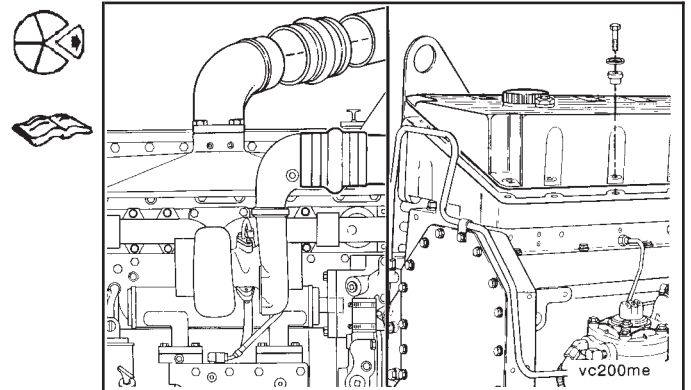
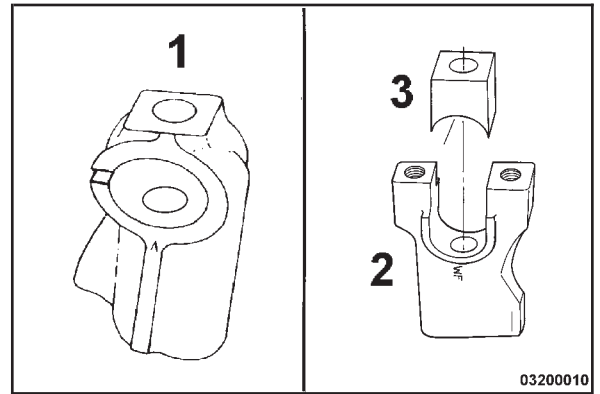
NOTE: Although the installation procedure is the same, the final torque value of the two types of supports is different. Both values are given.

The rocker levers and rocker lever shafts are the same regardless of which support the engine was built with.

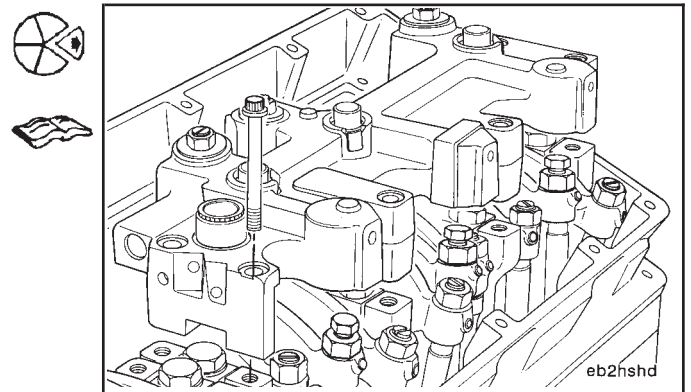
Remove (003-009-002)

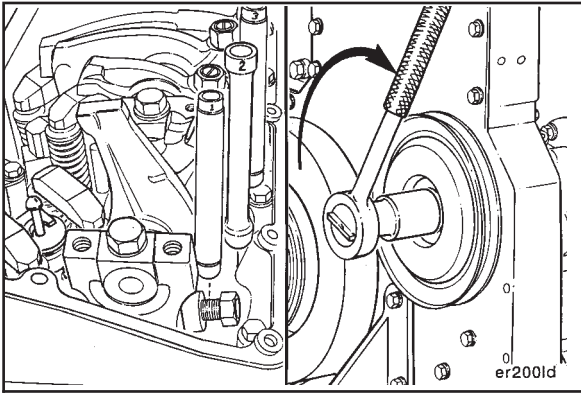
Remove the air piping from the intake manifold.

Remove the rocker lever cover. Refer to Procedure 003-011-002.

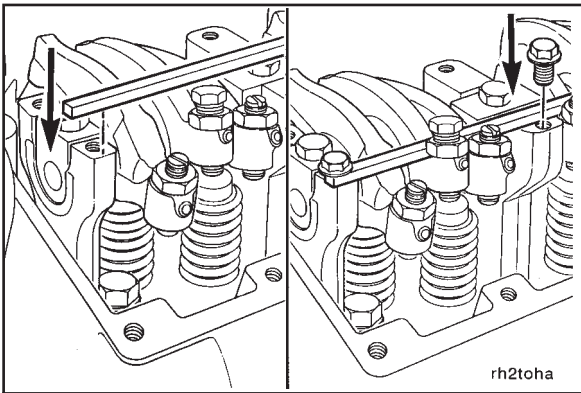


Remove the engine brakes, if equipped. Refer to Procedure 020-001-002.





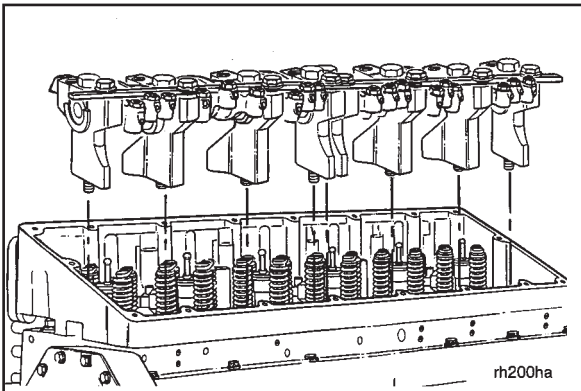
Remove the push rods and push tubes. Refer to Procedure 004-014-002.



NOTE: This action applies only to engines built with the cast iron supports.

Install a piece of 1/4 inch key stock 457 mm [18 in] long on top of the four front rocker lever assembly supports. Use four M10 - 1.50 x 25 flange head capscrews to secure the bar stock to the supports.

The capscrews on the two end supports will fasten to the engine brake mounting holes on one side of the bar stock. The capscrews on the two center supports will fasten to the engine brake mounting holes on the opposite side of the bar stock.



Loosen, but do **not** remove, the eight rocker shaft capscrews. The capscrews hold the rocker lever assemblies together.



On engines with the cast iron supports, grasp hold of the bar stock and lift the front rocker lever assembly from the engine. Do **not** lift the assemblies by grasping the rocker levers and shaft. The shaft and levers can lift out of the supports allowing the levers to slide off the shaft.

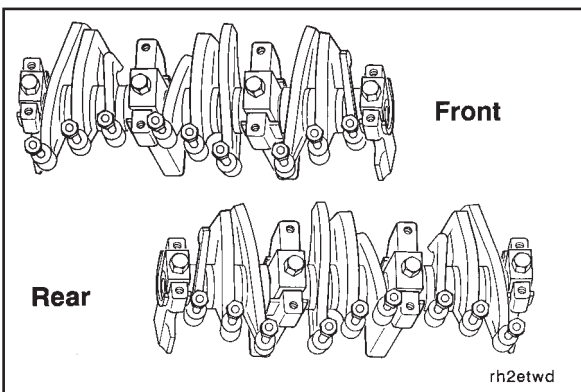
On engines with the aluminum supports, grasp hold of the assembly by the rocker levers and shaft and lift them from the engine.

Repeat the process to remove the rear rocker lever assembly.

Disassemble (003-009-003)

Mark each rocker lever, shaft and support with their relative position in the engine.

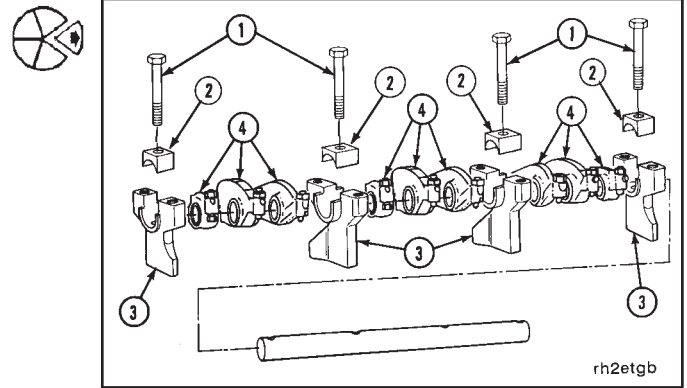
The rocker lever assemblies **must** be installed in the same position they were removed from.



Cast Iron Supports

Remove the rocker shaft capscrews (1) and retaining blocks (2). Lift the shaft and levers out of the supports (3).

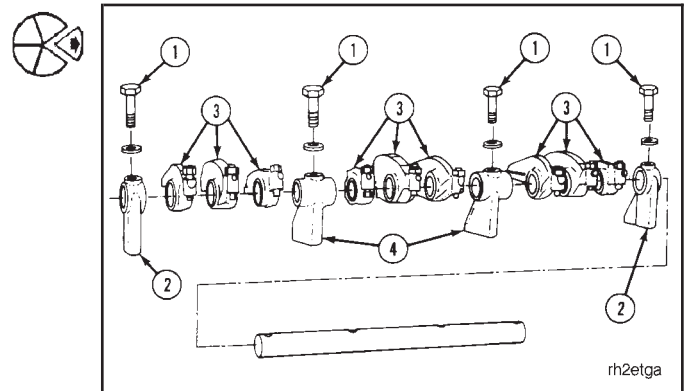
Remove the rocker levers (4) from both shaft assemblies.



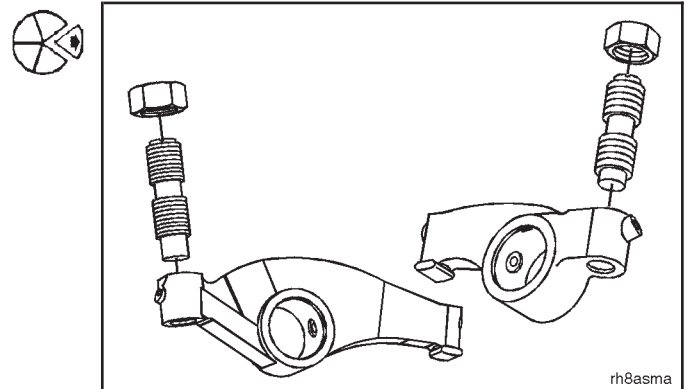
Aluminum Supports

Remove the rocker shaft capscrews (1) and end supports (2).

Remove the rocker levers (3) and middle supports (4) from both shaft assemblies.



Remove the locknuts and the adjusting screws from each rocker lever.



Clean (003-009-006)

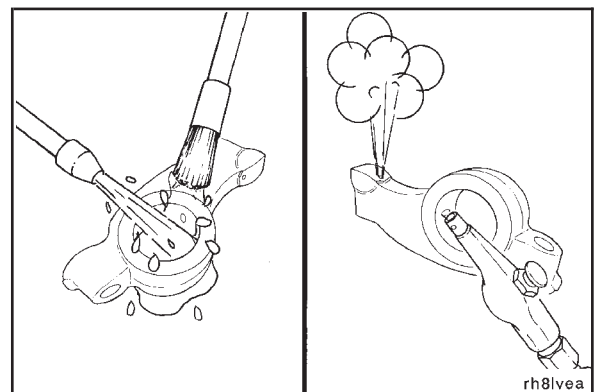


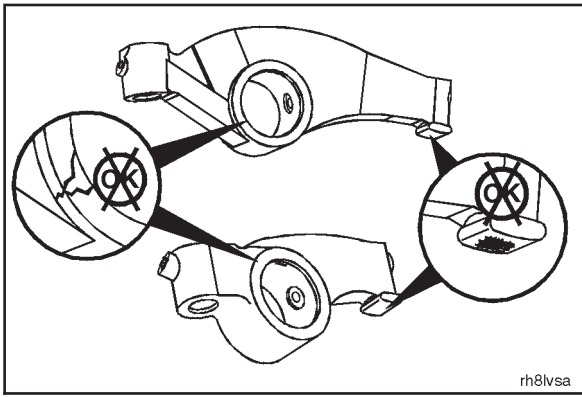
WARNING

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

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

Be sure to blow out the oil passages.



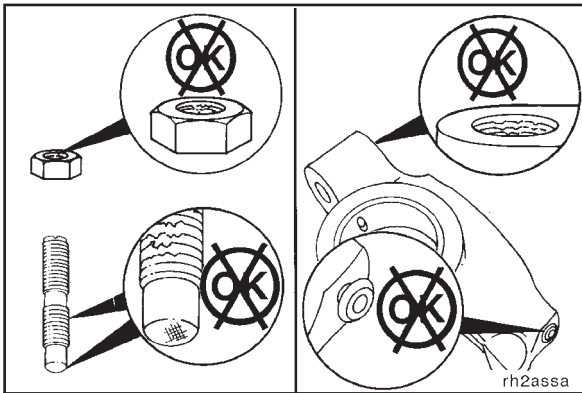


Inspect for Reuse (003-009-007)

Visually inspect the rocker levers for cracks, excessive pitting or unusual wear.



Refer to the Overhead Reuse Guidelines, Bulletin No. 3810388, to identify wear patterns and excessive wear.

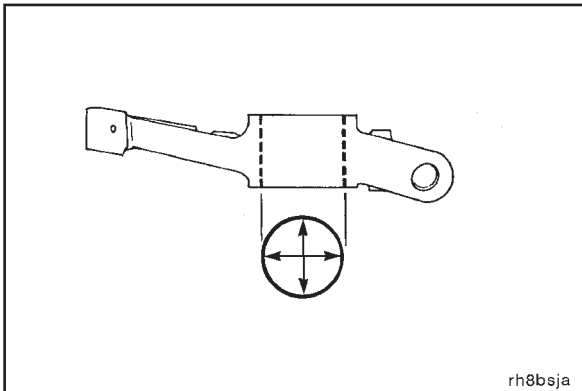


Visually inspect the adjusting screws and locknuts for damaged threads.

Visually inspect the adjusting screw threads in the rocker levers for damaged threads.

Visually inspect the rocker levers for loose rivets.

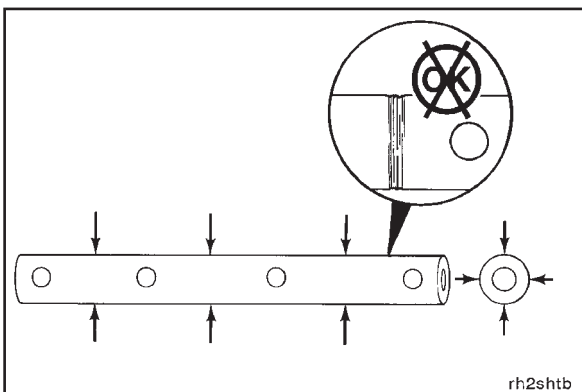
Visually inspect the adjusting screws for wear on the ball end.



Measure each rocker lever bushing bore inside diameter.

Rocker Lever Bushing I. D. (Installed)

mm		in
34.887	MIN	1.3735
34.990	MAX	1.3776



Visually inspect the rocker lever shafts for pitting, scoring, or other damage.



Measure each rocker lever shaft outside diameter.

Rocker Lever Shaft O. D.

mm		in
34.837	MIN	1.3715
34.864	MAX	1.3726



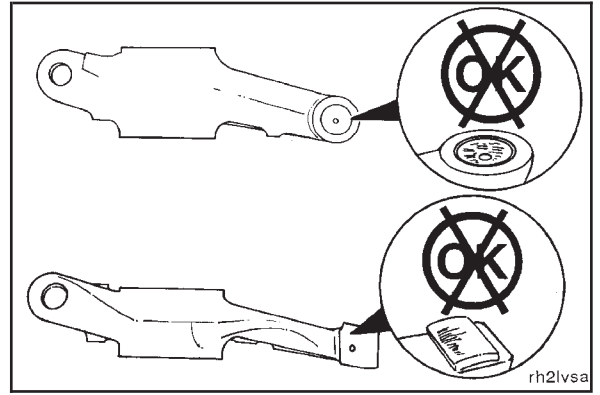
Refer to the Overhead Reuse Guidelines, Bulletin No. 3810388, to identify wear patterns and excessive wear.

If worn or damaged parts are found, or the rocker lever bushings or shafts are **not** within the specifications given, the rocker lever assemblies **must** be rebuilt. Refer to the M11 Shop Manual, Bulletin No. 3666075.

Visually inspect the sockets in the injector rocker levers for wear or damage.

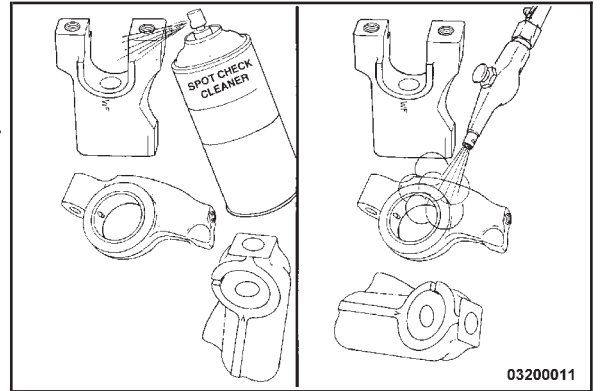
Visually inspect the valve rocker lever pads for wear, cracks, or other damage.

If wear, cracks, or other damage is found, the rocker lever **must** be replaced.



Use crack detection kit, Part No. 3375432, to inspect the rocker lever supports for cracks or damage.

Use crack detection cleaner, Part No. 3375433, to clean the rocker levers and shaft supports. Dry with compressed air.

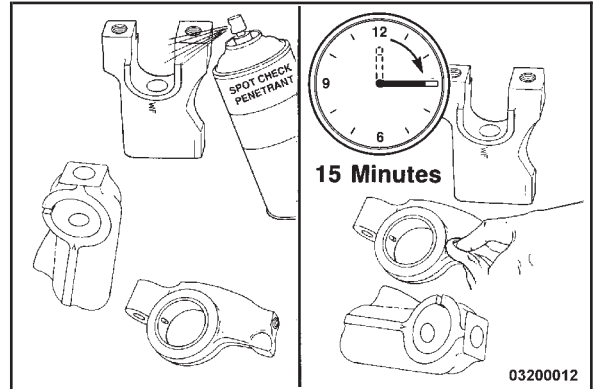


Use crack detection penetrant, Part No. 3375435, to spray the rocker levers and shaft supports.

NOTE: Do **not** dry with compressed air.

Allow the penetrant to dry for 15 minutes.

Remove the excess penetrant with a dry cloth.



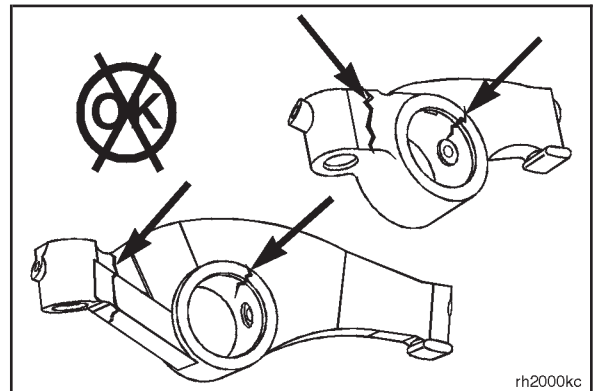
Use crack detection developer, Part No. 3375434, to spray the rocker levers and shaft supports.

Visually inspect the levers and supports.

Cracks will appear as a solid bright line.

Cavitation in the casting will appear as a small round mark.

If cracks or cavitation are found, the part **must** be replaced.



Assemble (003-009-025)

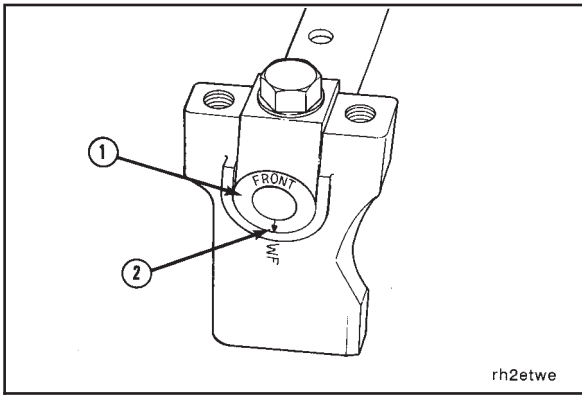
Cast Iron Supports



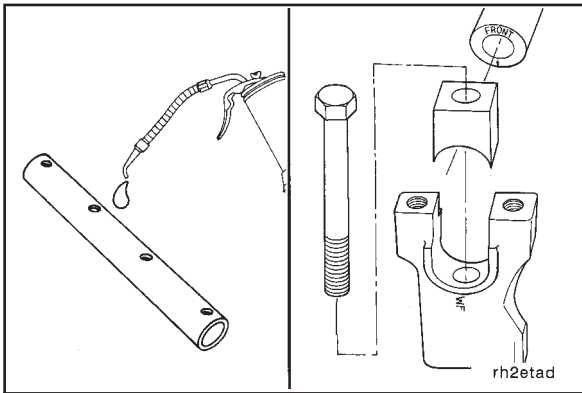
Ensure that the rocker lever shafts are installed with the arrow on the end of the shafts pointed downward. Failure to do so will prevent oil from lubricating the rocker levers.

The rocker lever shafts are labeled front and rear on the end of the shafts (1). The arrows on the shafts (2) **must** be pointed downward to ensure an oil flow to the rocker levers.

The shaft end supports are **not** interchangeable.



rh2etwe



rh2etad

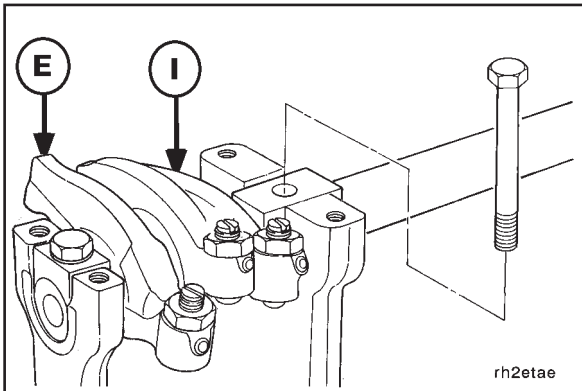


Use clean 15W-40 oil to lubricate both shafts.

Install the front end support on each shaft.



Install the retaining blocks, washers and capscrews through the end supports.



rh2etae

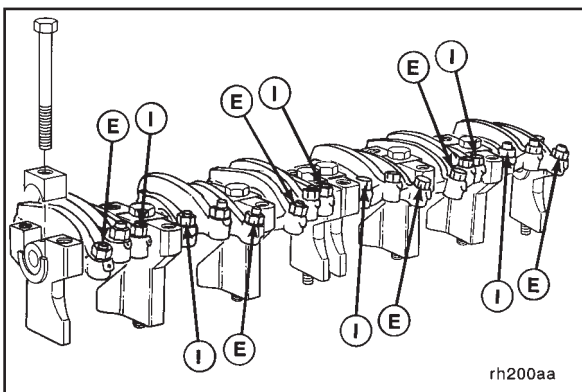


Install the rocker levers in the correct sequence as shown.

NOTE: The rocker levers **must** be installed so they will be in the same position in the engine as when they were removed.

Install one of the two shaft center supports on the shaft.

Install the retaining block, washer and capscrew through the center support.



rh200aa



Install the remaining levers and supports with the intake (I) and exhaust (E) valve levers in the correct position as shown.

Install the remaining retaining blocks, washers and capscrews.

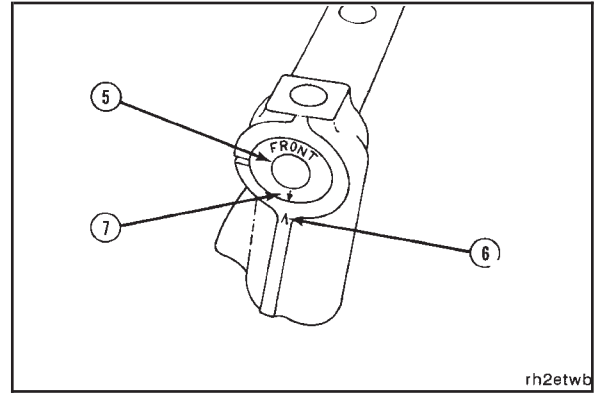
Install the key stock used to remove the rocker levers on top of the supports.

Aluminum Supports



Ensure that the rocker lever shafts are installed with the arrow on the end of the shafts pointed downward. Failure to do so will prevent oil from lubricating the rocker levers.

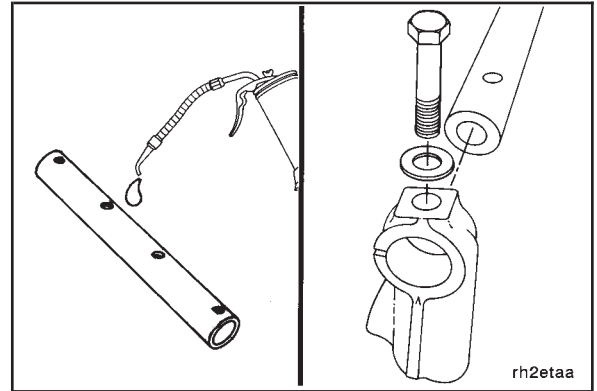
The rocker lever shafts are labeled front and rear on the end of the shafts (5). The shaft end supports have arrows (6) stamped on them to align with arrows (7) stamped on the ends of both rocker lever shafts. The arrows on the shafts and the shaft end support **must** be aligned to be installed correctly. The shaft end supports are **not** interchangeable.



Use clean 15W-40 oil to lubricate both shafts.

Install the front end support on each shaft.

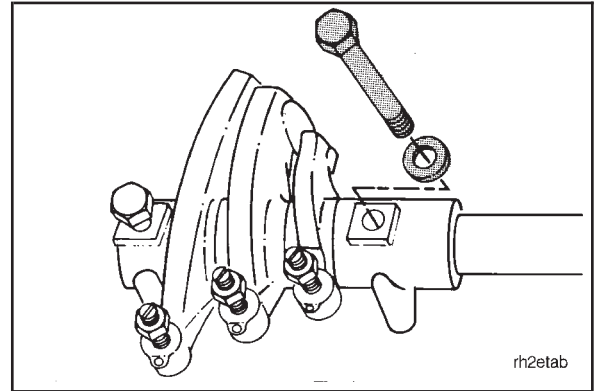
Install the washers and capscrews through the end supports.



Install the rocker levers in the correct sequence as shown.

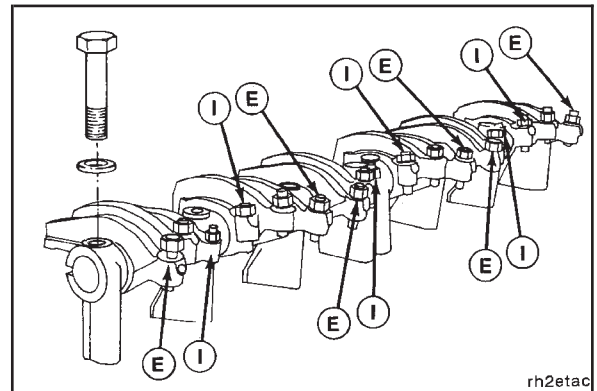
NOTE: The rocker levers **must** be installed so they will be in the same position in the engine as when they were removed.

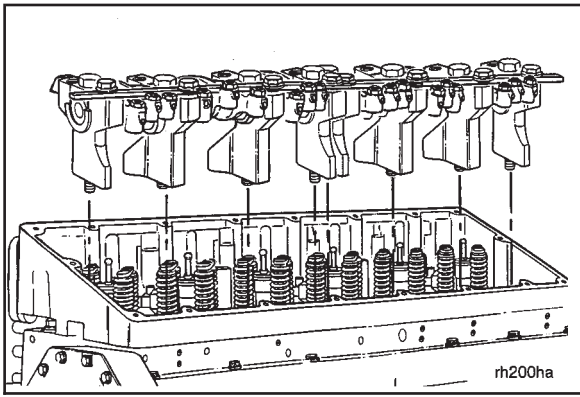
Install one of the two shaft center supports on the shaft.
Install the capscrew and washer through the center support.



Install the remaining levers and supports with the intake (I) and exhaust (E) valve levers in the correct position as shown.

Install the remaining capscrews and washers.





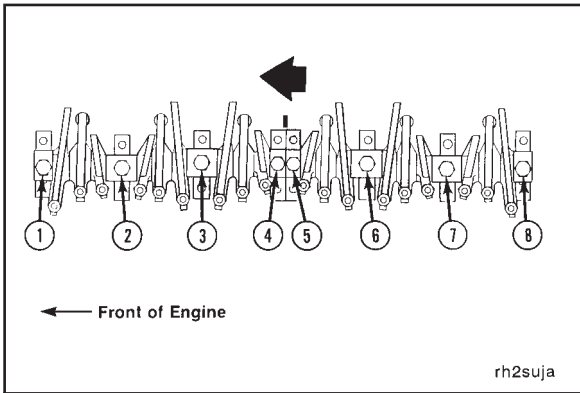
Install (003-009-026)

The rocker lever assemblies **must** be installed in the engine so they are in same position as they were removed from.



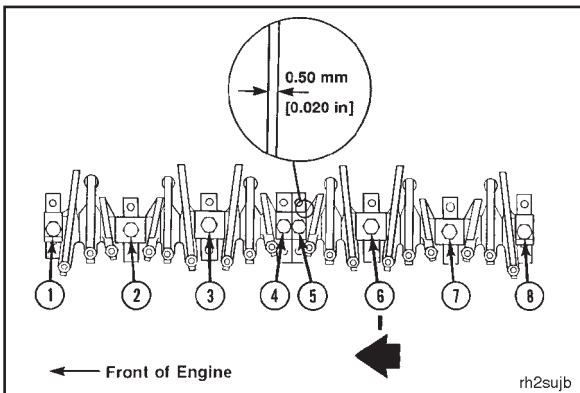
Install the assemblies on the engine.

Hand tighten the mounting capscrews at this time. The rocker lever side clearance **must** be adjusted before the capscrews are tightened to their final torque value.



Push or use a hammer to tap the number five rocker lever support toward the front of the engine.

Torque the mounting capscrews to 5 N•m [45 in-lb] at this time.

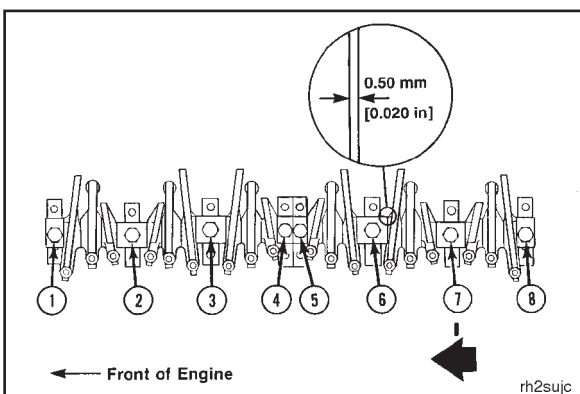


Install a 0.50 mm [0.020 inch] feeler gauge between the number five support and the intake lever for the number four cylinder.



Push or use a hammer to tap the number six support toward the front of the engine.

Torque the mounting capscrews to 5 N•m [45 in-lb] at this time.



Install a 0.50 mm [0.020 inch] feeler gauge between the number six support and the exhaust lever for the number five cylinder.



Push or use a hammer to tap the number seven support toward the front of the engine.

Torque the mounting capscrews to 5 N•m [45 in-lb] at this time.

M11 Series
Section 3 - Rocker Levers - Group 03

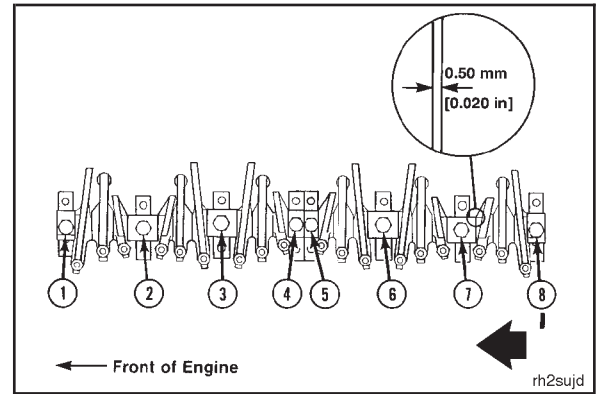
Install a 0.5 mm [0.020 inch] feeler gauge between the number seven support and the intake lever for the number six cylinder.

Push or use a hammer to tap the number eight support toward the front of the.

Tighten the No. 5, 6, 7, and 8 support capscrews to their final torque.

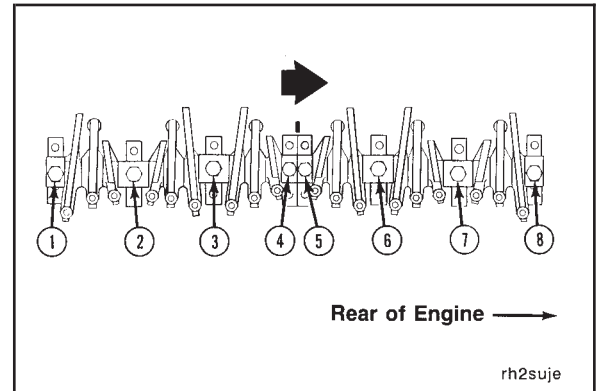
Torque Value:

Cast Iron	183 N•m	[135 ft-lb]
Aluminum	122 N•m	[90 ft-lb]



Push or use a hammer to tap the number four support toward the rear of the engine.

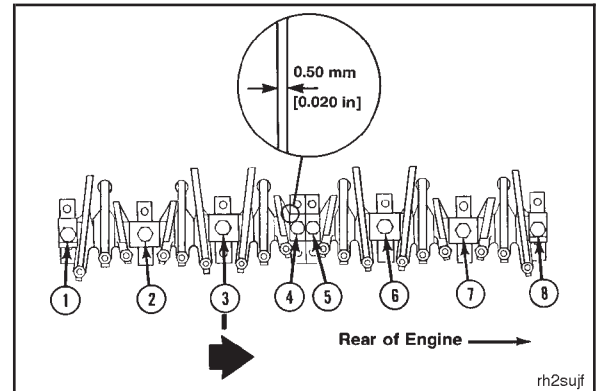
Torque the mounting capscrews to 5 N•m [45 in-lb] at this time.



Install a 0.5 mm [0.020 inch] feeler gauge between the number four support and the intake lever for the number three cylinder.

Push or use a hammer to tap the number three support toward the rear of the engine.

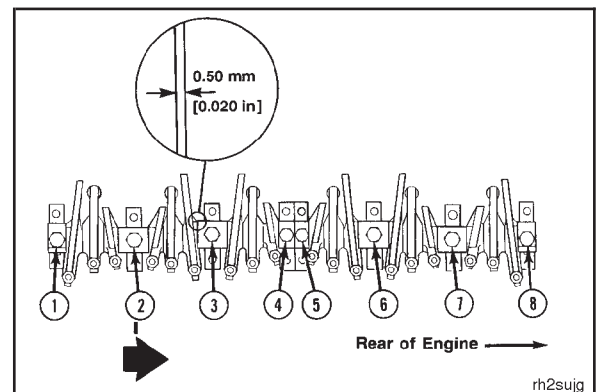
Torque the mounting capscrews to 5 N•m [45 in-lb] at this time.

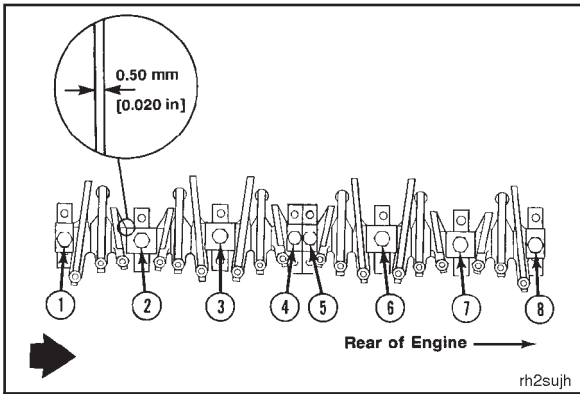


Install a 0.5 mm [0.020 inch] feeler gauge between the number three support and the exhaust lever for the number two cylinder.

Push or use a hammer to tap the number two support toward the rear of the engine.

Torque the mounting capscrews to 5 N•m [45 in-lb] at this time.





Install a 0.50 mm [0.020 inch] feeler gauge between the number two support and the intake lever for the number one cylinder.



Push or use a hammer to tap the number one support toward the rear of the engine.

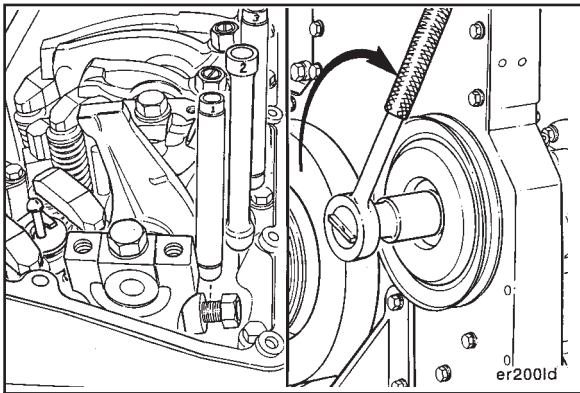
Tighten the No. 1, 2, 3, and 4 support capscrews to their final torque.



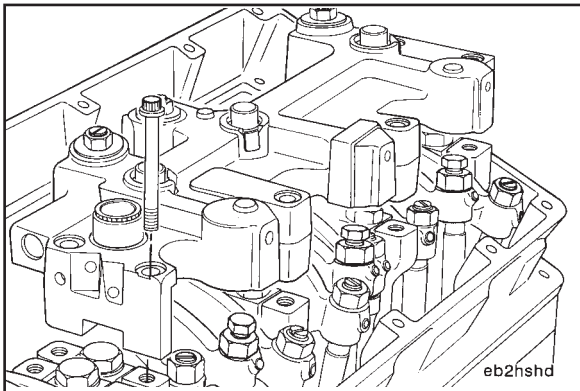
Torque Value:

Cast Iron	183 N•m	[135 ft-lb]
Aluminum	122 N•m	[90 ft-lb]

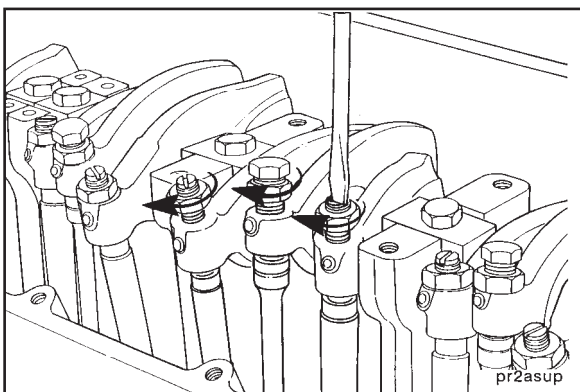
Check the front and rear assemblies for correct clearance. Check the support capscrews for the correct torque value.



Install the push rods and push tubes. Refer to Procedure 004-014-026.



Install the engine brakes, if applicable. Refer to Procedure 020-001-026.

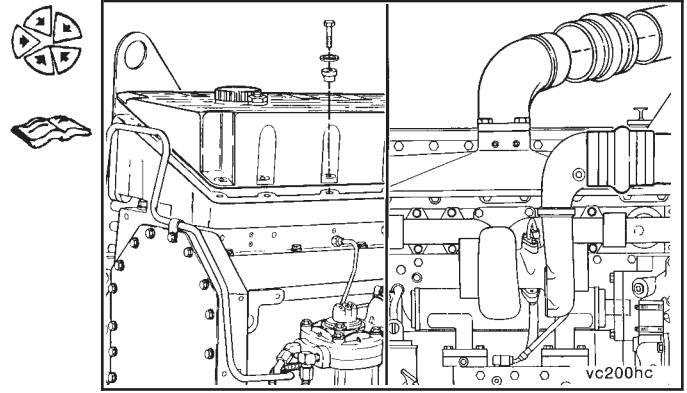


Adjust the valves and injectors. Refer to Procedure 003-004-029.



Install the rocker lever cover. Refer to Procedure 003-011-026.

Install the air piping to the intake manifold. Refer to the manufacturer's specifications for the correct torque value.



Rocker Lever Cover (003-011)

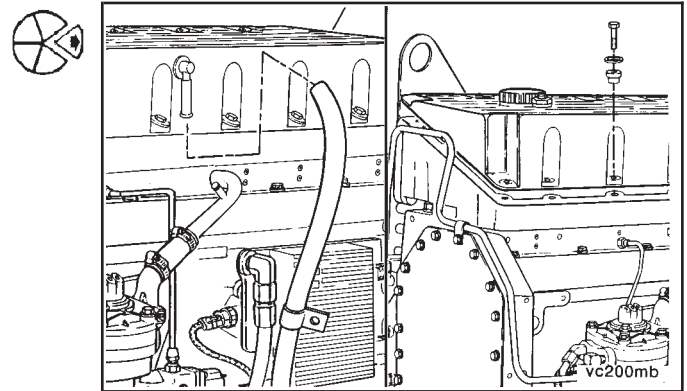
Remove (003-011-002)

Remove the air piping from the intake manifold.

Remove the hose from the crankcase breather.

Remove the 16 capscrews and the rocker lever cover.

Remove the 16 isolators from the cover.



Clean (003-011-006)

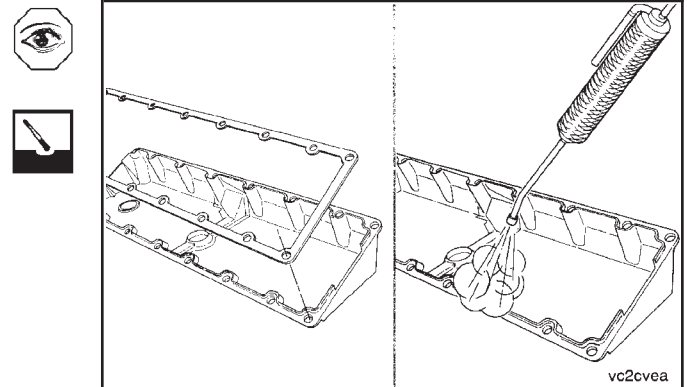
Remove the gasket and inspect for damage.

NOTE: The gasket can be reused if it is **not** damaged.



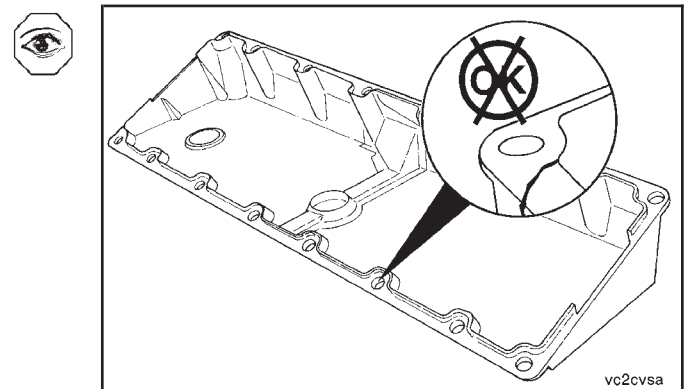
When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

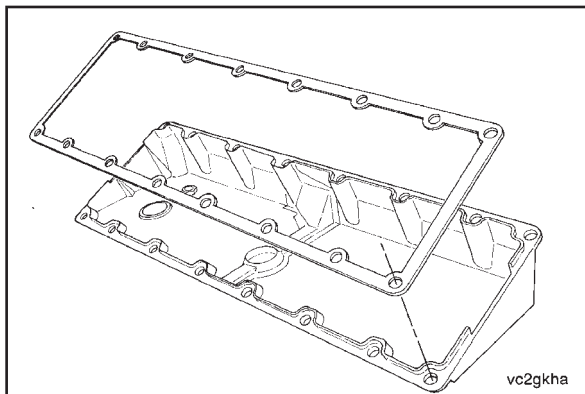
Steam clean and dry with compressed air.



Inspect for Reuse (003-011-007)

Inspect the cover for cracks or damage and replace if necessary.

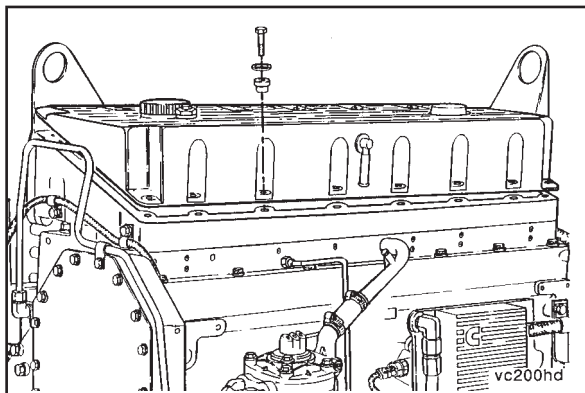




Install (003-011-026)

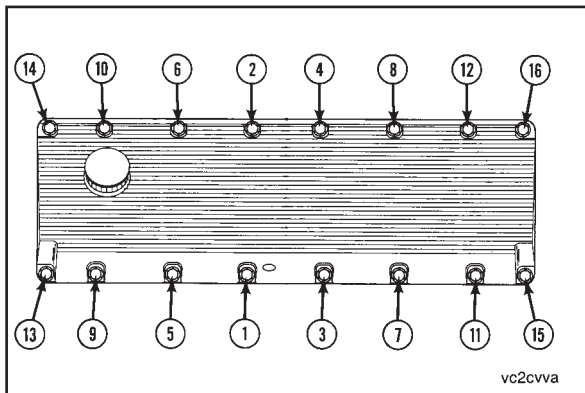
If the gasket was **not** damaged, it can be used again. If the gasket was damaged, it **must** be discarded and a new one used.

Install the gasket on the cover.



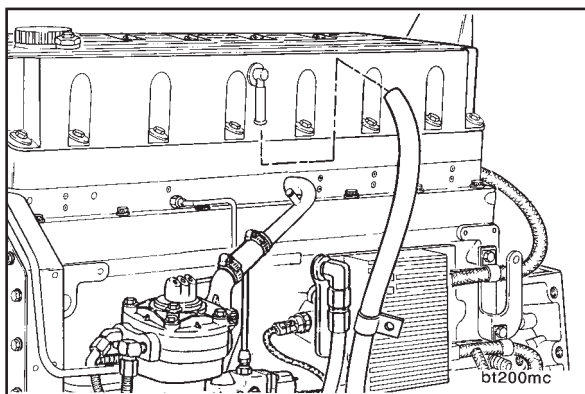
Install the cover on the rocker lever housing.

Install the 16 isolators, spacers and capscrews in the cover.



Tighten the capscrews in the sequence shown.

Torque Value: 15 N•m [130 in-lb]



Install the hose on the crankcase breather.

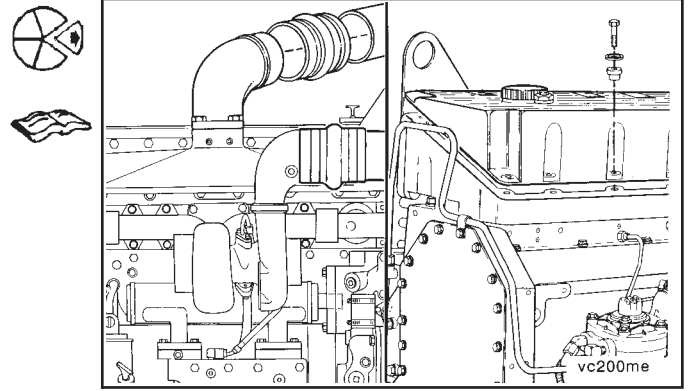
Install the air piping to the intake manifold. Refer to the manufacturer's specifications for the correct torque values.

Rocker Lever Housing (003-013)

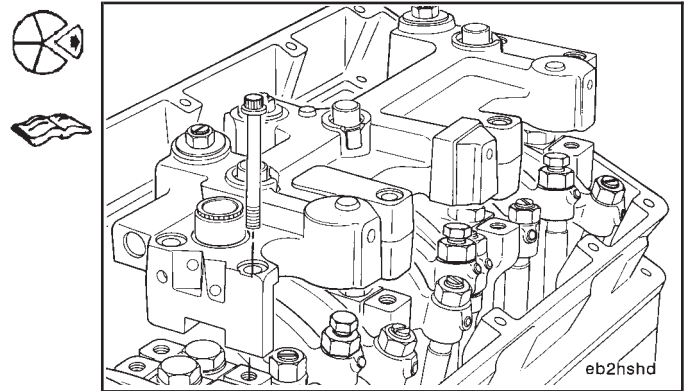
Remove (003-013-002)

Remove the air piping from the intake manifold.

Remove the rocker lever cover. Refer to Procedure 003-011-002.



Remove the engine brakes, if applicable, from the engine. Refer to Procedure 020-001-002.

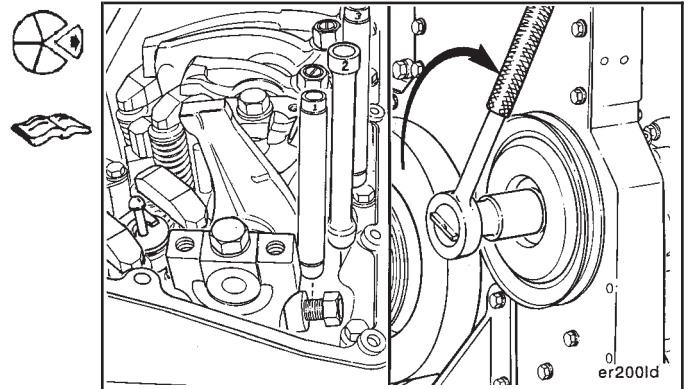


Remove all valve push tubes and injector push rods from the engine. Refer to Procedure 004-014-002.

Rotate the rocker levers up.

NOTE: Mark the position of the crossheads as they are removed. They **must** be installed in the same position as from which they were removed.

Remove the crossheads to prevent them from falling into the lower area of the engine.

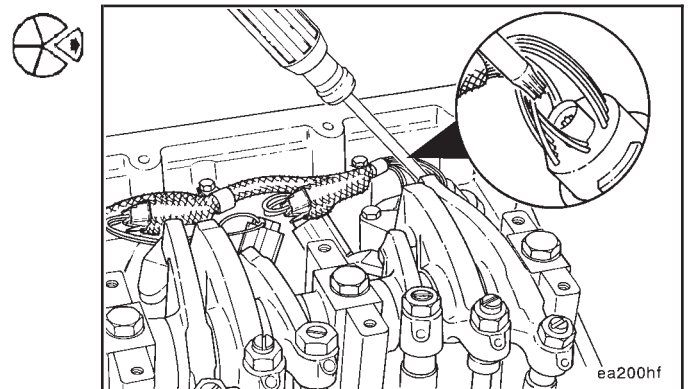


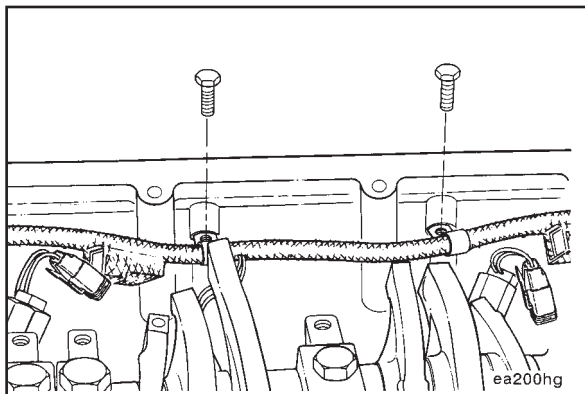
NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

The internal engine harness is located inside the rocker housing.

Remove the locking capscrew from the Metri-Pack 12-pin connector at the rear end of the rocker lever housing and separate the connector.

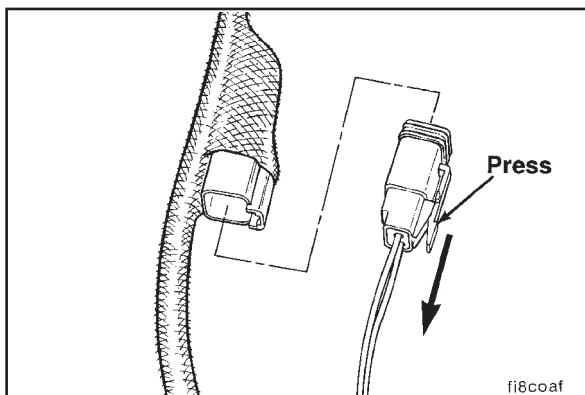
NOTE: The connector is held together with a Torx® (six pointed star) screw. Use a Torx® (size T-25) screwdriver to disconnect this connector.





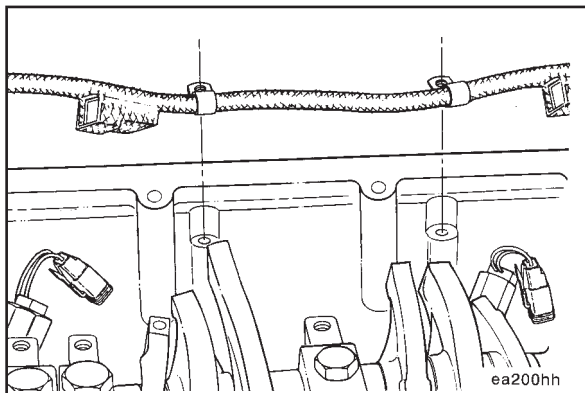
NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Remove the internal engine harness holding clamp capscrews.



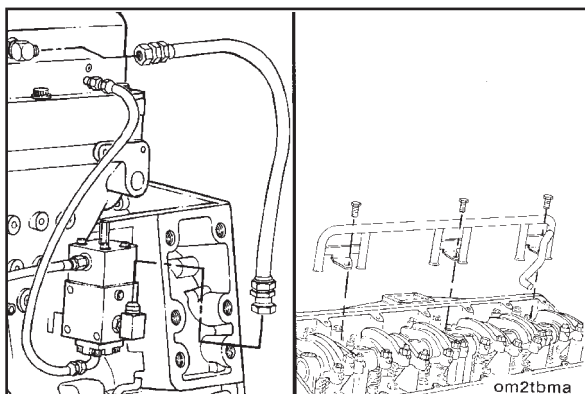
NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Separate the Deutsch 2-pin connectors from the internal engine harness to the fuel injectors.



NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Remove the internal engine harness from the engine.

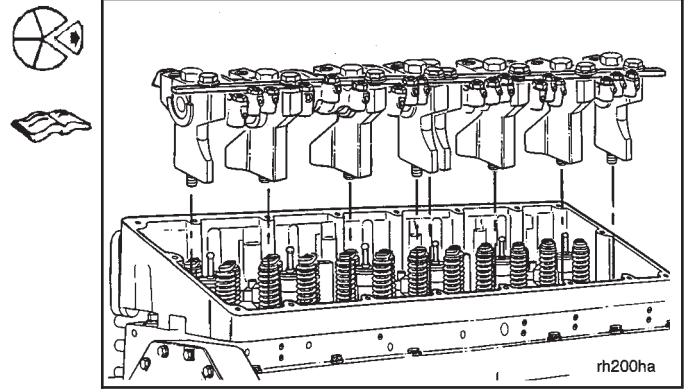


NOTE: This action applies to STC engines only.

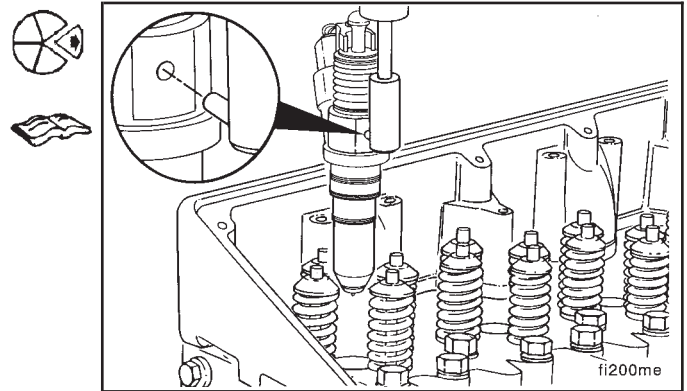
Disconnect the oil supply line and remove the STC oil manifold. Refer to Procedure 006-038-002.



Remove the rocker lever assemblies. Refer to Procedure 003-009-002.

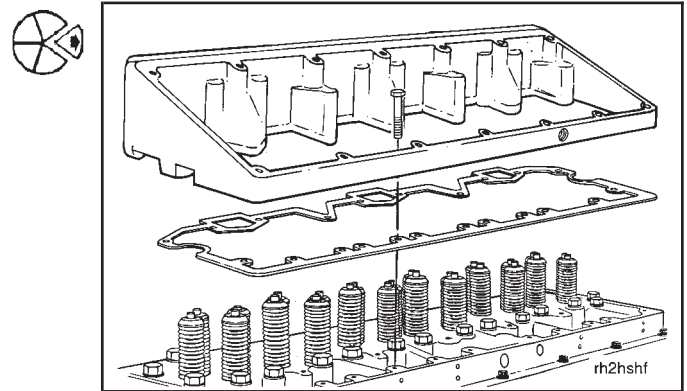


Remove the injectors. Refer to Procedure 006-026-002.



Remove the rocker housing mounting capscrews.
Remove the rocker housing and the intake manifold as a complete unit.

NOTE: If you are troubleshooting high blowby, the rocker housing gasket **must** be inspected before it is removed from the cylinder head.



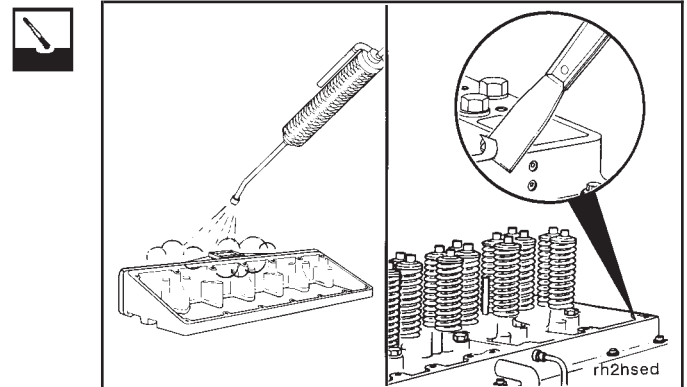
Clean (003-013-006)

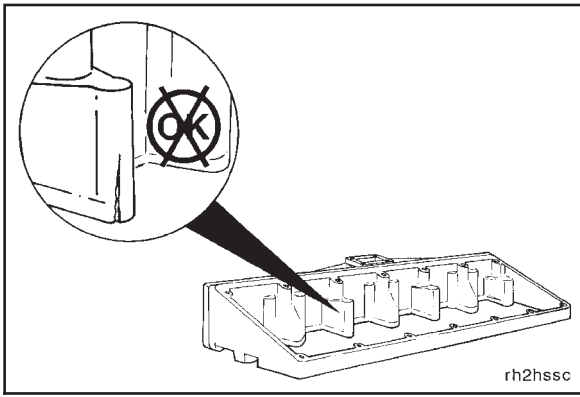


When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

Use steam to clean the rocker lever housing. Dry with compressed air.

Clean the cylinder head gasket surface.



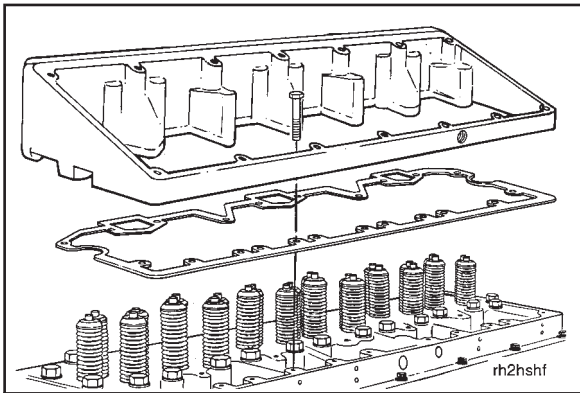


Inspect for Reuse (003-013-007)

Visually inspect the rocker housing gasket for cuts or damage on the portion of the gasket which seals around the intake ports. Damage to the gasket can cause high blowby.

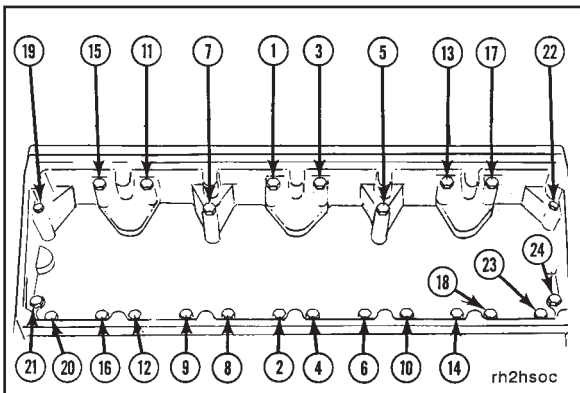
Visually inspect the housing for cracks or damage.

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



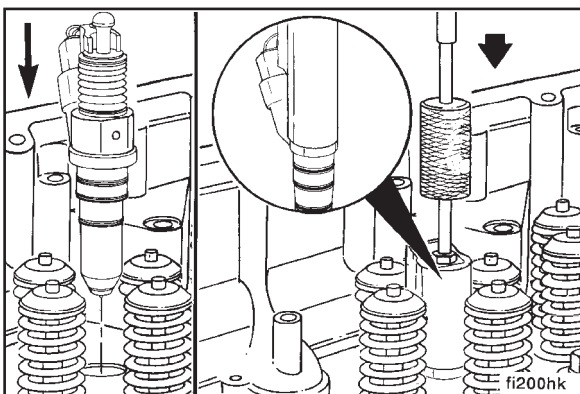
Install (003-013-026)

Use a new gasket and install the rocker lever housing.



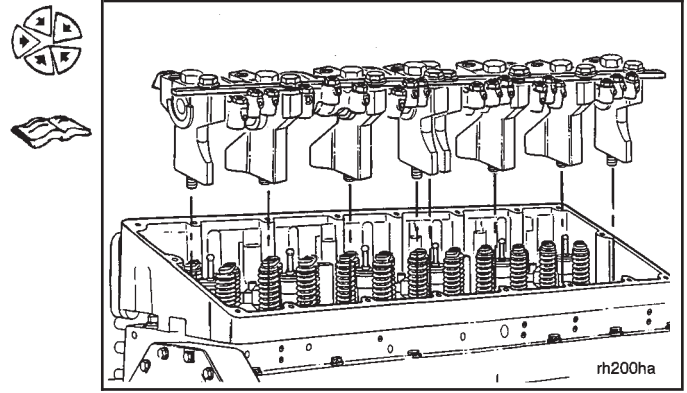
Torque the 24 capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]



Install the injectors. Refer to Procedure 006-026-026.

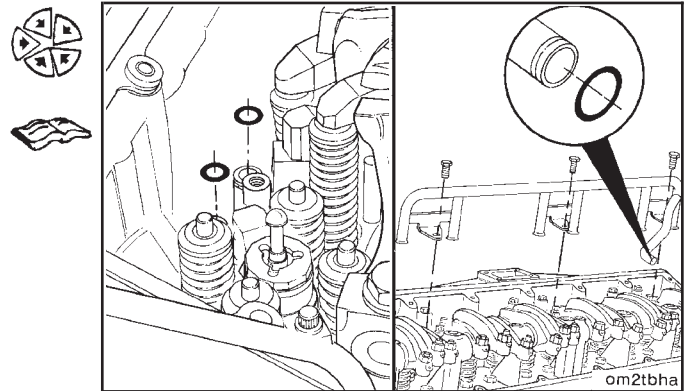
Install the rocker lever assemblies. Refer to Procedure 003-009-026.



NOTE: This action applies to STC engines only.

Install new o-rings on the STC oil connection blocks and STC oil manifold.

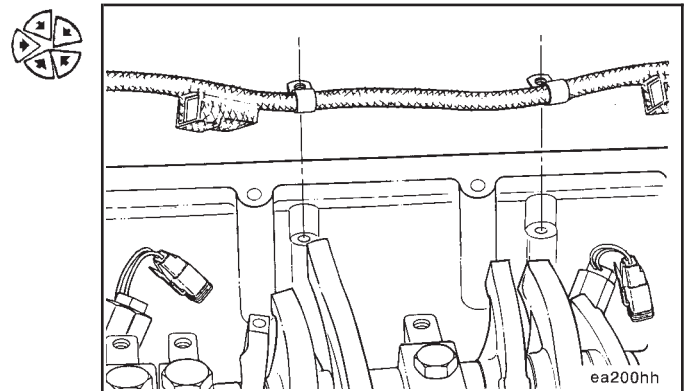
Install the STC oil manifold. Refer to Procedure 006-038-026.



NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Install the internal engine wiring harness on the engine.

The harness and connectors **must** be clear of any moving parts, so the wires will **not** be damaged during engine operation.



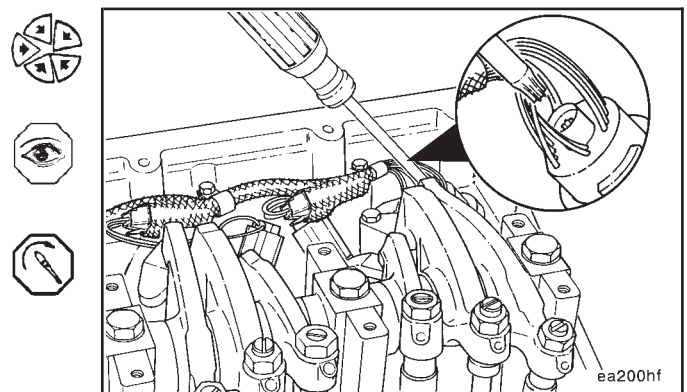
NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

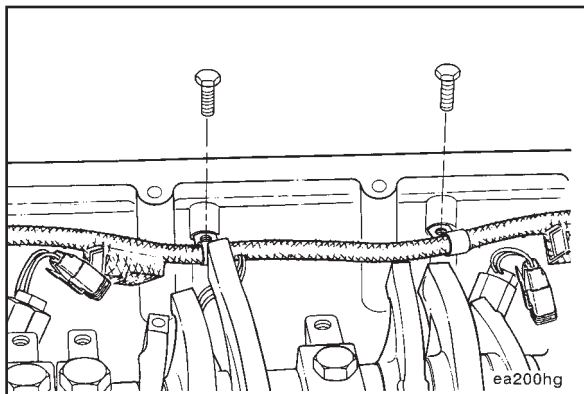
Connect the 12-pin connector of the internal engine harness to the 12-pin connector of the external engine harness.

NOTE: The internal and external Metri-Pack connectors are "keyed". Make sure both connectors are correctly aligned when they are joined together.

Install the locking capscrew (Torx® size T-25). Tighten the capscrew.

Torque Value: 3 N•m [25 in-lb]



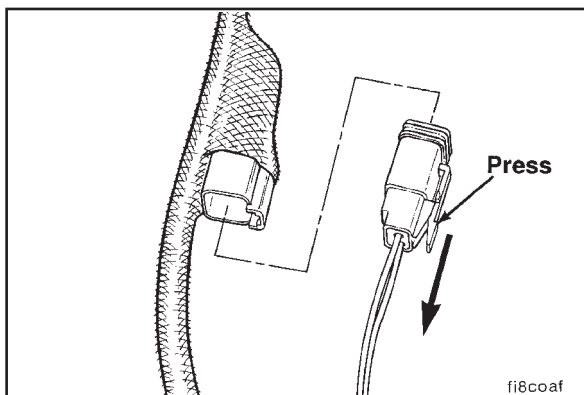


NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Install the holding clamps for the internal engine harness. Tighten the capscrews.



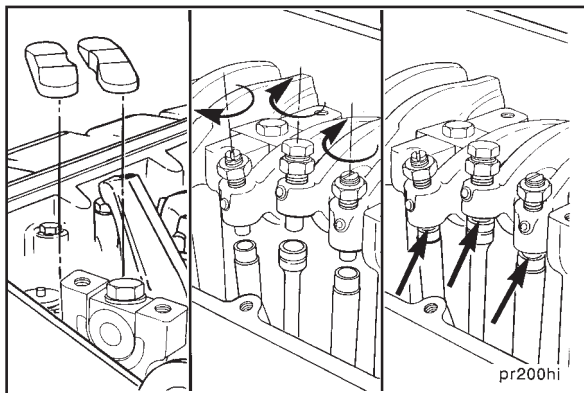
Torque Value: 20 N•m [15 ft-lb]



NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

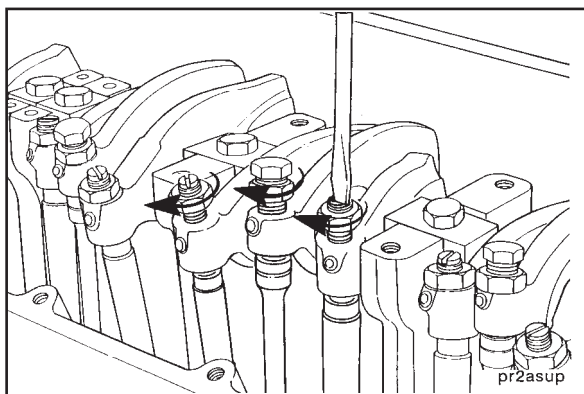
Lubricate the connector ends with lubricant, Part No. 3822934.

Connect the Deutsch 2-pin connectors from the internal engine harness to the fuel injectors.



Install the crossheads in the same position they were removed from, and rotate the rocker levers down.

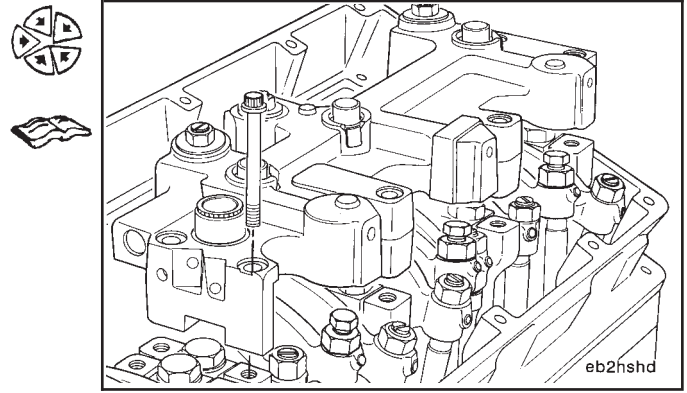
Install the push rods and push tubes. Refer to Procedure 004-014-026.



Adjust the valves and injectors. Refer to Procedure 003-004-029.

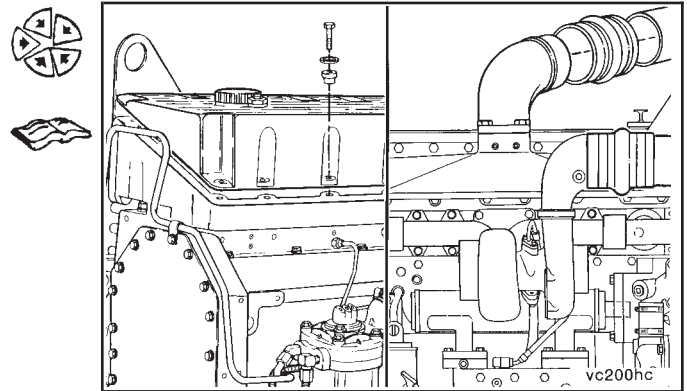


Install the engine brakes, if applicable. Refer to Procedure 020-001-026.



Install the rocker lever cover. Refer to Procedure 003-011-026.

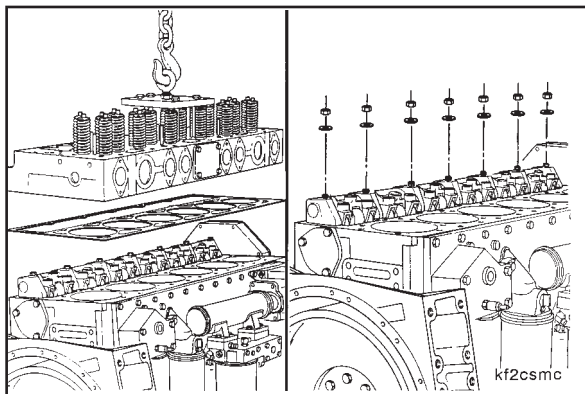
Install the air piping to the intake manifold. Refer to the manufacturer's specifications for the correct torque value.



Section 4 - Cam Followers/Tappets - Group 04

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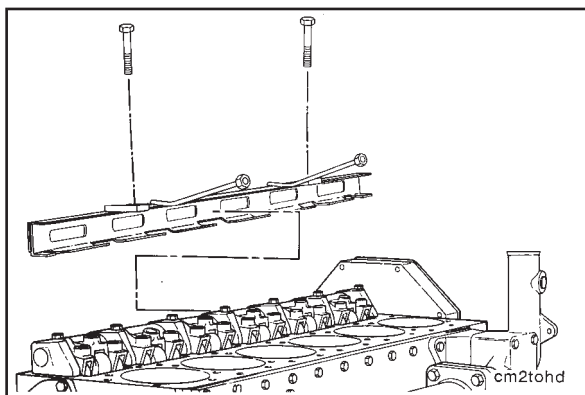
Cam Follower Assembly (004-001)

Remove (004-001-002)



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

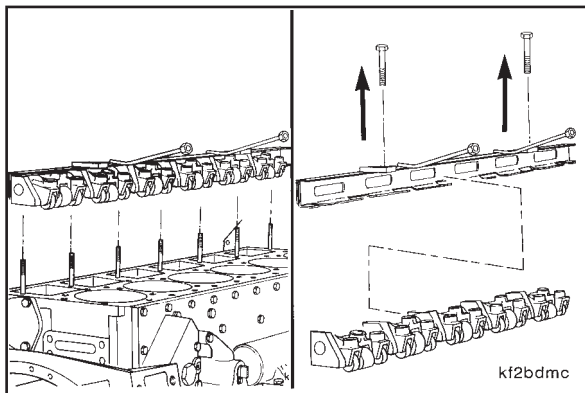
Remove the nuts and washers from the cam follower assembly supports.



Install the cam follower assembly installation and removal tool, Part No. 3824519. Slide the tool under the assemblies with the supports located in the cutouts on the bottom surface of the tool.

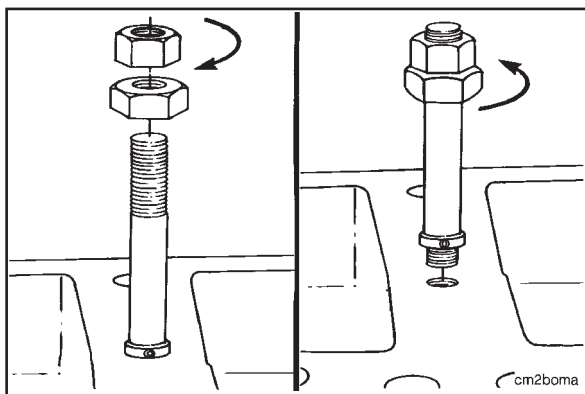
NOTE: The cam follower assembly consists of two shaft assemblies with a common center support.

Secure the tool to the assemblies by hand tightening the screws on top of the tool.



Lift both ends of the cam follower assemblies to remove them from the engine.

Set the assemblies on a flat surface. Loosen the two screws on top of the tool and remove the tool from the cam follower assemblies.



Install two M10 x 1.50 nuts on each stud.

Tighten the nuts together.

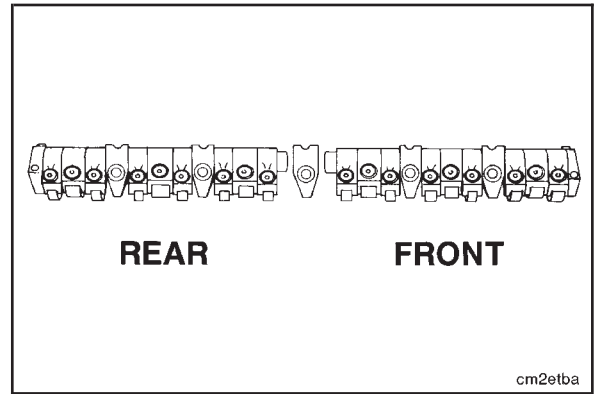
Turn the bottom nut **counterclockwise** to remove the stud.

NOTE: The cam follower studs have an internal oil passage to supply the cam followers with lubricating oil. The studs **must** be removed and checked.

Disassemble (004-001-003)

Separate the two shafts from the center support.

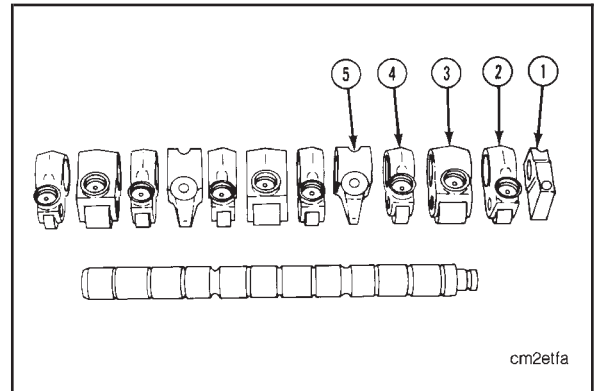
NOTE: The cam follower levers **must** be installed in the same position they were removed from. Mark both of the end supports, the center support and all of the cam followers to identify their location when they are removed. The end supports are **not** interchangeable. The center support is **not** interchangeable with any of the other inner supports.



Remove the end supports (1) from the shafts.

Remove the cam followers and supports from both shafts.

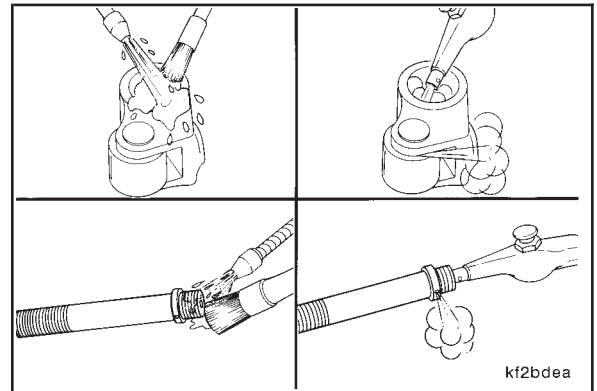
- Valve cam follower (2)
- Injector cam follower (3)
- Valve camfollower (4)
- Shaft support (5)



Clean (004-001-006)

Clean the cam follower parts with solvent and dry with compressed air.

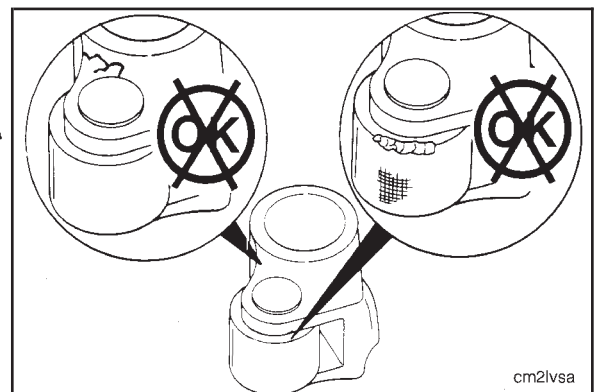
Make sure the oil passages in the cam followers and the cam follower studs are clean.

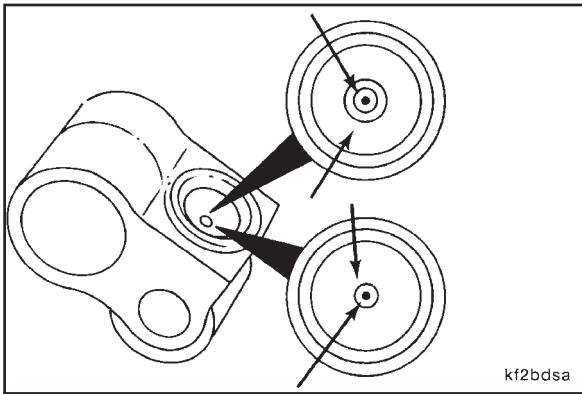


Inspect for Reuse (004-001-007)

Visually inspect the cam followers for cracks or other damage.

Refer to Camshaft Reuse Guidelines, Bulletin No. 3666052, for visual inspection criteria of cam follower rollers.



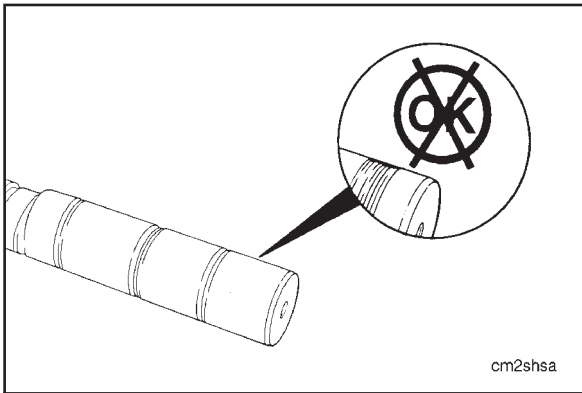


Visually inspect the cam follower sockets for excessive wear.

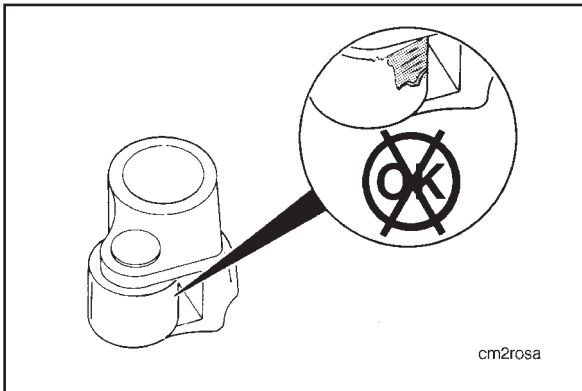


If excessive wear is found in the cam follower sockets, the push rods **must** be inspected. Refer to Procedure 004-014-007. Refer to the Overhead Reuse Guidelines, Bulletin No. 3810388, to identify wear patterns and excessive wear.

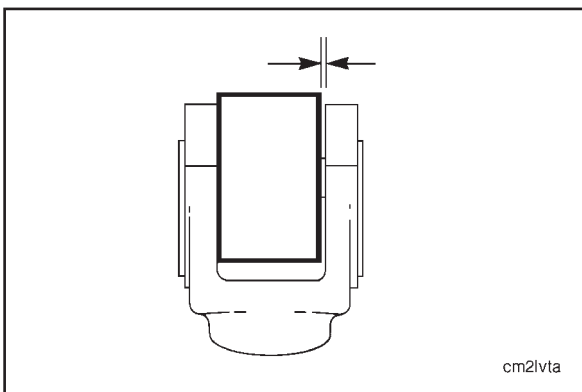
Replace all parts that do **not** meet the reuse guidelines.



Visually inspect the cam follower shafts for scoring or damage.



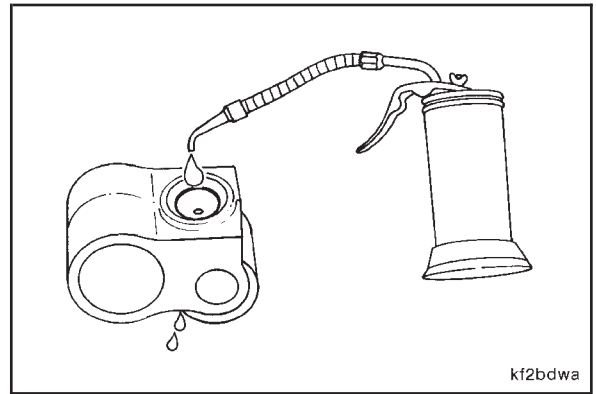
Visually inspect the cam follower rollers for flat spots, freedom of rotation or other damage.



Measure the cam follower roller side clearance.

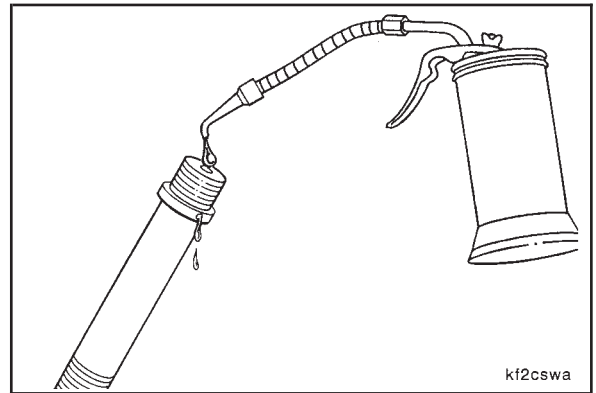
Cam Follower Roller Side Clearance		
mm		in
0.19	MIN	0.007
0.65	MAX	0.026

Use clean 15W-40 oil to check the oil flow through the cam followers.



kf2bdwa

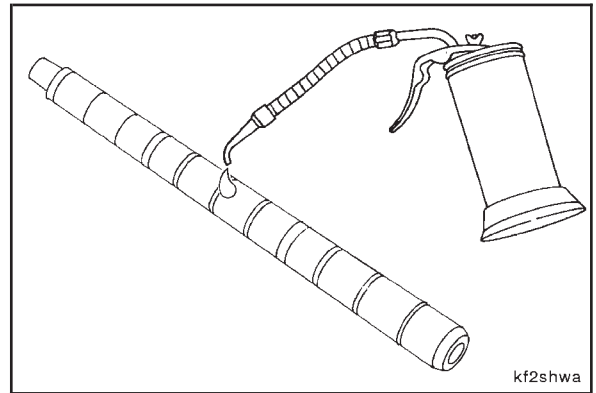
Use clean 15W-40 oil to check the oil flow through the cam follower studs.



kf2cswa

Assemble (004-001-025)

Use clean 15W-40 oil to lubricate the cam followers and shafts.



kf2shwa

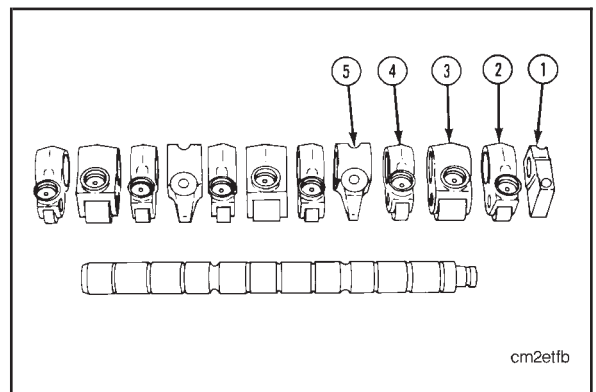
The cam followers, supports and shafts **must** be installed in the same position from which they were removed. The shaft end supports are **not** interchangeable.



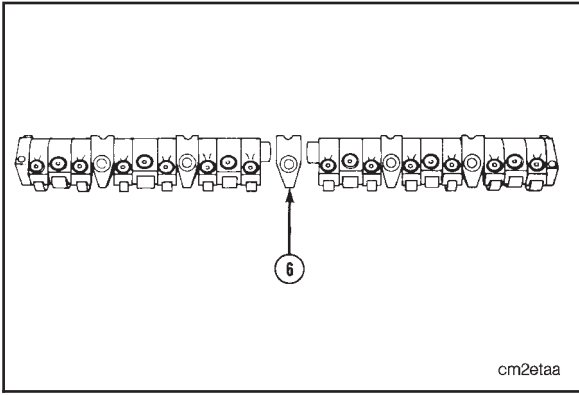
Install the end support (1) on the shaft.

Install the cam followers on the shaft in the following sequence:

- Valve cam follower (2)
- Injector cam follower (3)
- Valve cam follower (4)
- Shaft support (5)

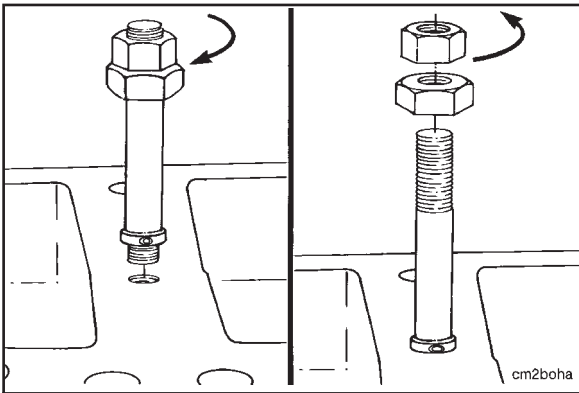


cm2etfb



Install the two cam follower shaft assemblies in the common center support (6).

NOTE: The common center support (6) has a locating dowel hole. The other inner supports do **not** have this hole.



Install (004-001-026)

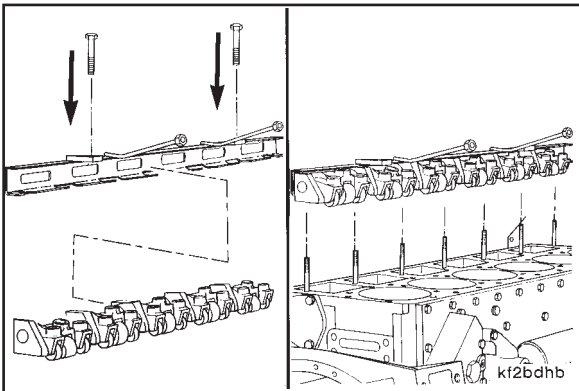
Install the cam follower studs with two M10 x 1.50 nuts tightened together.



Tighten the studs.

Torque Value: 34 N•m [25 ft-lb]

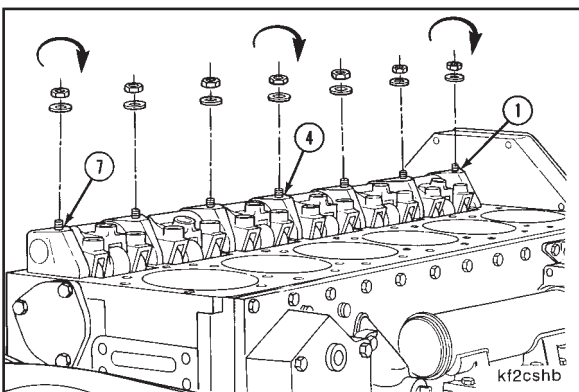
Remove the two nuts.



Install cam follower assembly installation and removal tool, Part No. 3824519 onto the cam follower assemblies.



NOTE: Before installing the cam follower assemblies, the cylinder head deck **must** be cleaned. Refer to Procedure 002-004-006.



Supports one, four and seven are doweled. The supports **must** align with the dowel pins in the cylinder block.

Install the cam follower assemblies on the studs.



Remove the service tool.

Install the washers and nuts on each stud.

Tighten the nuts on supports one, four and seven.

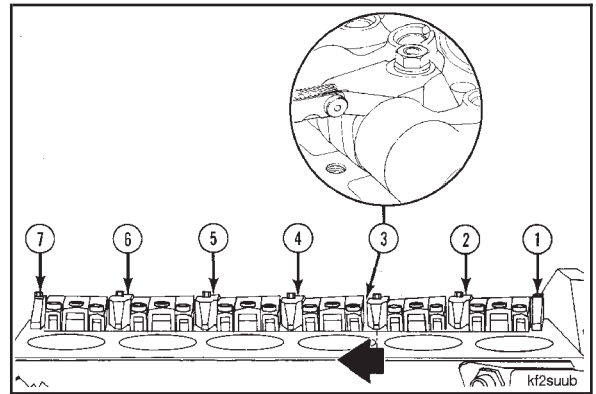
Torque Value: 47 N•m [35 ft-lb]

M11 Series
Section 4 - Cam Followers/Tappets - Group 04

Install a 0.76 mm [0.030 inch] feeler gauge between the number three support and the exhaust lever for cylinder number three. Push the number three support toward the number four support.

Tighten the number three support nut.

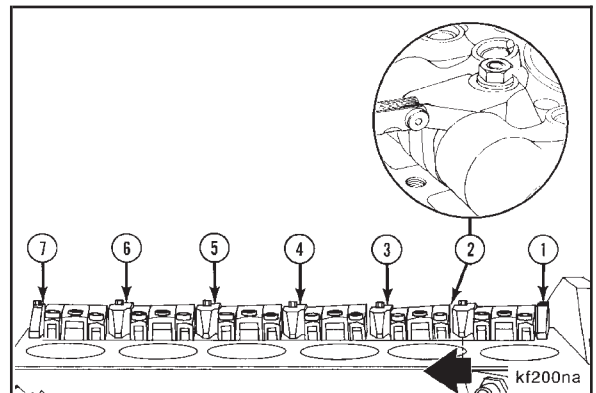
Torque Value: 47 mm [35 ft-lb]



Install a 0.76 mm [0.030 inch] feeler gauge between the number two support and the intake lever for cylinder number two. Push the number two support toward the number three support.

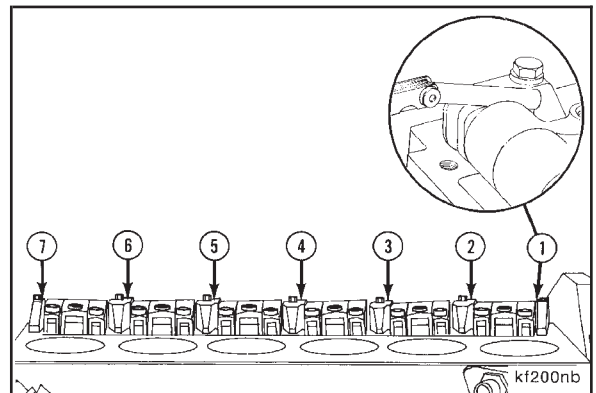
Tighten the number two support nut.

Torque Value: 47 N•m [35 ft-lb]



Measure side clearance between the number one and two supports.

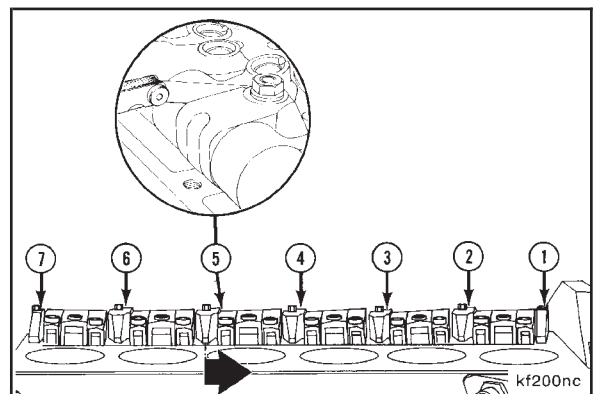
Cam Follower Side Clearance Between Supports		
mm		in
0.76	MIN	0.030

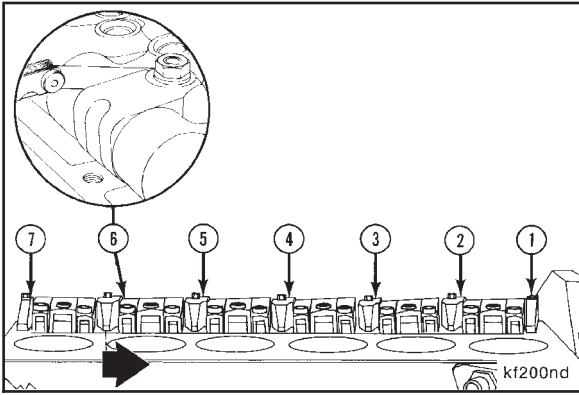


Install the 0.76 mm [0.030 inch] feeler gauge between the number five support and the exhaust lever for cylinder number four. Push the number five support toward the number four support.

Tighten the number five support nut.

Torque Value: 47 N•m [35 ft-lb]



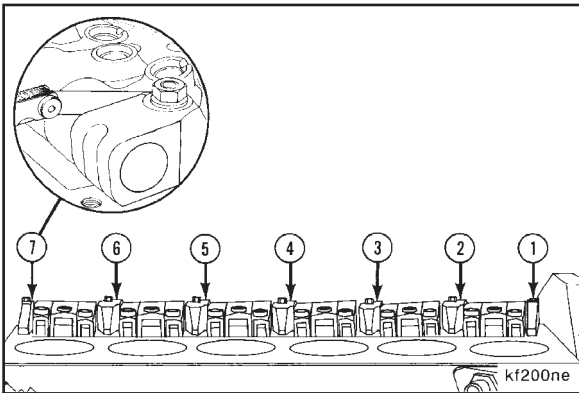


Install the 0.76 mm [0.030 inch] feeler gauge between the number six support and the intake lever for cylinder number five. Push the number six support toward the number five support.



Tighten the number six support nut.

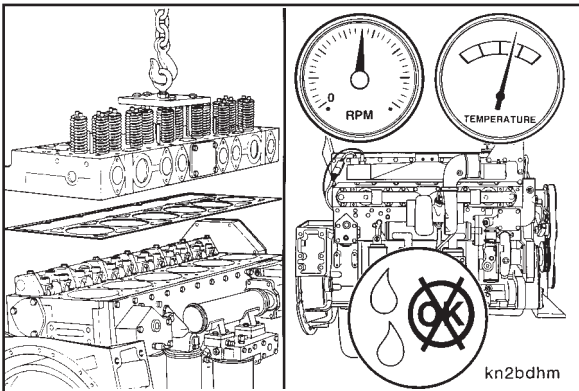
Torque Value: 47 N•m [35 ft-lb]



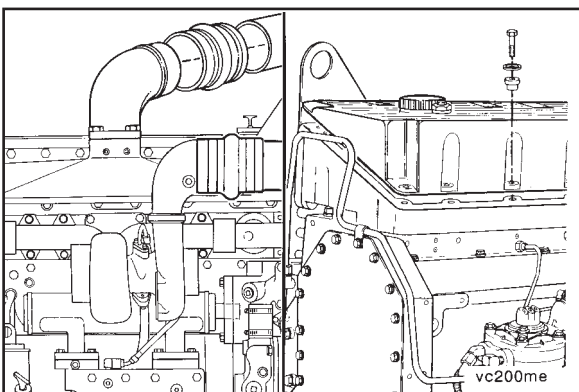
Measure the side clearance between the number six and seven supports.

Cam Follower Side Clearance Between Supports

mm		in
0.76	MIN	0.030



Install the cylinder head. Refer to Procedure 002-004-026.
Operate the engine and check for leaks.



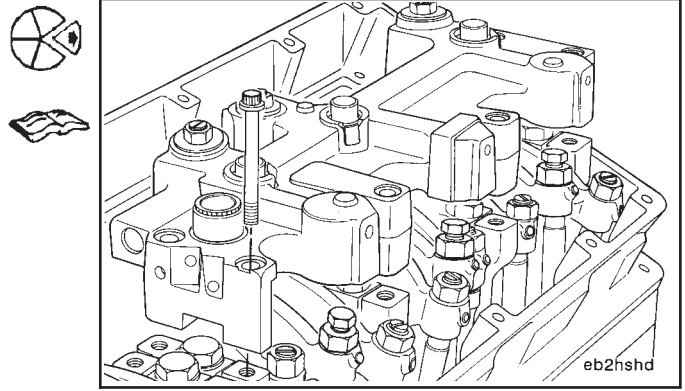
**Push Rods or Tubes (004-014)
Remove (004-014-002)**



Remove the air piping from the intake manifold.

Remove the rocker lever cover. Refer to Procedure 003-011-002.

Remove the engine brakes, if applicable. Refer to Procedure 020-001-002.

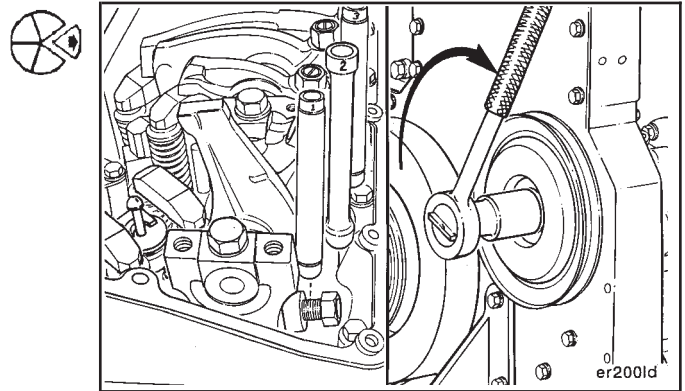


NOTE: Mark the position of the valve push tubes and injector push rods as they are removed. The push tubes and push rods **must** be installed in the same positions when the engine is assembled.

Loosen the rocker lever adjusting screws and remove the valve push tubes and injector push rods.

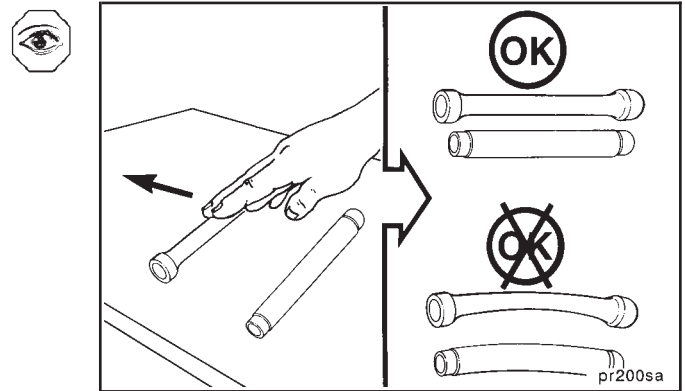
Hold the push tubes and push rods while loosening the adjusting screws. Do **not** let them fall into the engine while rotating the accessory drive pulley.

NOTE: Some push tubes and rods are under compression due to the valves being open. Rotate the crankshaft **clockwise** with the accessory drive pulley to relieve the spring tension.

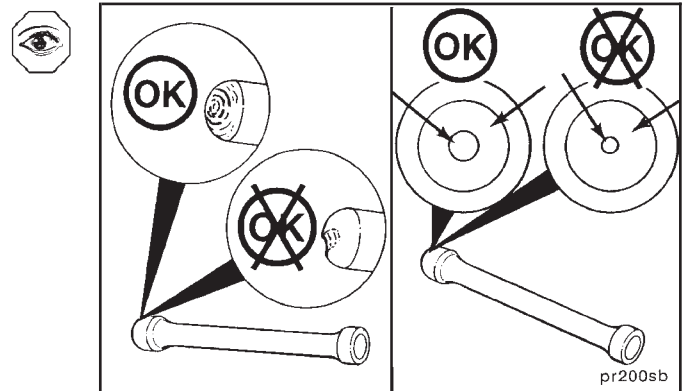


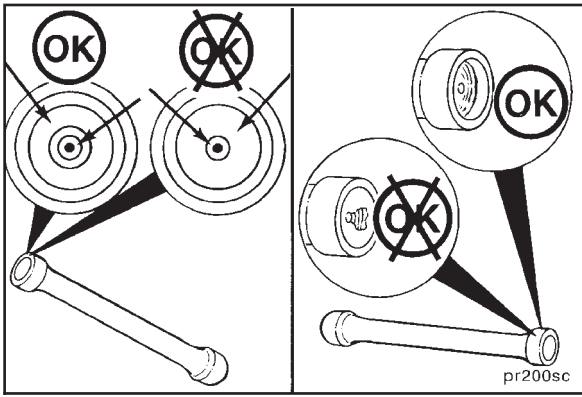
Inspect for Reuse (004-014-007)

Inspect the straightness of the push tubes and push rods by rolling them on a level bench. If any push tube or push rod is bent, it **must** be replaced.



Visually inspect the ball and socket ends for uneven wear or scratches.





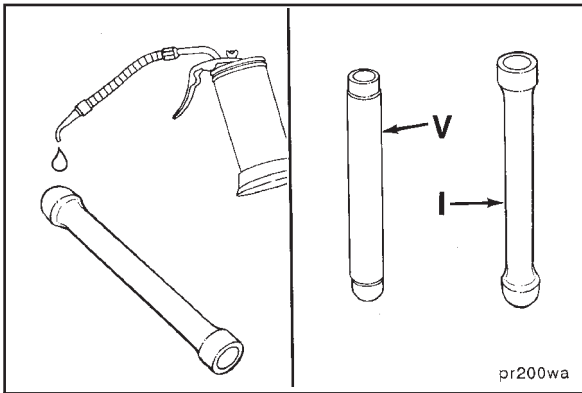
Visually inspect the seating pattern in the socket for excessive wear.

Visually inspect the ball end for excessive wear.



If excessive wear is found on the ball end, the cam follower sockets **must** be inspected. Refer to Procedure 7-09. Refer to the Overhead Reuse Guidelines, Bulletin No. 3810388, to identify wear patterns and excessive wear.

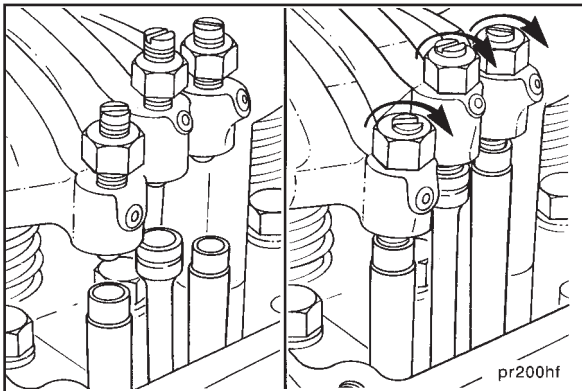
Replace all parts that do **not** meet the reuse guidelines.



Install (004-014-026)

Use clean 15W-40 oil to coat the ball end of the push tubes and push rods.

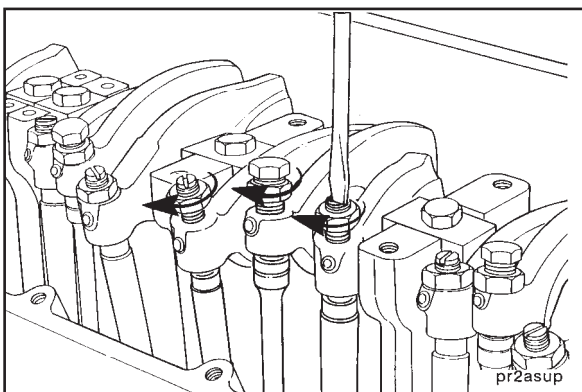
NOTE: The injector push rods (I) are smaller in diameter and longer than the valve push tubes (V).



Install the valve push tubes and injector push rods.

Position the push tubes and push rods under the rocker lever adjusting screws.

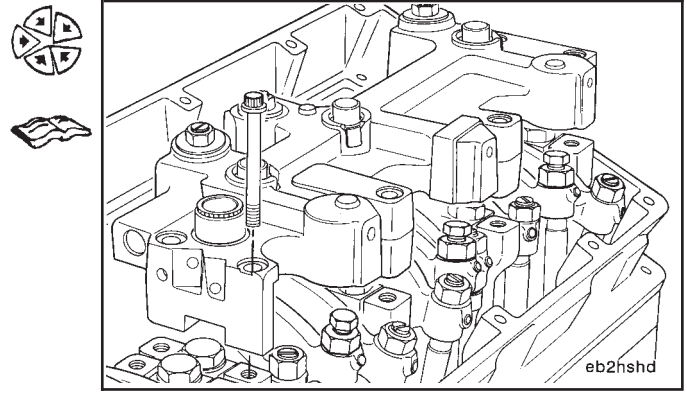
Tighten the adjusting screws enough to hold the push tubes and push rods in position.



Adjust the valves and injectors. Refer to Procedure 003-004-029.

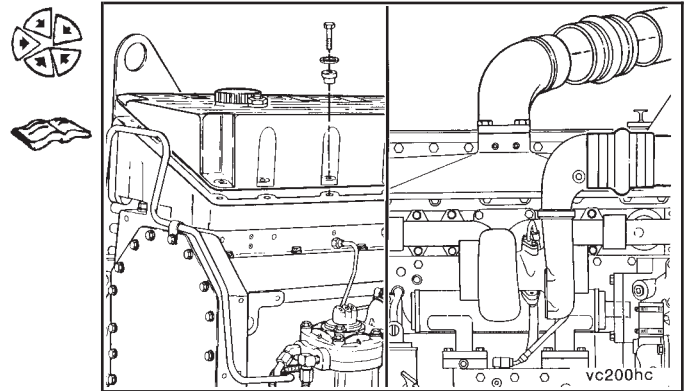


Install the engine brakes, if applicable. Refer to Procedure 020-001-026.



Install the rocker lever cover. Refer to Procedure 003-011-026.

Install the air piping to the intake manifold. Refer to the manufacturer's specifications for the correct torque.



Section 5 - Fuel System - Group 05

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Fuel System - General Information

The PT fuel system is used exclusively on Cummins diesels. The identifying letters "PT" are an abbreviation of pressure-time.

The STC system is used on Cummins diesels to advance the injection timing under idle or light load conditions.

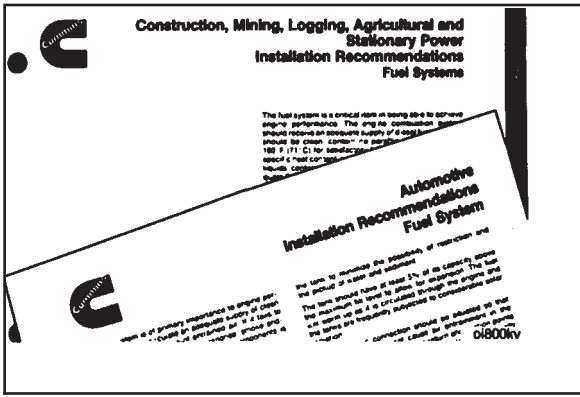
The STC system includes fuel pump, supply lines, drain lines, fuel passages, oil passages, check valves, STC oil control valve, and STC injectors.

NOTE: Refer to Section 6 for repair procedures to the STC injectors, fuel lines, and STC oil control valve.

The CELECT™ and CELECT™ Plus fuel systems are used exclusively on Cummins diesels.

The CELECT™ and CELECT™ Plus fuel systems consist of the fuel pump, Electronic Control Module (ECM), ECM cooling plate, supply lines, drain lines, engine wiring harness, sensors, and injectors.

NOTE: For repairs being made to the CELECT™ or CELECT™ Plus sensors, ECM, and engine wiring harness, refer to the Troubleshooting and Repair Manual CELECT™ Plus engines, Bulletin No. 3666130.



Installation Recommendations

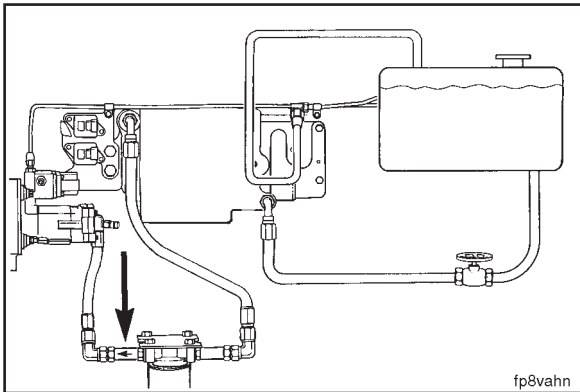
Installation Publications

The following publications are available to provide fuel system installation recommendations approved by Cummins Engine Co., Inc.:

Automotive Installation Recommendations (Fuel System), Bulletin No. 952849.

Construction, Mining, Logging, and Agriculture Installation Recommendations (Fuel System), Bulletin No. 3382015.

Contact the nearest Cummins Authorized Repair Location for engine fuel system specifications and requirements provided on the "Engine Data Sheet" for your specific engine and application.

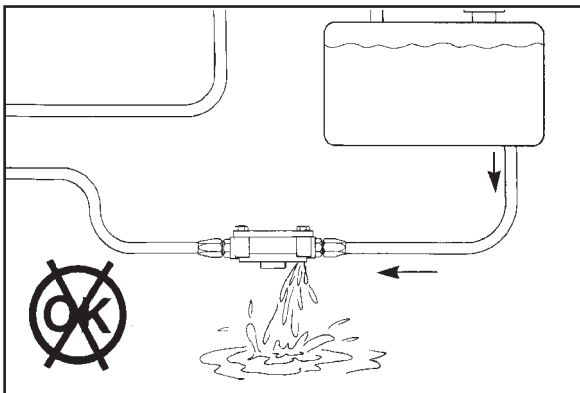


Overhead Fuel Tank Requirements

If the fuel filter is lower than the fuel pump, install a check valve in the filter outlet fuel line. Refer to the Installation Recommendations.

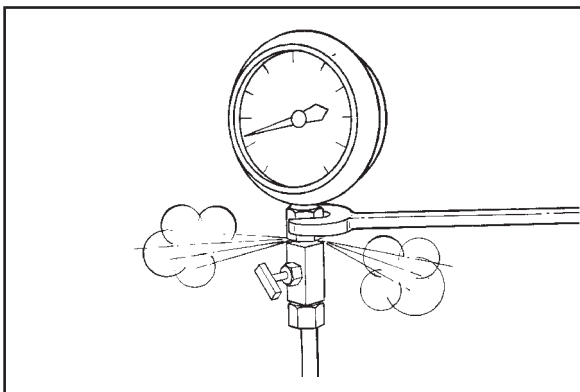
The check valve on the outlet side of the fuel filter prevents gear pump fuel drainback during filter removal.

Install a shutoff valve between the filter and the fuel tank.



⚠ CAUTION ⚠

If the fuel line valve is not used, the overhead tank can drain when the fuel filter is changed. Spilled fuel is a fire hazard.



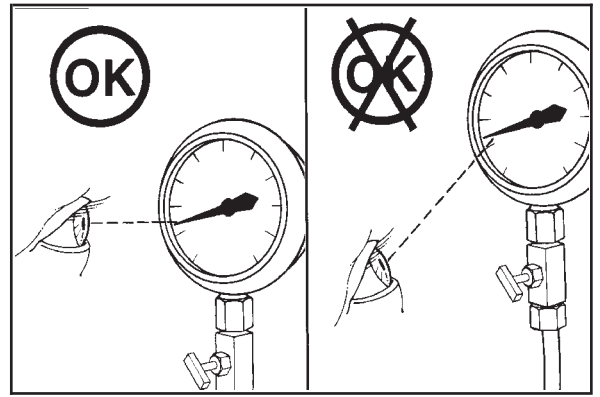
Proper Use of Fuel System Gauges

NOTE: To be sure the reading is correct, always remove the air from the pressure gauge line before taking a reading.

Loosen the connection at the gauge to remove the air.

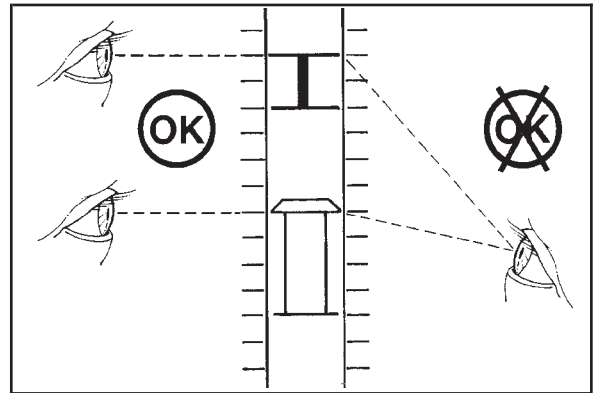
NOTE: Do **not** loosen the vacuum gauge connections when the engine is operating.

Read the gauge in direct alignment with the gauge hand.

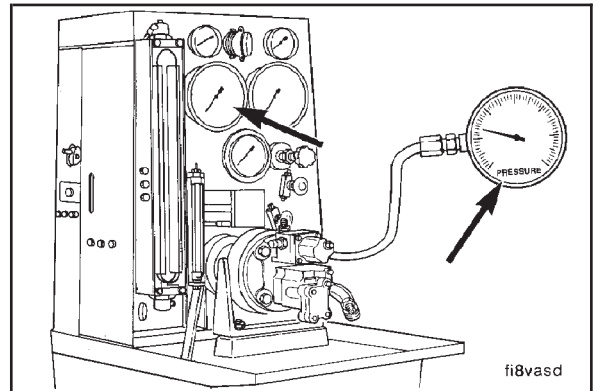


Read the flow meter in direct alignment with the float.

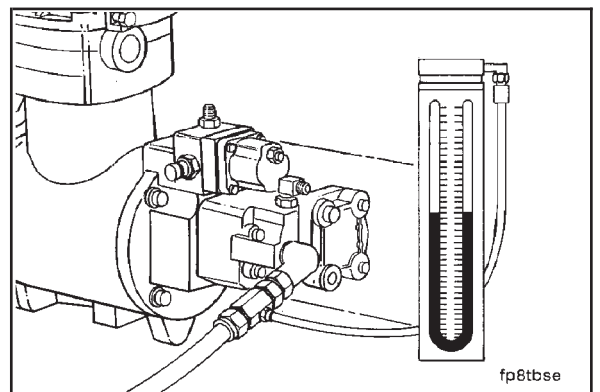
NOTE: Read the level of the floats where indicated.

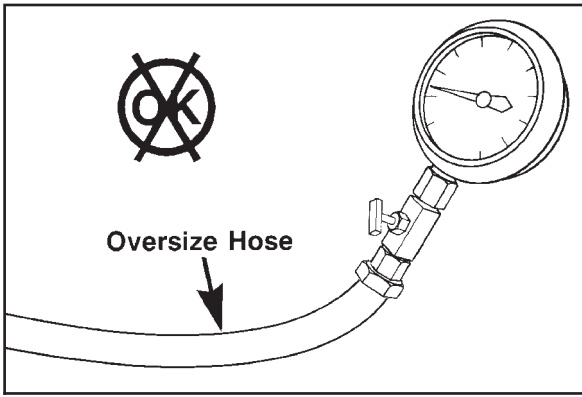


Portable fuel pressure gauges **must** be checked regularly against a reference gauge or against the gauge on the fuel pump test stand. Adjust the valve on the gauge until the gauge needle stops vibrating.

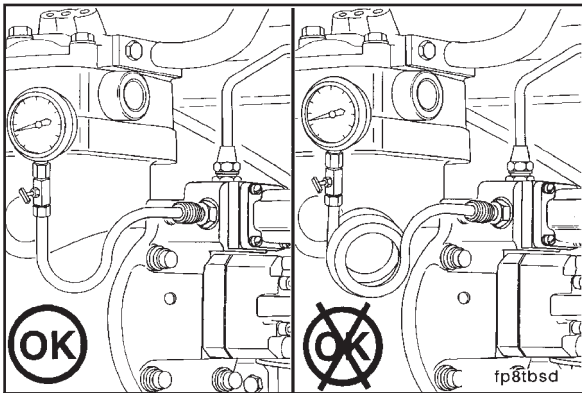


When measuring the fuel inlet and drain line restriction, the manometer or gauges **must** be on the same level as the connection point.

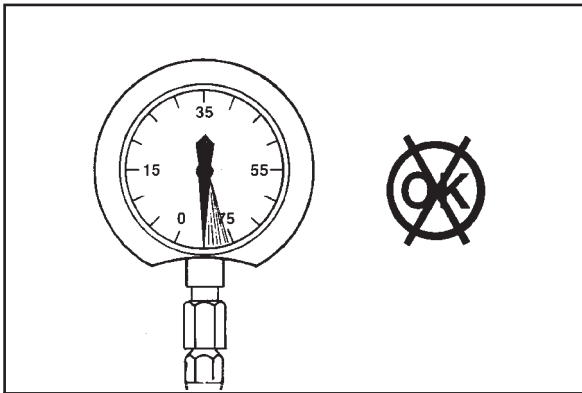




NOTE: Always use the same size and material of line or hoses as was originally supplied with the gauge.



The distance from the gauge to the connection point **must** be as short as possible.

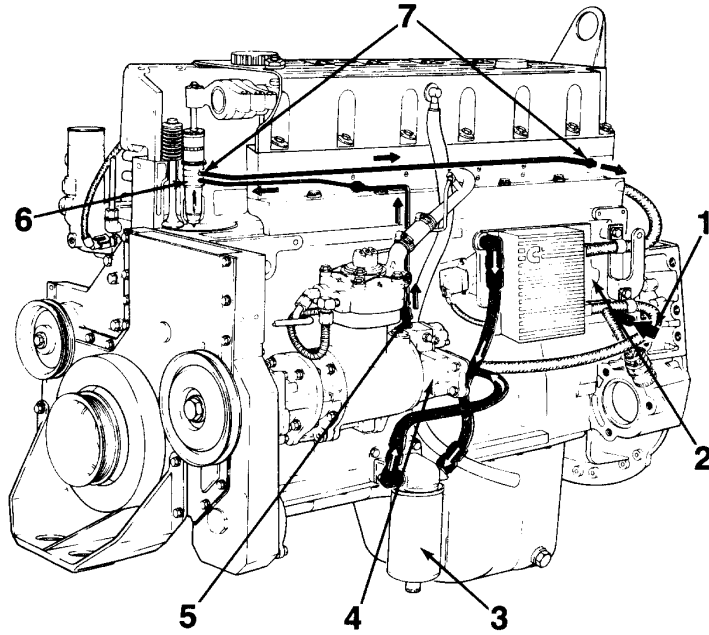


△ CAUTION △

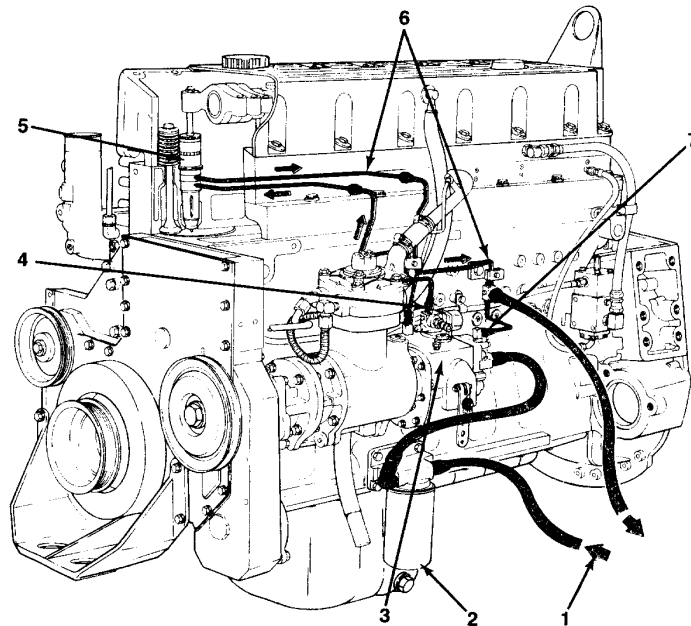
Never exceed the maximum capacity of the gauge or flow meter. If the maximum is exceeded, check the gauge against a reference gauge.

Flow Diagram, Fuel System

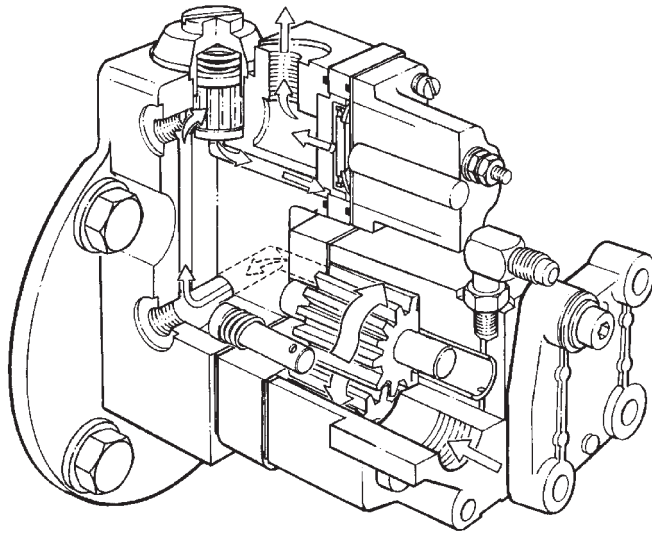
1. Fuel Inlet Supply
2. ECM Cooling Plate
3. Fuel Filter
4. Fuel Pump
5. Fuel to Injector
6. Injector
7. Fuel Drain Return



1. Fuel Inlet Supply
2. Fuel Filter
3. Fuel Pump
4. Fuel to Injectors
5. Injector
6. Fuel Drain Return
7. Gear Pump Cooling Return



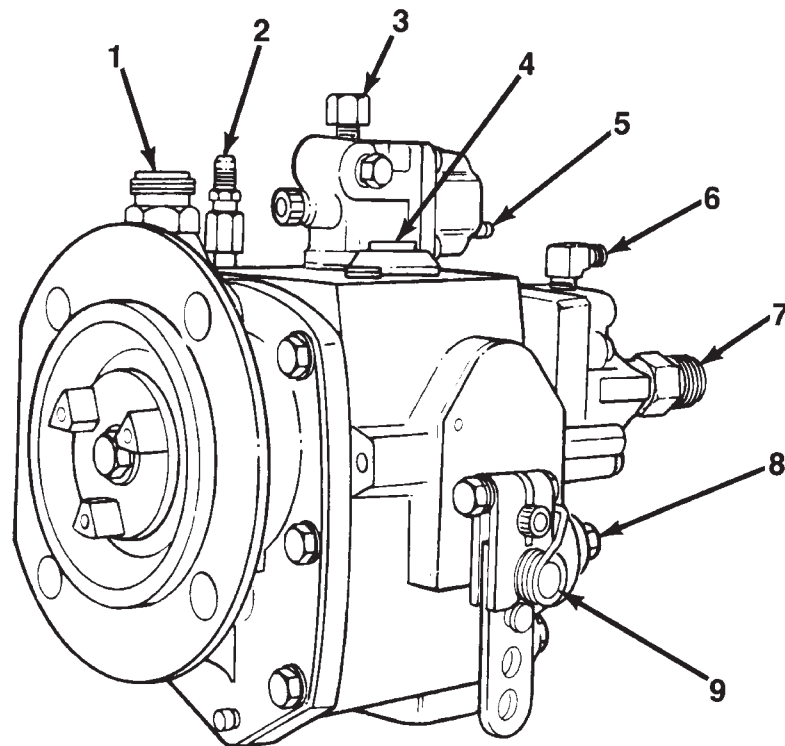
CELECT™ AND CELECT™ PLUS FUEL PUMP



fp800gc

PT (TYPE G) AFC FUEL PUMP

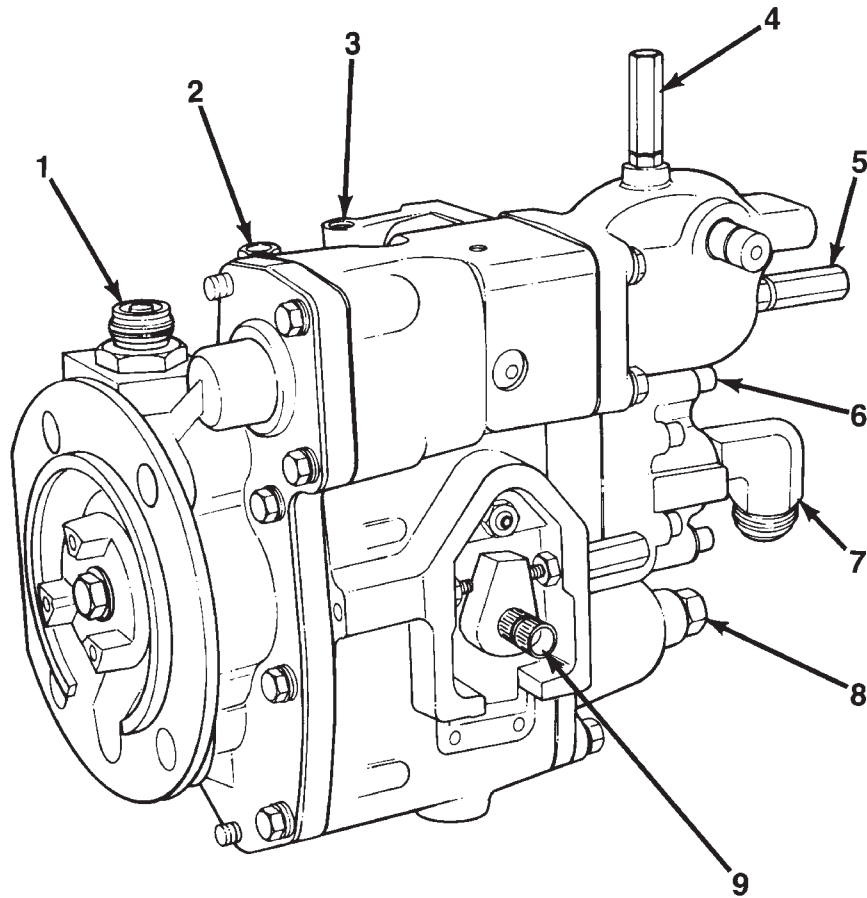
1. Tachometer Drive
2. AFC Air Supply
3. Fuel to Injectors
4. Priming Plug
5. Shutoff Valve Electric Connection
6. Gear Pump Cooling Fitting
7. Fuel Inlet Connection
8. Idle Speed Screw Location
9. Fuel Rate (Pressure) Screw



fp201gn

PT (TYPE G) AFC VS FUEL PUMP

1. Tachometer Drive
2. AFC Air Supply
3. Fuel to Injectors
4. VS High Speed Screw
5. VS Low (Idle) Speed Screw
6. Gear Pump Cooling Fitting
7. Fuel Inlet Connection
8. Idle Speed Screw Location
9. Fuel Rate (Pressure) Screw



fp201gp

Specifications

Fuel System

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

Engine Idle Speed

CELECT™	650 to 800 rpm
CELECT™ Plus	600 to 800 rpm

Fuel Inlet Maximum Restriction:

CELECT™ and CELECT™ Plus	
Clean Fuel Filter	152 mm Hg [6 in Hg]
Dirty Fuel Filter	254 mm Hg [10 in Hg]

STC

Clean Fuel Filter	102 mm Hg [4 in Hg]
Dirty Fuel Filter	204 mm Hg [8 in Hg]

Fuel Drain Line Maximum Restriction

CELECT™ and CELECT™ Plus	89 mm Hg [3.5 in Hg]
--------------------------	----------------------

STC

Without Check Valves	63 mm Hg [2.5 in Hg]
With Check Valves	165 mm Hg [6.5 in Hg]

Minimum Fuel Pressure:

During Cranking	172 kPa [25 psi]
1200 rpm	827 kPa [120 psi]

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

Engine Minimum Cranking Speed	150 rpm
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Shutoff Valve Solenoid Coil Resistance

12 VDC	7.0 to 8.0 ohms
--------	-----------------

Fuel Recommendations

▲ WARNING ▲

Do not mix gasoline, alcohol, or gasohol with diesel fuel. This mixture can cause an explosion.

▲ CAUTION ▲

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

▲ CAUTION ▲

Do not use diesel fuel blended with lube oil in engines equipped with a catalytic converter. Damage to the converter will result.

Cummins Engine Company, Inc. recommends the use of ASTM No. 2 D fuel. The use of No. 2 diesel fuel will result in optimum engine performance.

At operating temperatures below 0°C [32°F], acceptable performance can be obtained by using blends of No. 2 D and No. 1 D.

NOTE: Lighter fuels can reduce fuel economy.

The viscosity of the fuel **must** be kept above 1.3 cSt at 40°C [104°F] to provide adequate fuel system lubrication.

The following chart lists acceptable alternate fuels for M11 engines.

Acceptable Substitute Fuels - Cummins CELECT™ Plus Fuel System									
No. 1D Diesel	No. 2D Diesel	No. 1K Kerosene	Jet-A	Jet-A1	JP-5	JP-8	Jet-B	JP-4	CITE
1	OK	1	1	1	OK	OK	NOT OK	NOT OK	NOT OK
<p>1. OK - ONLY if fuel lubricity is adequate. Refer to Fuel for Cummins Engines, Bulletin No. 3379001.</p> <p>2. Acceptable ONLY if</p> <ul style="list-style-type: none"> - chrome plated injector plated injector plungers fuel additive AND the heavy duty carbon graphite bushed gear pump are used, or - the fuel is blended with enough fuel additive to increase the lubricity above the minimum level. Refer to Fuel for Cummins Engines, Bulletin No. 3379001. <p>NOTE: Any adjustment to compensate for reduced performance with a fuel system using substitute fuel is not warrantable.</p>									

Additional information for fuel recommendations and specifications can be found in Fuel for Cummins Engines, Bulletin No. 3379001. See ordering information in the back of this manual.

Fuel Oil Recommended Properties:


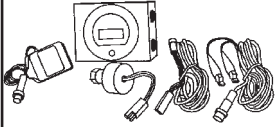
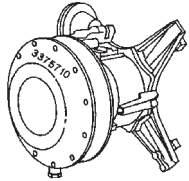

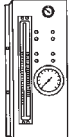

Cummins diesel engines are designed to operate on No. 2 diesel fuel. These engines will also operate satisfactorily on fuels that meet the following specifications:

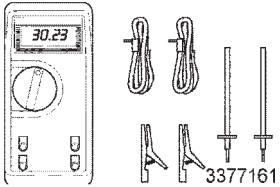
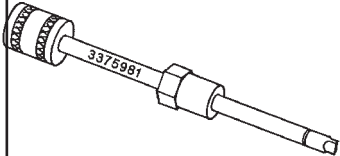
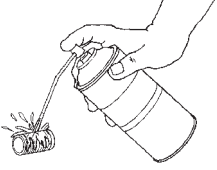
Property	Recommended Specifications
Viscosity (ASTM D445)	1.3 to 5.8 centistokes [1.3 to 5.8 mm per second] at 104°F [40°C]
Cetane Number (ASTM D613)	40 Minimum above 32°F. 45 Minimum below 32°F.
Sulfur Content (ASTM D129 or 1552)	Not to exceed 1.0 mass percent*.
Active Sulfur (ASTM D130)	Copper Strip Corrosion not to exceed No. 2 rating after three hours at 122°F [49°C].
Water and Sediment (ASTM D1796)	Not to exceed 0.1 volume percent.
Carbon Residue (Rams-bottom, ASTM D524 or Conradson, ASTM D189)	Not to exceed 0.35 mass percent on 10 volume percent residuum.
Density (ASTM D287)	42 to 30° API gravity at 60°F [0.816 to 0.876 g/cc at 15°C].
Cloud Point (ASTM D97)	10°F [6°C] below lowest ambient temperature at which the fuel is expected to operate.
Ash (ASTM D482)	Not to exceed 0.02 mass percent (0.05 mass percent with lubricating oil blending).
Distillation (ASTM D86)	The distillation curve must be smooth and continuous.
Acid Number (ASTM D664)	Not to exceed 0.1 Mg KOA per 100 ML.

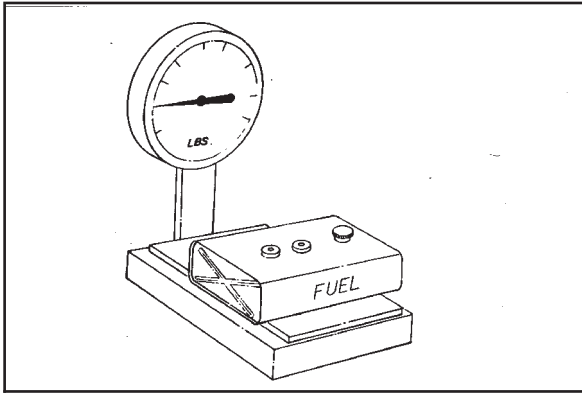
* **NOTE:**Effective October 1, 1993, the Environmental Protection Agency required a maximum sulfur content not to exceed 0.05 mass percent.


Service Tools Fuel System

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

Tool No.	Tool Description	Tool Illustration
3375388	Pressure Gauge (0-100 psi) Used to measure fuel pressure during cranking.	 <p style="text-align: right;">3375388</p>
3375631	Digital Tachometer Kit Used to measure engine rpm.	 <p style="text-align: right;">3375631</p>
3375710	Drive Line Dynamometer Used to measure engine horsepower.	 <p style="text-align: right;">3375710</p>
3375932	Pressure Gauge and Hose (0-300 psi) Used to measure oil pressure or measure fuel pump pressure. Includes necessary hoses and hardware to attach to a fuel pump. Part No. ST-435-1 is the hose and Part No. ST-435-6 is the pressure gauge.	 <p style="text-align: right;">eg8togh</p>
3376375	Fuel Measurement Device Used to measure fuel rate on the engine.	 <p style="text-align: right;">eg8togf</p>
3376506	Remote Starter Switch Turn engine on and off from a remote location.	 <p style="text-align: right;">3376506</p>

Tool No.	Tool Description	Tool Illustration
3377161	<p>Digital Volt Ohm Meter Used to measure electrical circuits: voltage (volts), resistance (ohms), and current (amps).</p>	
3823480	<p>Fuel Idle Adjusting Tool Used to adjust the idle speed while the engine is running.</p>	
3823717	<p>Safety Solvent Used to safely clean parts and tools.</p>	

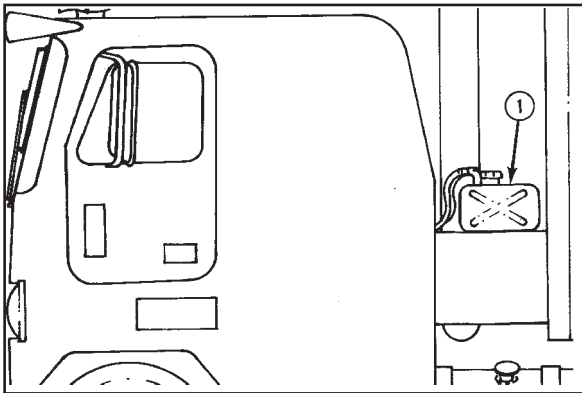



 **Fuel Consumption (005-010)**
Measure (005-010-010)

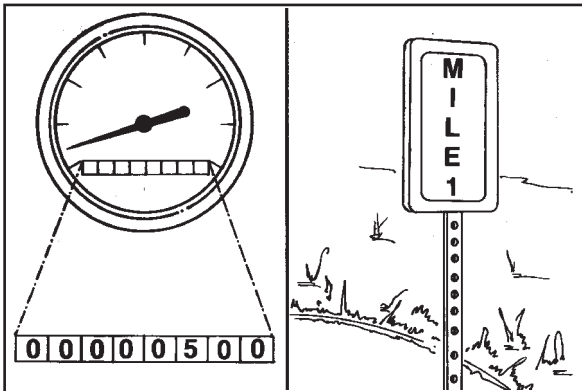
Refer to the fuel consumption check list sheets in the back of Section TS.


NOTE: The most accurate method to check the fuel consumption is to weigh the fuel used. Use a scale capable of measuring within 0.045 kg [0.1 lb] to weigh the fuel tank. Use a remote mount tank with enough capacity to run 80 kilometers [50 miles].

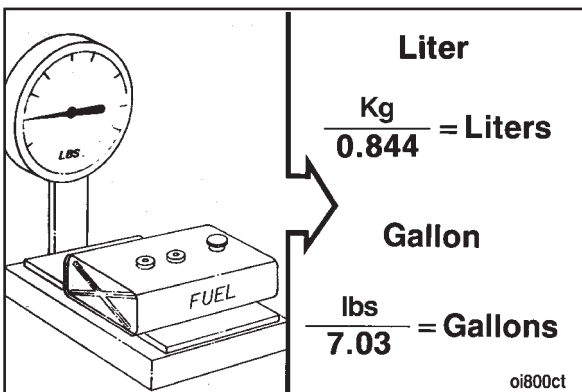
Fill the fuel tank. Weigh the tank with the fuel. The weight on No. 2 diesel fuel is nominally 0.844 kg per liter [7.03 pounds per gallon].



 Install the remote tank (1).



 Measure the distance traveled with an accurate odometer. The odometer accuracy can be checked by using measured miles, or kilometers.


Liter

$$\frac{\text{Kg}}{0.844} = \text{Liters}$$

Gallon

$$\frac{\text{lbs}}{7.03} = \text{Gallons}$$

oi800ct

 After traveling the route, remove the tanks and weigh the fuel remaining. Compute the fuel used in liters [gallons] as required.



Compute the kilometers per liter or miles per gallon.

$$\frac{\text{Miles}}{\text{Gallons}} = \text{MPG}$$
$$\frac{\text{Kilometers}}{\text{Liters}} = \text{KPL}$$

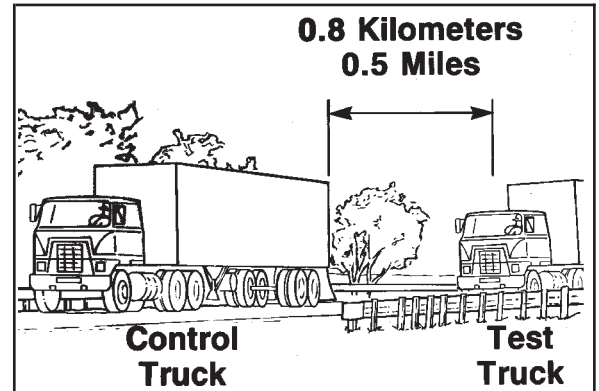
In addition to the measurement of the fuel used, the following factors provide points for running a test similar to the recognized Type II Society of Automotive Engineers Fuel Test.

These procedures are helpful to determine differences in fuel consumption between two vehicles under the same environmental, road, and test conditions.

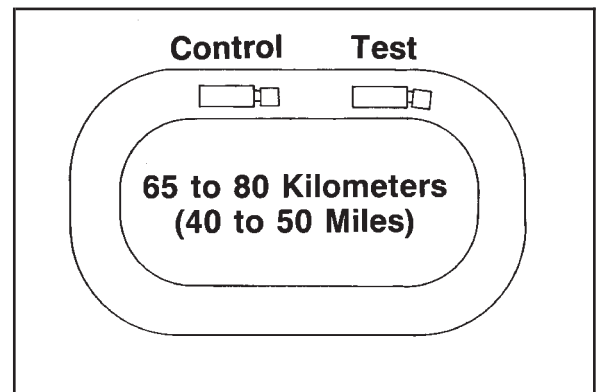
**Type II
Fuel Test
SAE
RCCC
ATA**

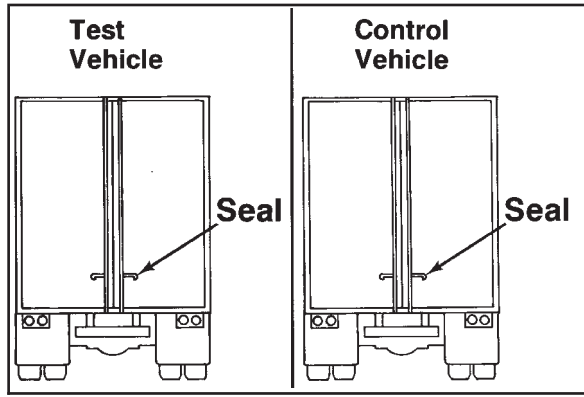
Perform the test with the test vehicle and a control vehicle. The control vehicle compensates for changes in traffic conditions.

The vehicles **must** stay close together to experience the same varying traffic and weather conditions, but **not** so close as to affect other's driving or headwind.

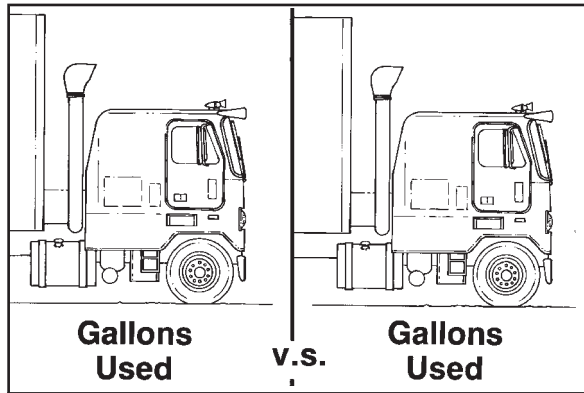


The test course **must** be 65 to 80 kilometers [40 to 50 miles] long.

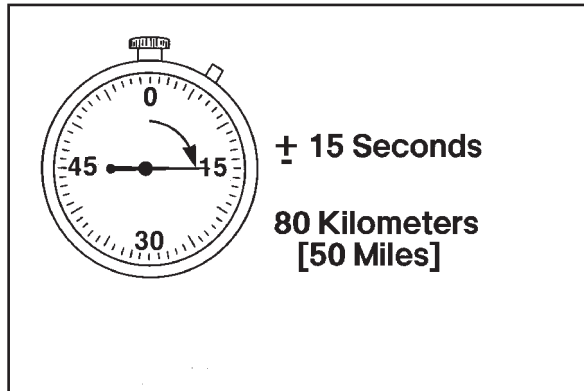




This test route and truck weights **must not** change during the test.

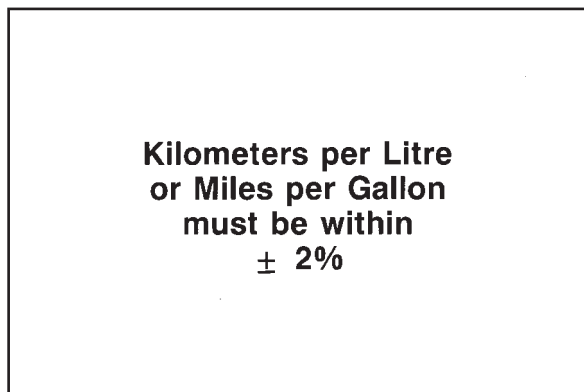


All of the test results are based on comparing the fuel used by the test truck to the fuel used by the control truck.



Drive the truck on a warm up test run. Drive enough tests to achieve:

- Difference in elapsed time between each test run can only be plus or minus 0.5 percent. This will be ± 15 seconds on 80 kilometers [50 miles] at 60 miles per hour.

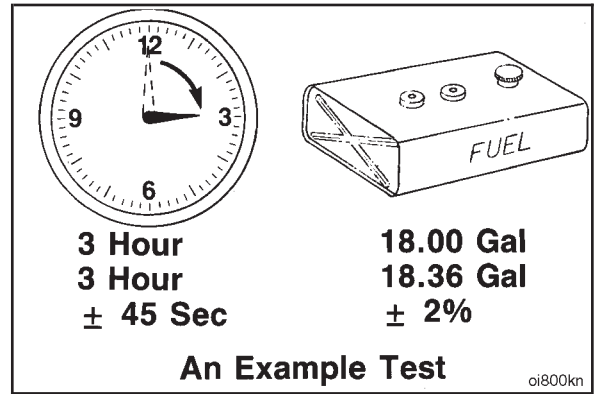


The fuel usage of the test truck between test drives **must** fall within a 2 percent range, (6.00 mpg vs. 6.12 mpg).

The same range also applies between drives of the control truck.

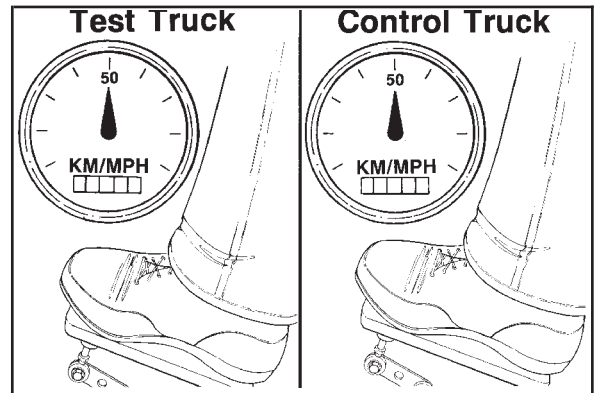
NOTE: The differences in traffic and driving practices can make the test drive fall out of the 2 percent range.

A minimum of three test drives that meet these conditions make a valid test. A single test drive is unreliable.



Use the same experienced drivers for all of the tests.

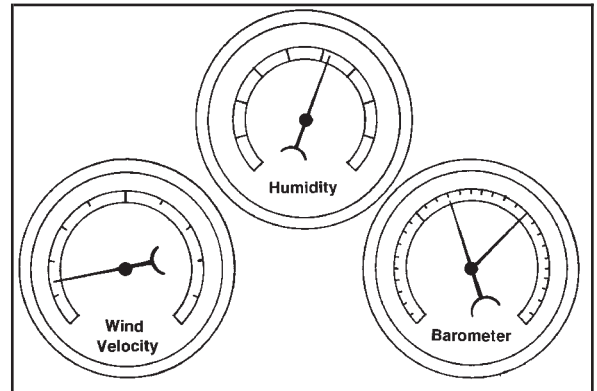
NOTE: The vehicle speeds **must** be representative of a typical operation.



During the test, record the following:

- Ambient temperature
- Humidity
- Barometric pressure
- Wind velocity
- Wind direction

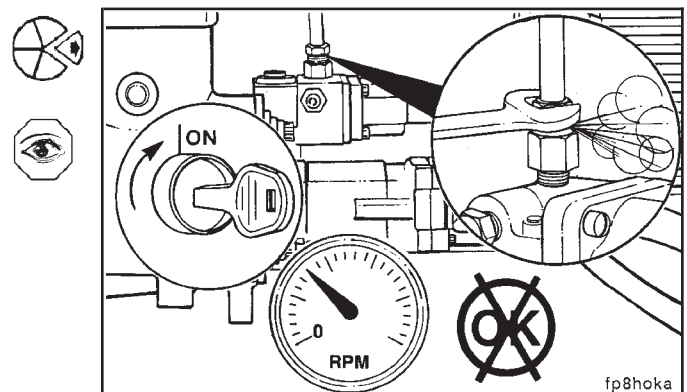
NOTE: Avoid testing under any extreme conditions.

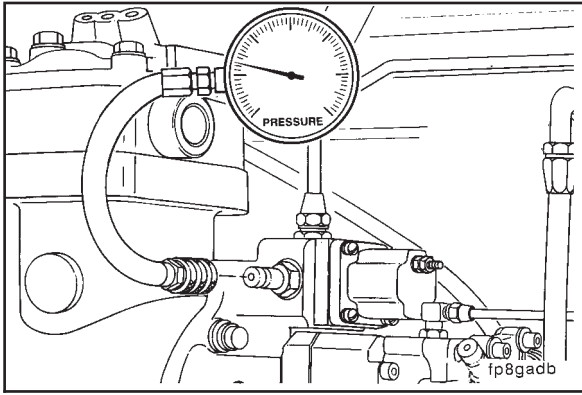


Fuel Flow (005-011)

Initial Check (005-011-001)

Loosen the fuel line at the shutoff valve while the engine is cranking. If fuel does **not** come out of the connection, the pump **must** be primed.





Pressure Test (005-011-013)

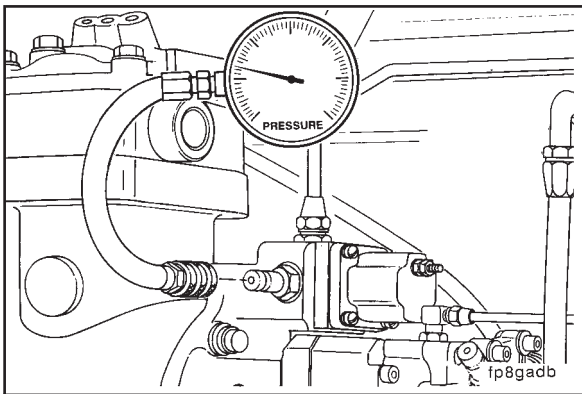
Minimum Cranking Pressure

Connect a pressure gauge to the quick disconnect fitting of the fuel pump.

Start cranking the engine and observe the cranking fuel pressure.

Minimum Cranking Fuel Pressure			
	kPa		psi
CELECT™ or CELECT™ Plus	172	MIN	25
STC	34	MIN	5

If the fuel pressure is below the specification, check to be sure there is a fuel supply to the pump and that it is **not** restricted. Refer to Procedure 006-020. Prime the fuel pump if necessary. Refer to Procedure 005-016-050.



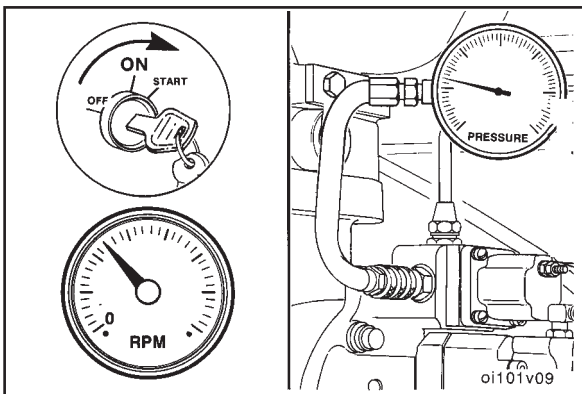
Minimum Operating Pressure

Connect a 0-300 psi pressure gauge to the quick disconnect fitting to the fuel pump.

Start the engine and operate it at 1200 rpm with no load applied.

Record the fuel pressure.

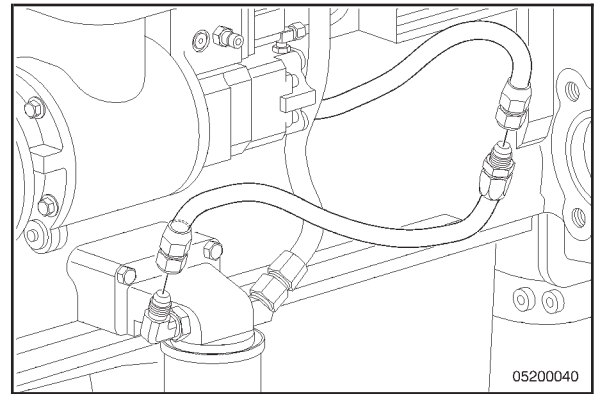
Minimum Fuel Pressure at 1200 RPM (CELECT™ and CELECT™ Plus Only)		
kPa		psi
827	MIN	120



Leak Test (005-011-014)

Install an 18 inch piece of clear tubing on the suction side of the gear pump or the fuel filter head. Tygon R-3603 is the correct size for use with standard Stratoflex No. 10 hose fittings.

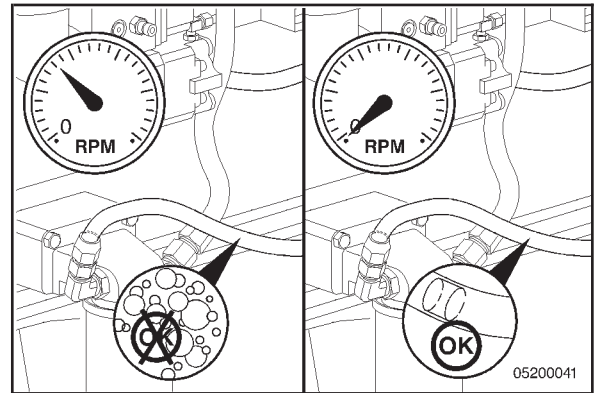
NOTE: Add the 18 inch piece of clear tubing to the existing fuel suction line. Do **not** replace any portion of the suction line to install the 18 inch piece of clear tubing.



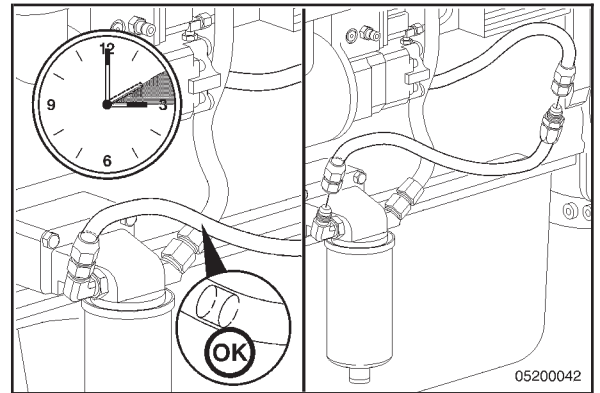
Start the engine and allow the air to purge from the clear tubing. No air bubbles can appear.

Shut off the engine and observe the clear tubing.

NOTE: Generally an air space will appear in the clear tubing that is drawn from the top of the fuel filter.

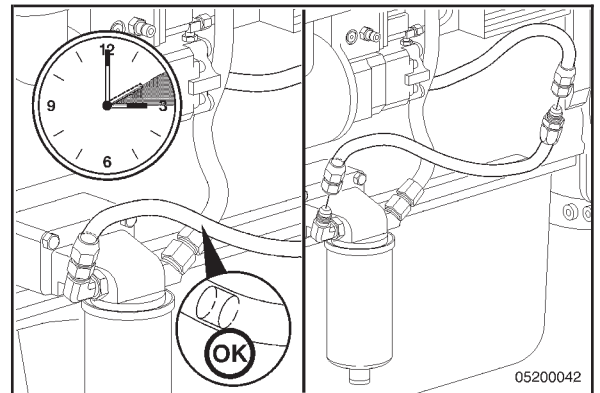


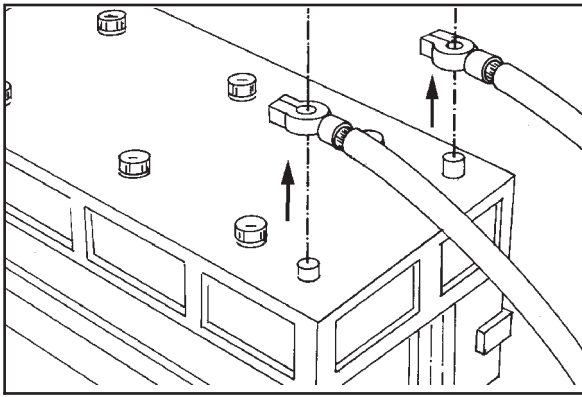
Observe the fuel in the clear tubing. It should stop moving within one minute if the system is leak free. If the fuel continues to move toward the fuel tank, there is a leak in the system. Observe from which direction air bubbles are coming into the clear tubing. If they are coming from the fuel tank side then the leak is in the cooling plate, fittings, fuel line, or fuel tank.



If the fuel did **not** move immediately, let the vehicle sit for about one hour. If there is no movement of the fuel, the system is sealed and should **not** cause a hard start due to drain-back of the suction lines.

Remove the clear tubing and connect the suction line back to its original connection.



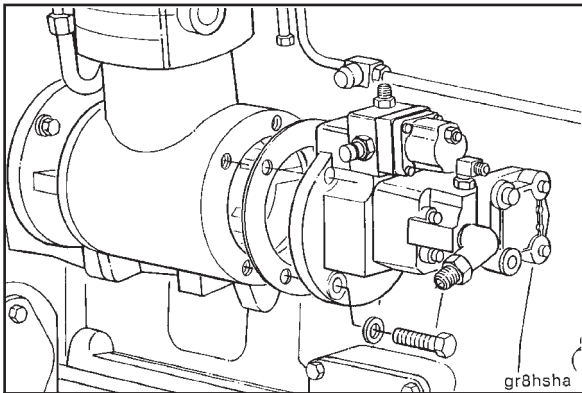


Fuel Pump (005-016)

Remove (005-016-002)

CELECT™ or CELECT™ Plus

Disconnect the battery cables, negative (-) cable first.



Clean the supply pump and the surrounding area.

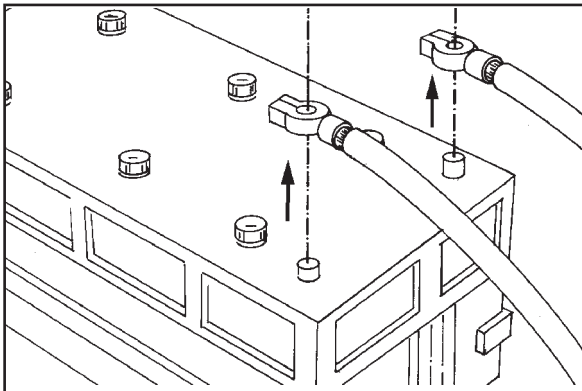
Remove the electric wire to the fuel shutoff solenoid.

Remove the fuel plumbing.



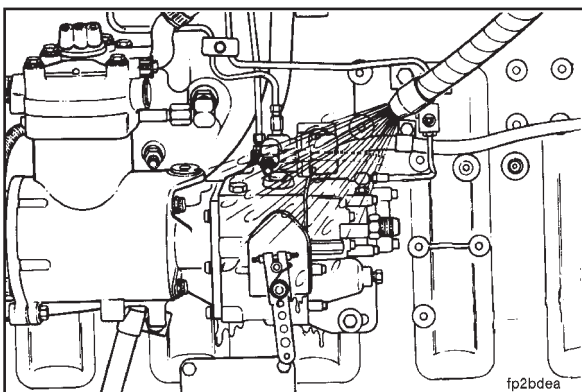
Remove the two support bracket capscrews from the cylinder block bracket.

Remove the four fuel pump mounting capscrews and remove the fuel pump.



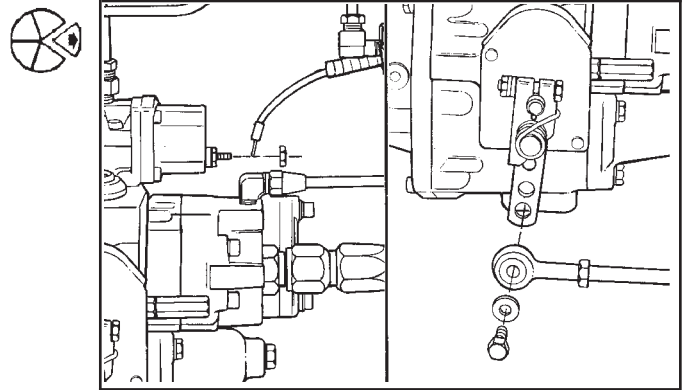
STC

Disconnect the negative and positive battery cables in that order.



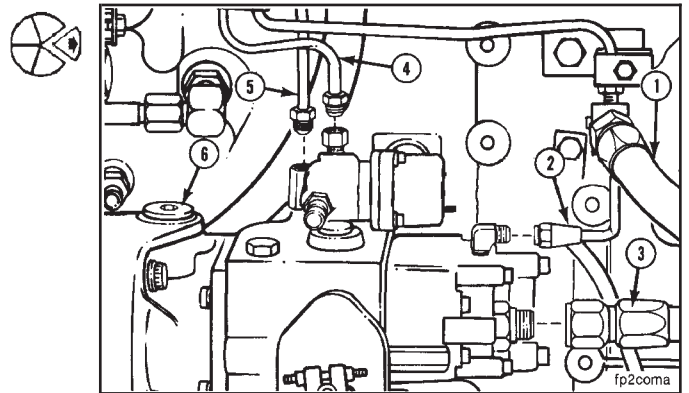
Clean the fuel pump and the surrounding area before removing it from the engine.

Remove the wire to the fuel shutoff valve.
Remove the linkage from the throttle lever.



Remove the fuel tubing and air tube:

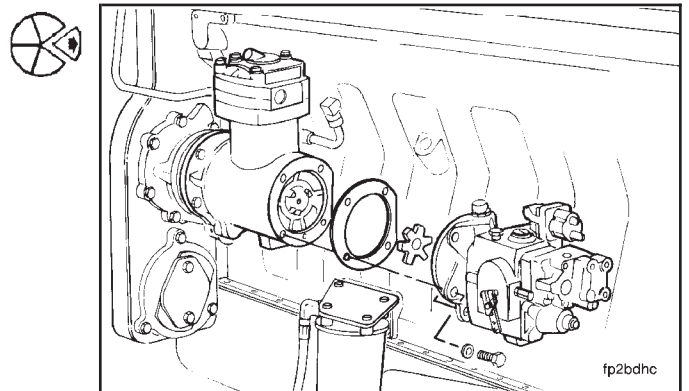
- Fuel drain line from the T-block connection (1)
- Gear pump cooling drain (2)
- Gear pump suction line (3)
- Fuel supply to the injectors (4)
- AFC air supply tube (5)
- Tachometer cable (if used) (6)



Remove the two fuel pump support bracket to cylinder block bracket mounting capscrews.

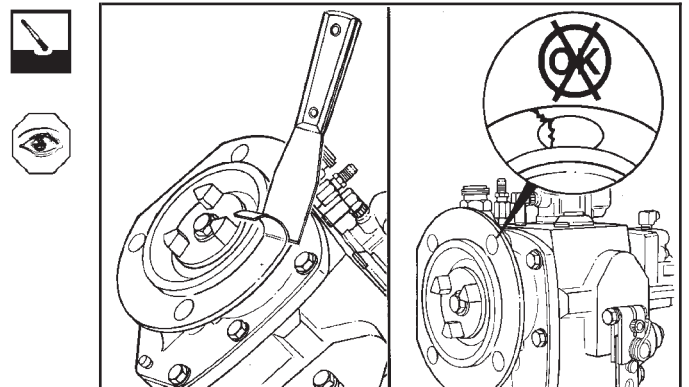
Remove the four fuel pump mounting capscrews and the fuel pump.

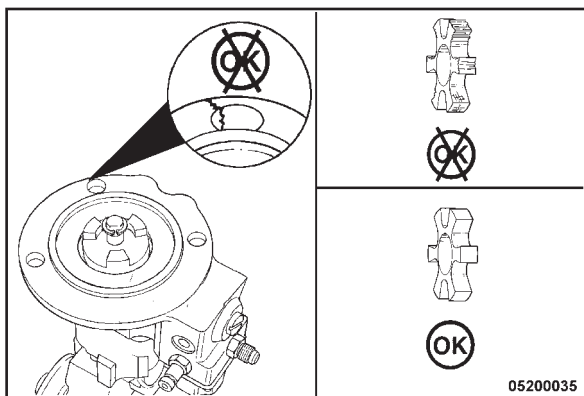
Remove the drive coupling.



Clean (005-016-006)

Clean the gasket surfaces of the pump support and the air compressor.

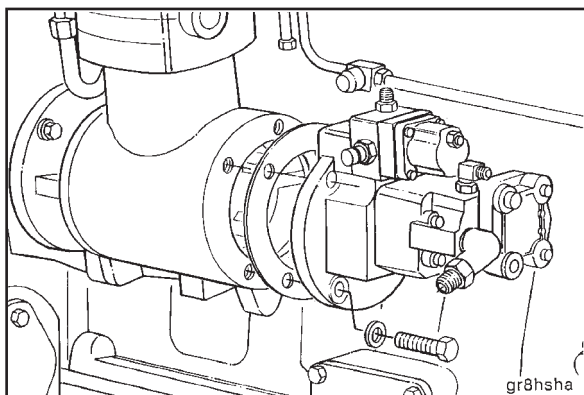




Inspect for Reuse (005-016-007)

Inspect the mounting surfaces for damage.

Inspect the jaw coupling spider and the jaw coupling hub for damage or wear.

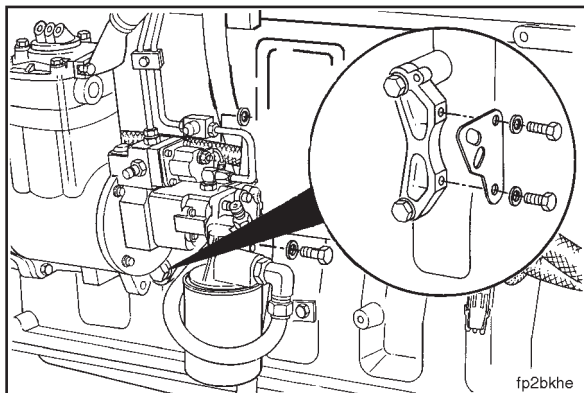


Install (005-016-026)

CELECT™ or CELECT™ Plus

Install the jaw coupling spider, the mounting gasket, and the fuel pump.

Install the two outside mounting capscrews.



Install the two fuel pump support brackets to cylinder block bracket capscrews.

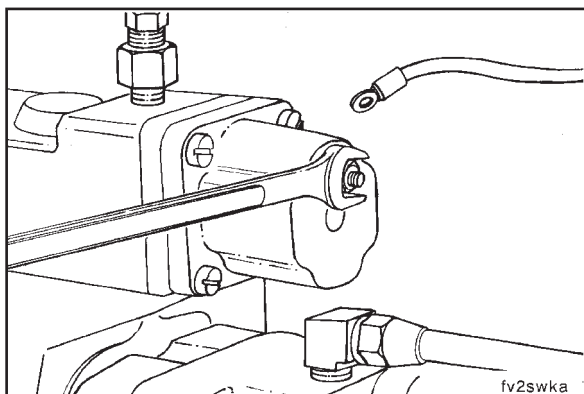
Tighten the support bracket to engine mounting capscrews.



Torque Value: 47 N•m [35 ft-lb]

Tighten the fuel pump mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]



Connect the fuel plumbing.

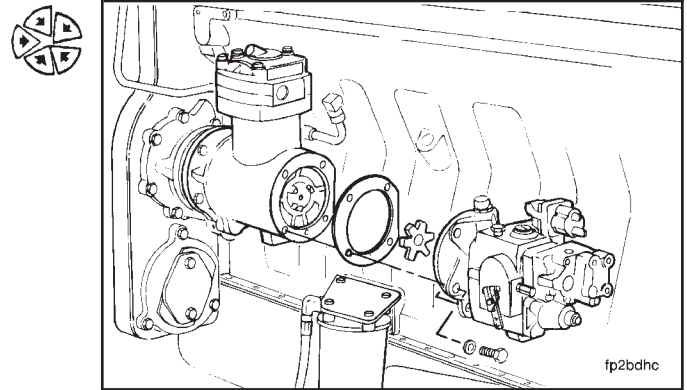
Connect the electric wire to the shutoff solenoid.

Connect the battery cables.

Start the engine and check for leaks.

STC

Install the fuel pump drive coupling.
Use a new gasket when installing the fuel pump.
Install the four 12 point fuel pump mounting capscrews.

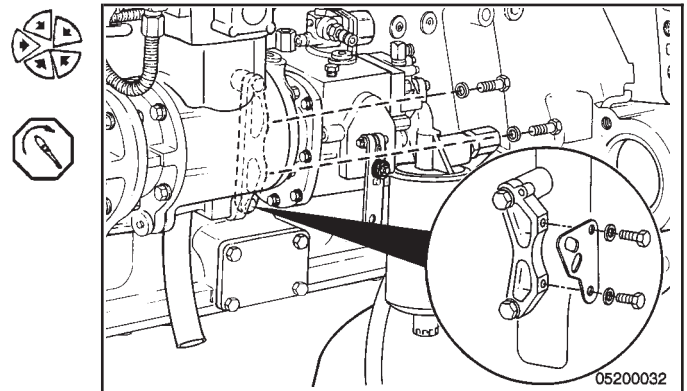


Install the two fuel pump support bracket capscrews to the cylinder block bracket. Tighten the four fuel pump mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]

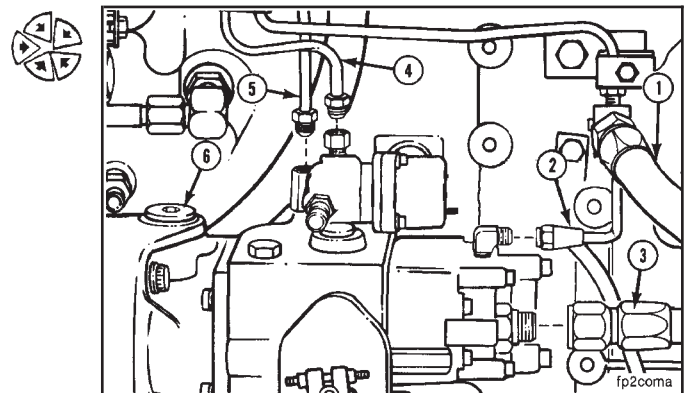
Tighten the two support bracket to cylinder block capscrews.

Torque Value: 47 N•m [35 ft-lb]



Install the AFC air tube and fuel tubing:

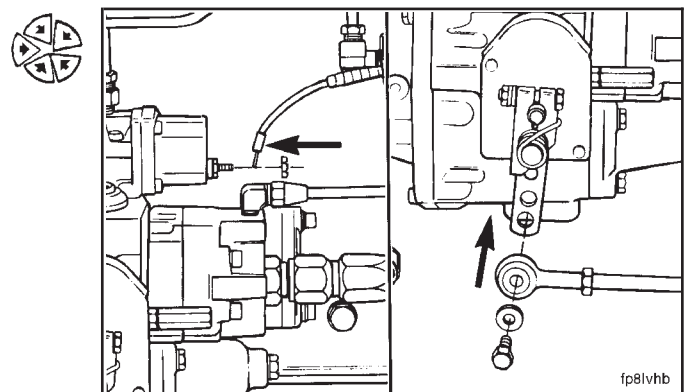
- Fuel drain from the T-block connection (1)
- Gear pump cooling drain (2)
- Gear pump suction line (3)
- Fuel supply to the injectors (4)
- AFC air supply tube (5)
- Tachometer cable (if used) (6)

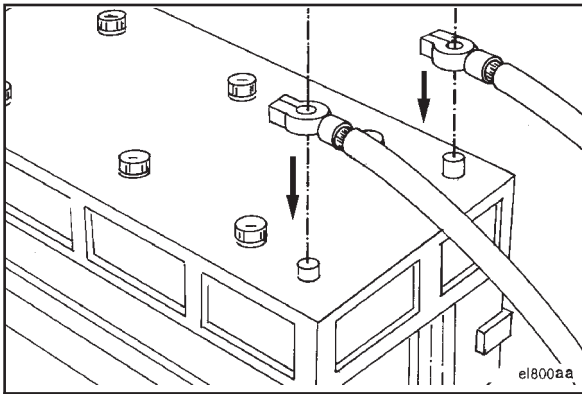


Install the electric wire to the fuel shutoff valve. The wire connection nut **must** be clean and tight.

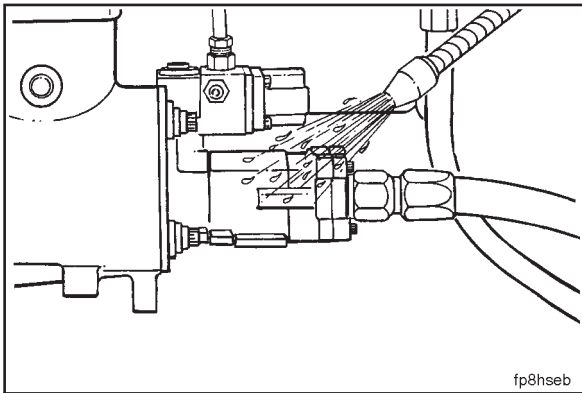
Torque Value: 3 N•m [25 in-lb]

Install the linkage to the throttle lever.





Install the battery cables.

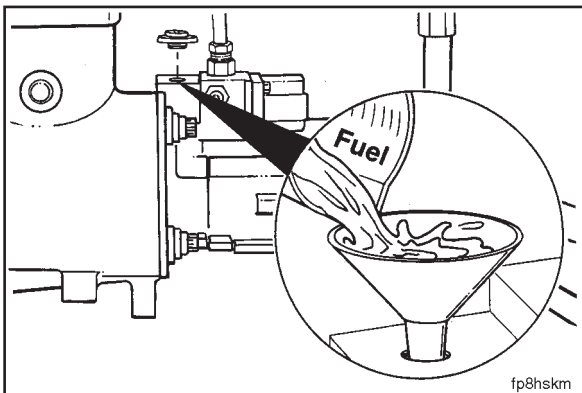


Prime (005-016-050)

General Information

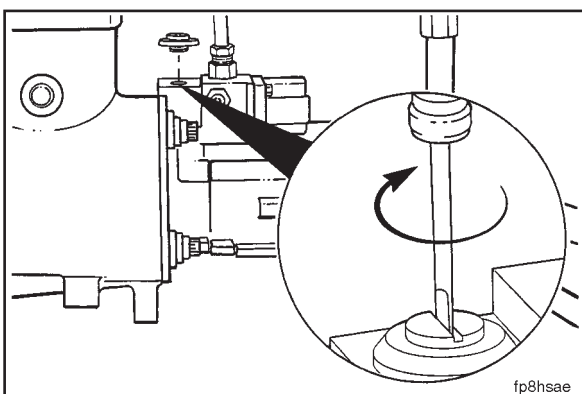
To reduce engine cranking time, prime the fuel supply pump.

NOTE: If the fuel supply pump is dirty, clean the outside of the pump.



CELECT™ or CELECT™ plus

remove the filter cap from the top of the front support.
fill the pump with clean fuel oil.



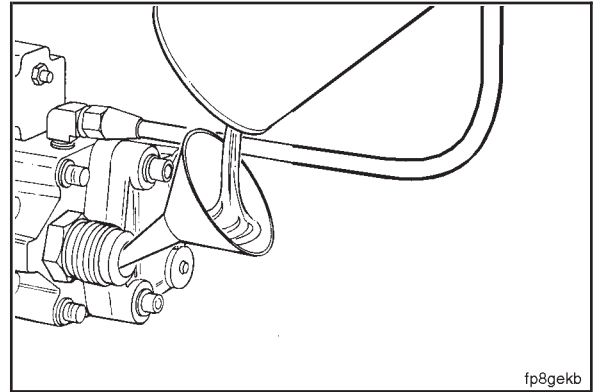
Install and tighten the filter cap.

Torque Value: 16 N•m [12 ft-lb]

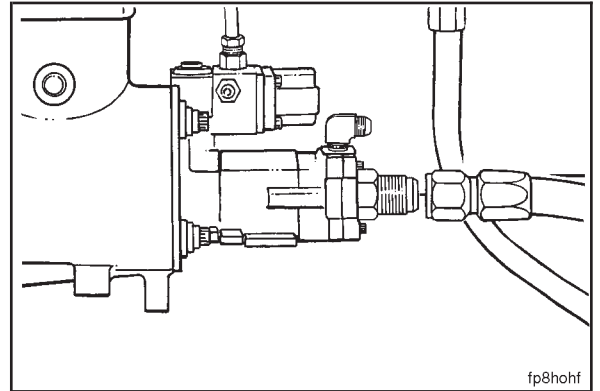


If the filter cap opening **cannot** be used, remove the fuel supply hose to the gear pump.

Fill the pump with clean fuel.



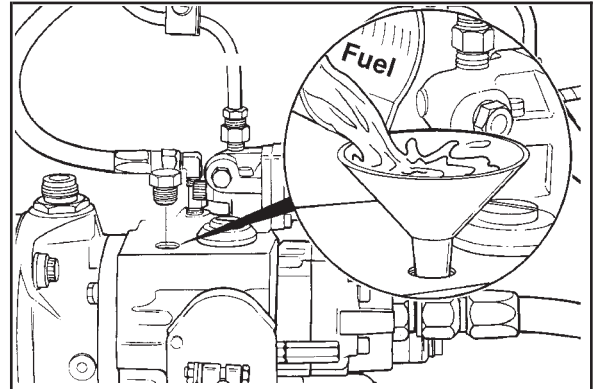
Install the fuel supply hose to the gear pump.



STC

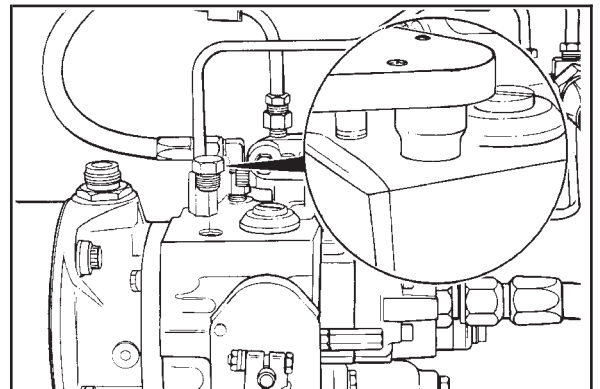
Remove the plug from the top of the housing.

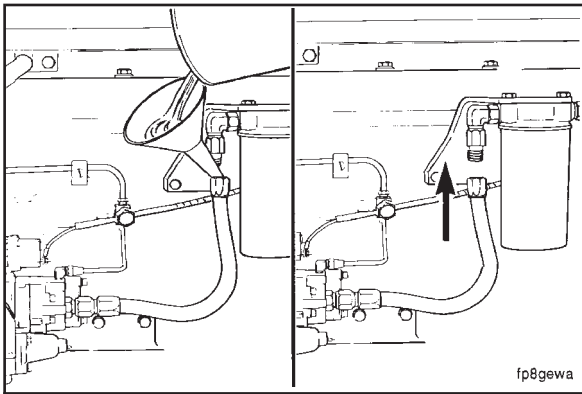
Fill the housing with clean fuel oil.



Install the plug into the top of the housing.

Torque Value: 27 N•m [20 ft-lb]



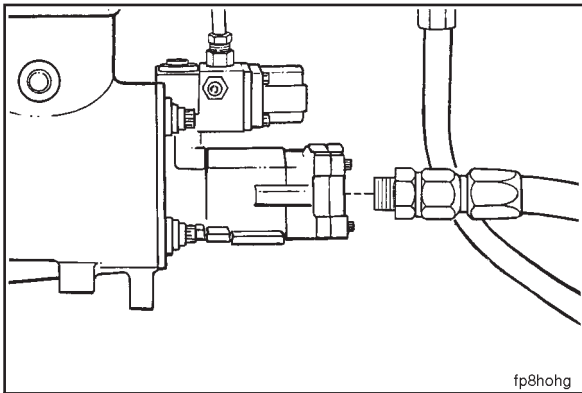


If the priming plug is hard to remove or the fuel pump is a VS type, remove the fuel supply hose to the gear pump.

Fill the hose and gear pump with clean fuel.

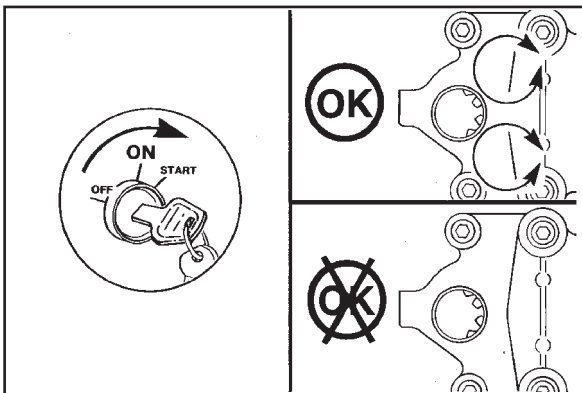


Install the fuel supply hose to the filter head.

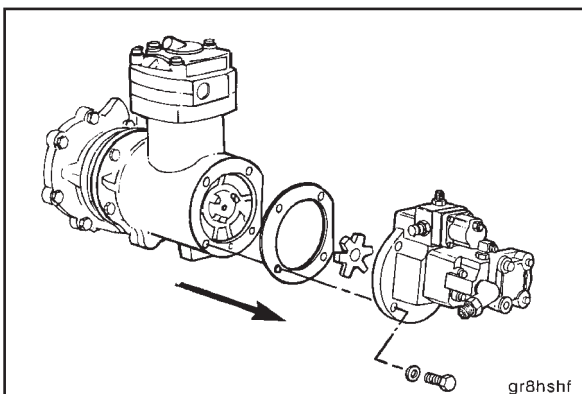


Rotation Check (005-016-052)

Remove the fuel supply hose and the fuel inlet fitting from the gear pump.



Look into the gear pump and crank the engine. The gear pump gears **must** turn.



If the supply pump gears do **not** turn, remove the fuel pump. Refer to Procedure 005-016-002.

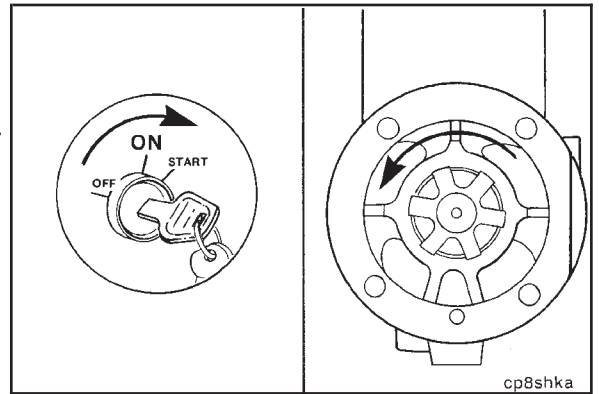


M11 Series
Section 5 - Fuel System - Group 05

Crank the engine and check the air compressor or the accessory drive shaft for rotation.

If the shaft turns, the fuel pump is damaged and **must** be replaced or repaired. Refer to the M11 Shop Manual, Bulletin No. 3666075, for rebuilding instructions.

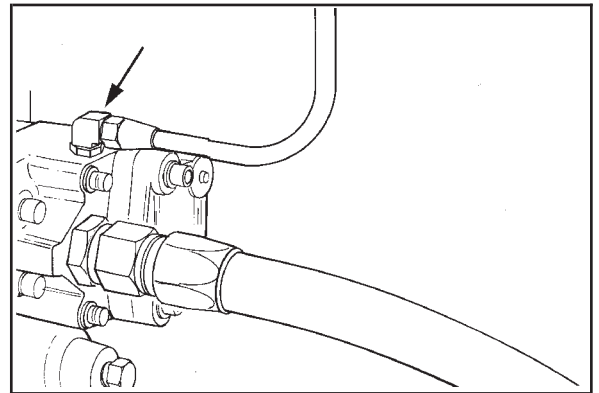
If the shaft does **not** turn, remove the air compressor and check the accessory drive for rotation. If the accessory drive shaft turns, the air compressor or air compressor coupling is damaged and **must** be replaced.



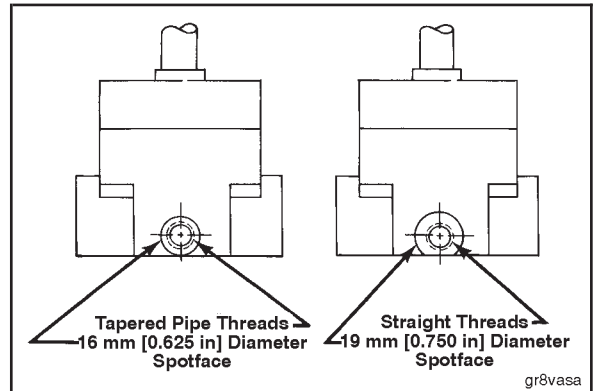
Fuel Pump Gear Pump Check Valve (005-026)

Remove (005-026-002)

If the check valve in the gear pump return elbow stays open or closed, replace the elbow.

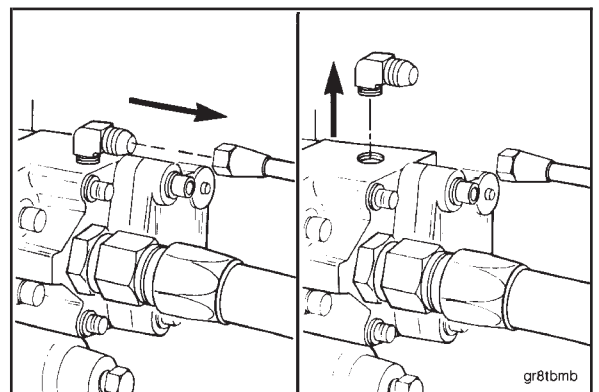


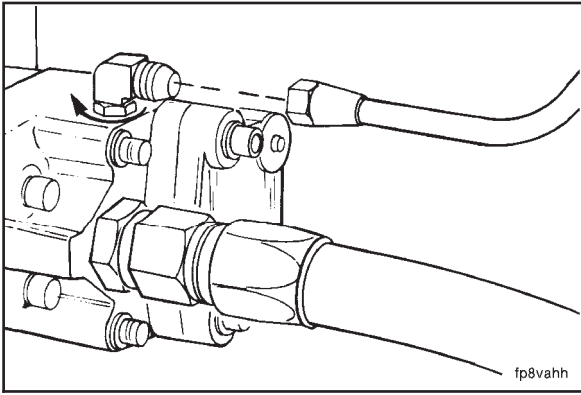
NOTE: Check the elbow threads. Do not install an elbow that has straight machine threads in a hole that has a pipe tap thread. A gear pump that has a straight thread will have a 19 mm [0.750 inch] spotface in the valve area. A gear pump that has a pipe tap thread will have a 16 mm [0.625 inch] spotface or no spotface.



Remove the drain line.

Remove the check valve elbow.





Install (005-026-026)

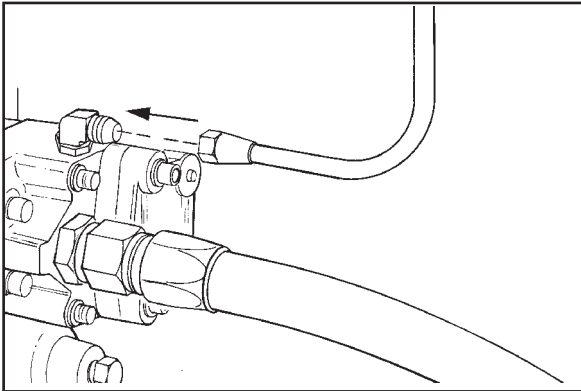
Install the check valve elbow.

- If the check valve elbow has machine threads to the maximum thread depth, turn the elbow out until it is pointed toward the drain line. Tighten the jam nut.

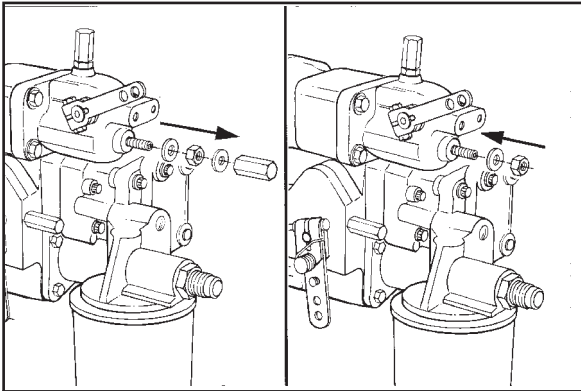


Torque Value: 6 N•m [50 in-lb]

- If the check valve has a pipe thread, install the elbow until it is tight and pointed toward the drain line.



Install the drain line.



Fuel Pump High Idle Speed (VS Governor) (005-028)

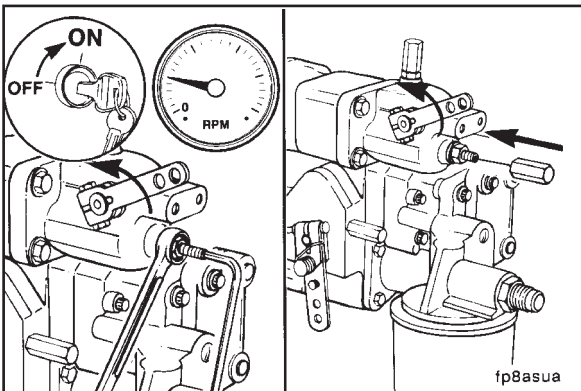


Adjust (005-028-029)

Idle Speed

To adjust the VS idle speed, remove the locknut and jam nut from the screw in the rear of the VS cover.

Install a new copper washer and the jam nut.



Start the engine. Hold the VS lever **counterclockwise** in the idle position. Adjust the idle screw to the correct rpm and tighten the jam nut.

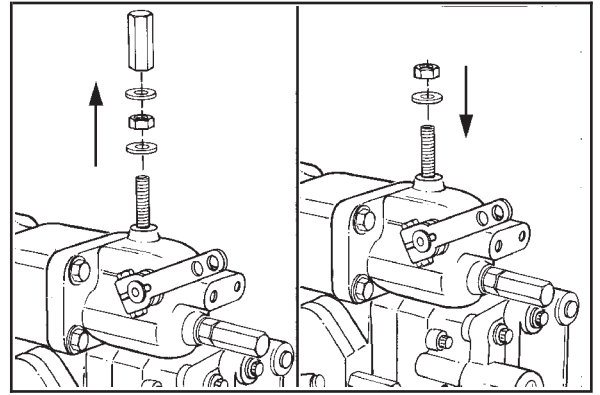


Install a new copper washer and locknut.

High Speed

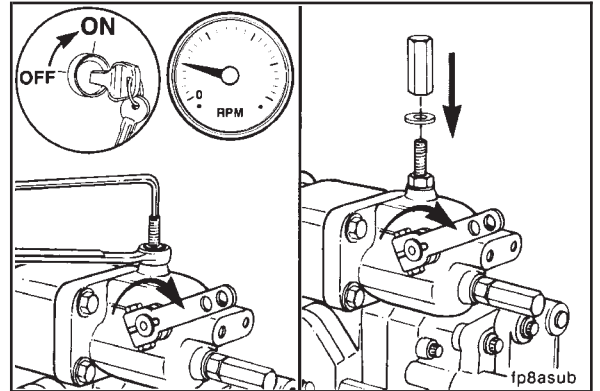
To adjust the VS high speed, remove the locknut and jam nut from the top screw of the VS cover. Discard the copper washers.

Install a new copper washer and the jam nut.



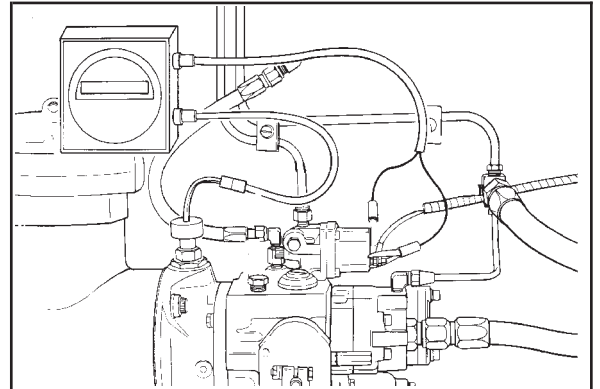
Start the engine. Hold the VS lever **clockwise** in the high speed position. Adjust the screw to the correct rpm and tighten the jam nut.

Install a new copper washer and the locknut.

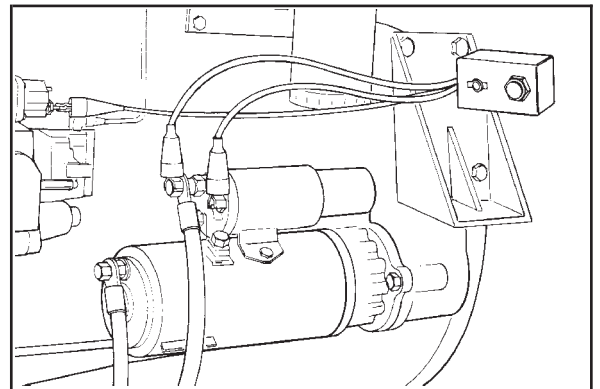


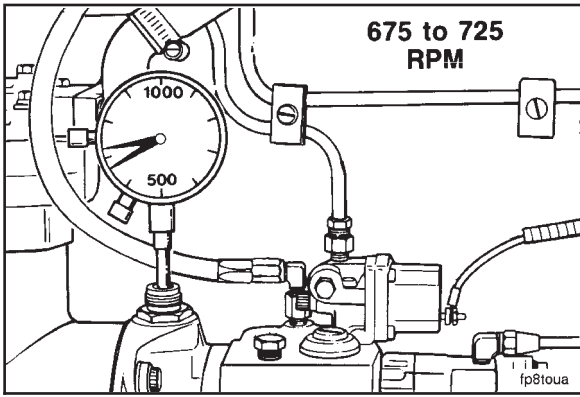
Fuel Pump Idle Speed (005-029) Adjust (005-029-029)

To check the engine speed, use digital tachometer kit, Part No. 3375631, or optical tachometer, Part No. 3377462.



The remote starter, Part No. 3376506, can be used to start the engine. The leads are marked for their connection points.





NOTE: The idle speed can vary on some applications.

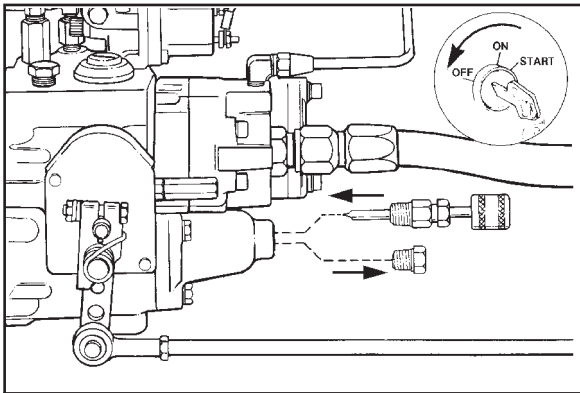
Refer to the fuel pump code for the specified engine idle speed.



Adjust the engine low idle speed between 600 and 800 rpm.



NOTE: This adjustment is sometimes necessary on a new engine to compensate for the added engine driven accessories that are installed by the truck or vehicle manufacturer.

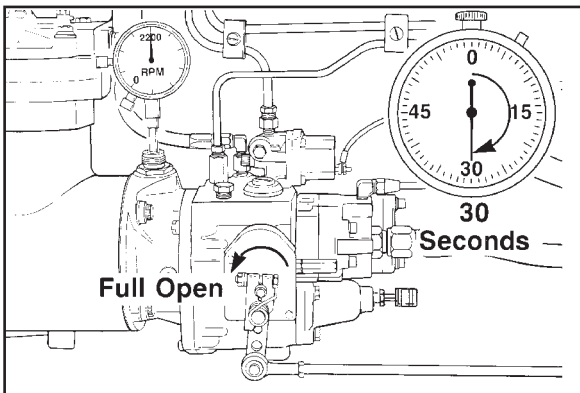


Shut off the engine.

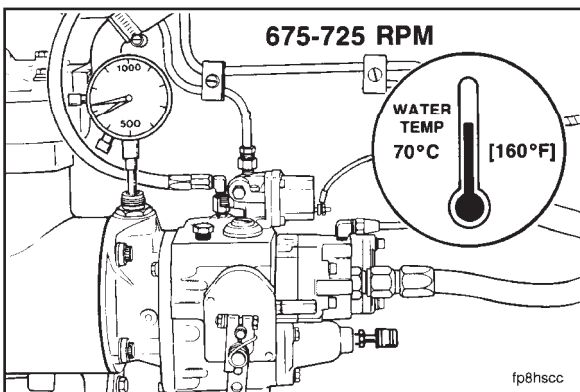
Remove the plug from the spring pack cover.



Install the fuel pump idle adjusting tool into the plug hole. Use tool, Part No. 3375981, for holes with pipe threads and tool, Part No. 3823480, for holes with straight threads.



Operate the engine for 30 seconds at high idle to remove the air from the fuel system.



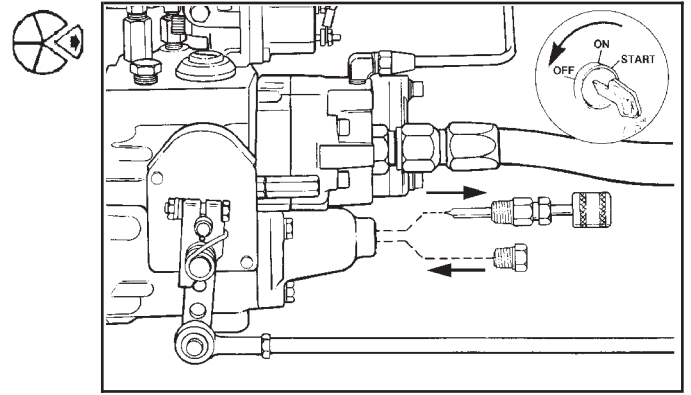
NOTE: Make sure the engine is at or above 70°C [160°F].

Adjust the idle speed. Turn the tool **clockwise** to increase the idle speed and **counterclockwise** to decrease the idle speed.

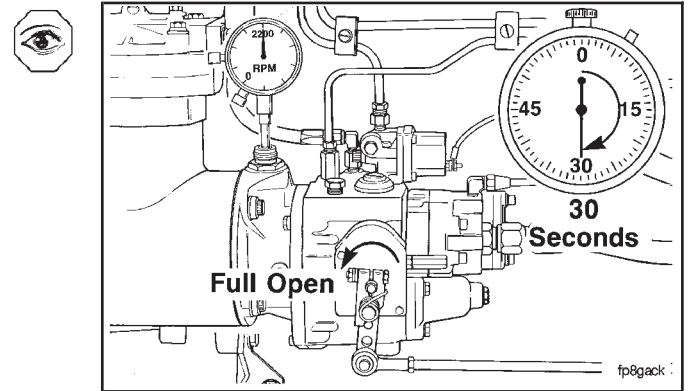


Shut off the engine.

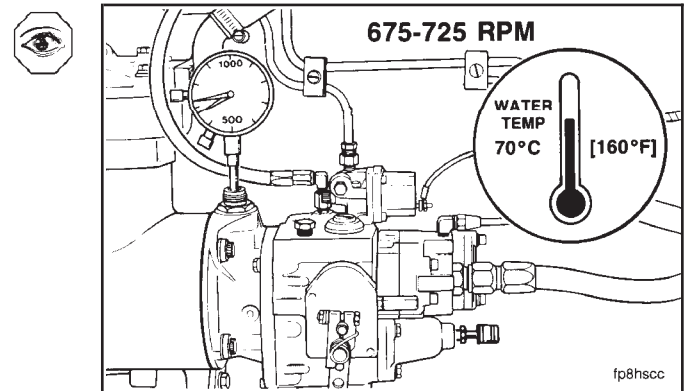
Remove the tool and install the plug.



Operate the engine until the rpm is constant and all of the air is out of the fuel system.



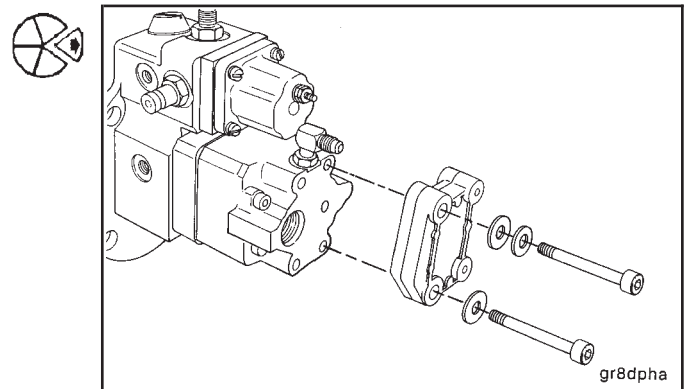
Check the idle speed again.

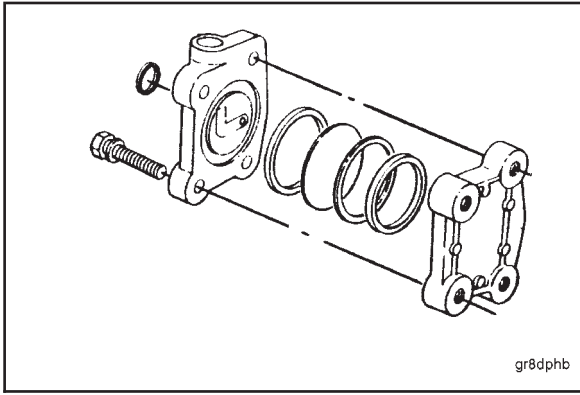


Fuel Pump Pulsation Damper (005-031)

Inspect for Reuse (005-031-007)

Remove the fuel inlet connection and pulsation damper or the filter head damper assembly. Discard the rubber o-rings.



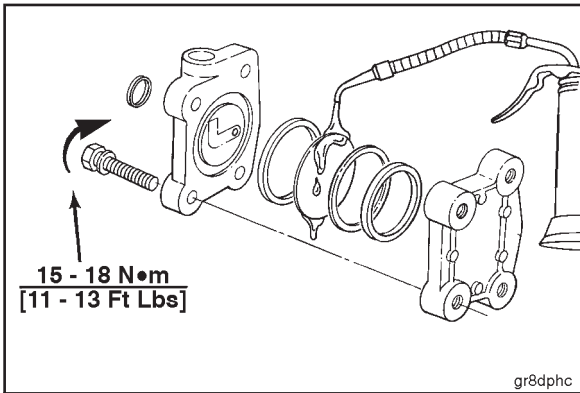


Remove the housing from the cover. Remove the spring steel diaphragm. Discard the o-rings. Inspect the nylon washer and discard it if it is damaged.



Check for corrosion, wear, or cracks in the cover or the diaphragm. Replace the damaged parts.

To check the diaphragm for hidden cracks, drop it on a flat hard surface. It **must** have a clear ring. If it has a flat sound, replace the diaphragm.

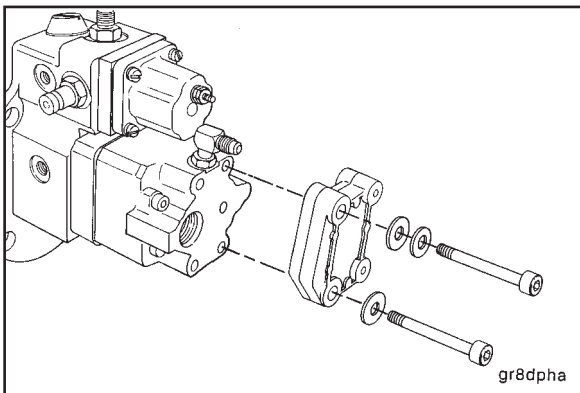


Install new o-rings in the grooves and a new nylon washer. Clean the diaphragm. Coat the diaphragm with clean engine oil. Install the diaphragm in the cover.



Assemble the cover to the housing. Tighten the capscrews.

Torque Value: 18 N•m [13 ft-lb]



Remove the two damper mounting capscrews. Install the damper assembly with a new o-ring on the gear pump. Tighten the capscrews.



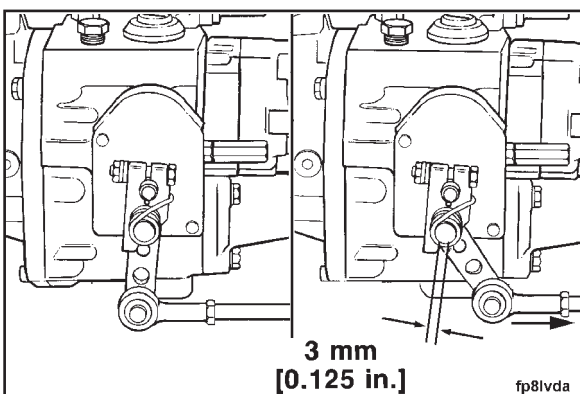
Torque Value: 18 N•m [13 ft-lb]

NOTE: If a fuel filter and damper assembly are mounted on the gear pump, remove the four mounting capscrews.



Install the fuel inlet connection. Be careful not to let dirt enter the fuel pump.

Check for free rotation of the gear pump.



Fuel Pump Throttle Lever (005-035)

Adjust (005-035-029)



Do not make any adjustments to the throttle stop screws. If the throttle does not break over correctly, adjust the throttle lever or linkage.

Make sure the throttle linkage is adjusted so the throttle lever breaks over 3 to 6 mm [1/8 to 1/4 inch] when the lever is in the full throttle position.

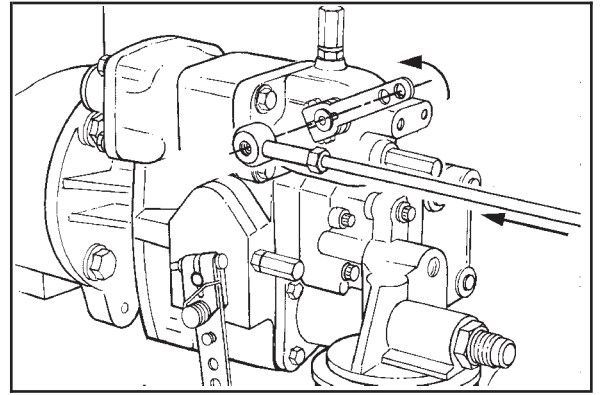
NOTE: The throttle lever stop **must** contact the rear throttle stop screw.

Fuel Pump Throttle Linkage (005-036)

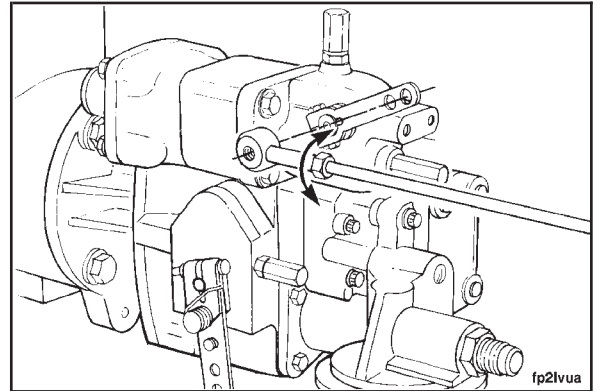
Adjust (005-036-029)

Remove the throttle linkage from the throttle lever.

Hold the VS lever **counterclockwise** in the idle position.
Move the linkage to the idle position.

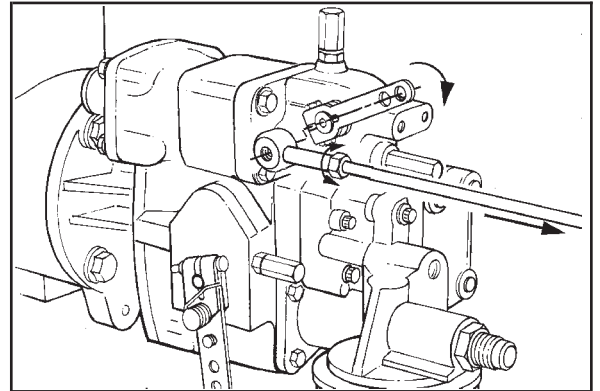


If the lever and the linkage are **not** aligned, adjust the linkage.

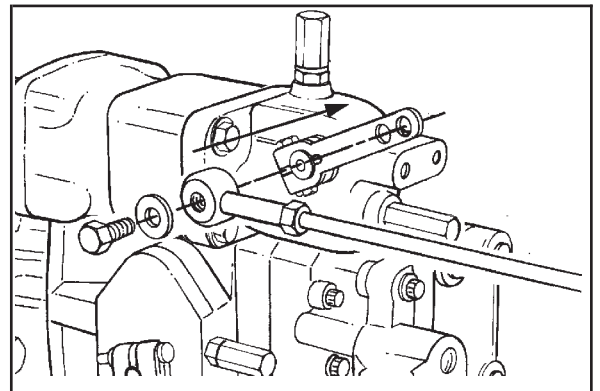


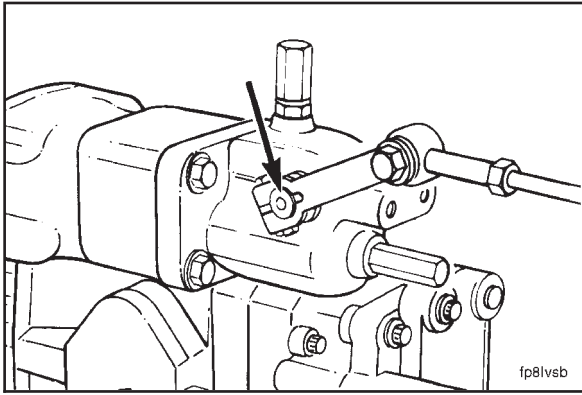
Move the VS lever linkage **clockwise** to the maximum speed position.

If the lever and the linkage are **not** aligned, adjust the linkage.



Install the linkage on the lever.

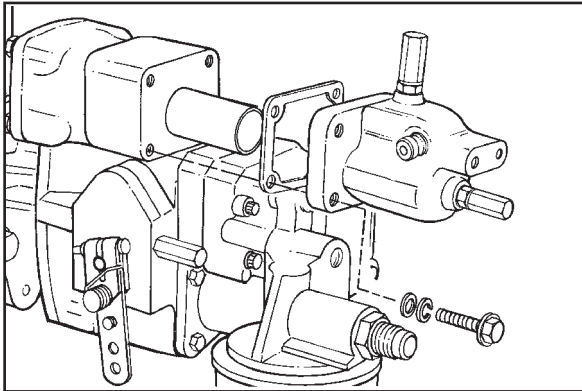




Fuel Pump VS Throttle Shaft Housing (005-038)

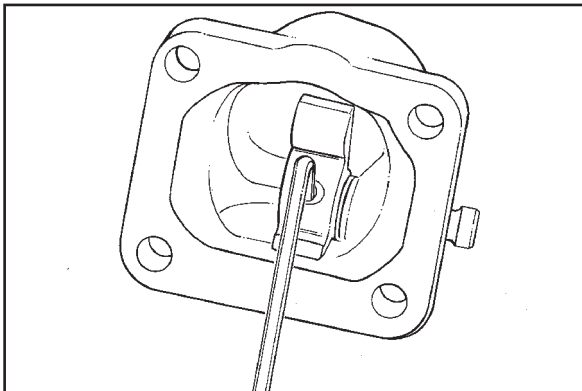
Remove (005-038-002)

Mark the angle of the VS throttle lever on the VS throttle shaft. Remove the VS throttle lever.

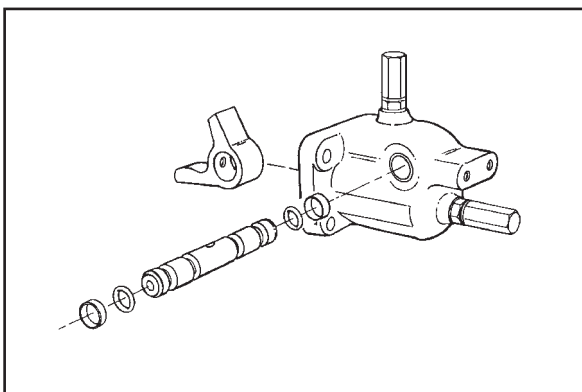


NOTE: Make sure the components in the spring pack guide do **not** fall out when the cover is removed.

Remove the VS spring pack housing cover.



Loosen the set screw in the VS throttle stop.

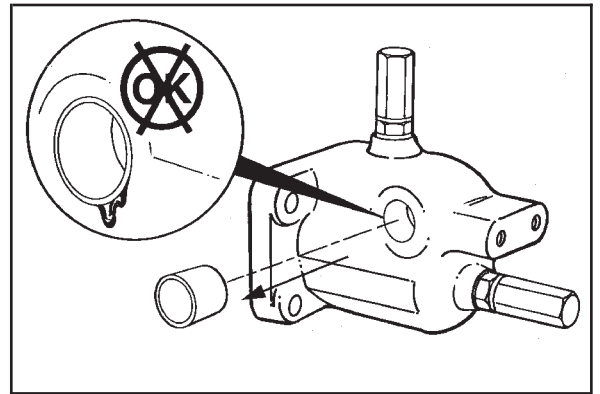


Remove the VS throttle shaft from the cover. Discard the o-rings.

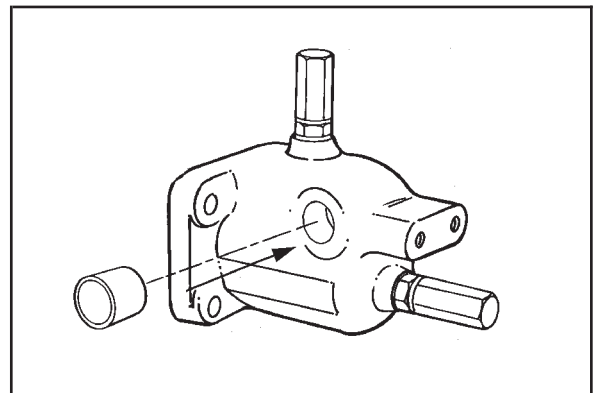
Remove the shaft dust seals from the cover and discard.

If fuel is leaking between the bushings and the cover, replace the bushings.

- Press the bushings from the cover



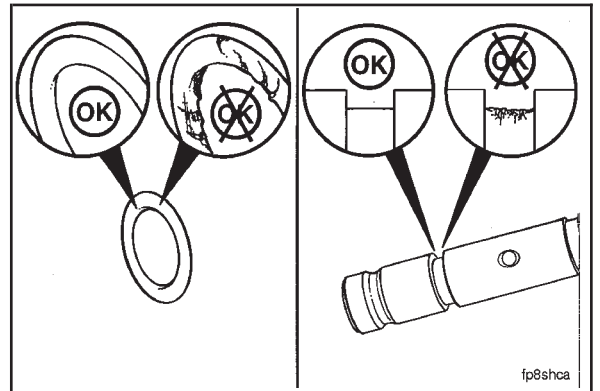
- Install the new bushings into the cover



Examine the o-ring for excessive wear.

If the o-ring wear is due to inadequate surface finish in the throttle shaft o-ring groove, replace the throttle shaft.

NOTE: Before installing the new shaft, mark the end of the new shaft in the same location as the mark on the old shaft to allow correct alignment of the VS throttle lever.

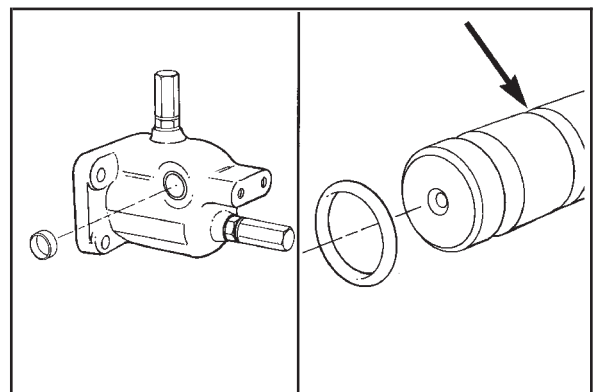


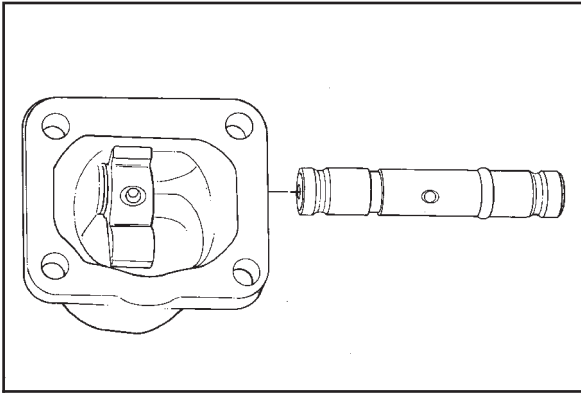
Install (005-038-026)

Install new dust seals into the cover.

Install an o-ring on the shaft near the lever end.

Apply clean vegetable oil to the o-ring before installation.

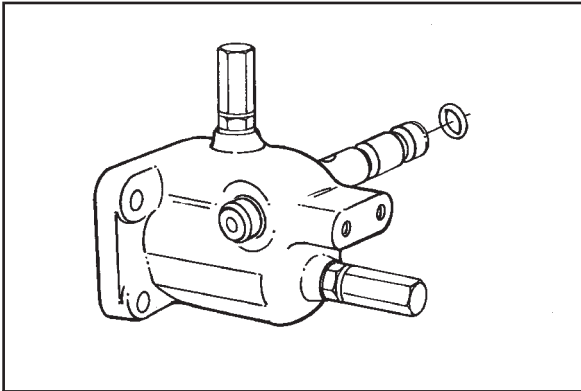




Place the throttle stop into the cover.

NOTE: The longest lever on the stop goes toward the rear adjustment screw.

Install the shaft into the cover and through the stop.

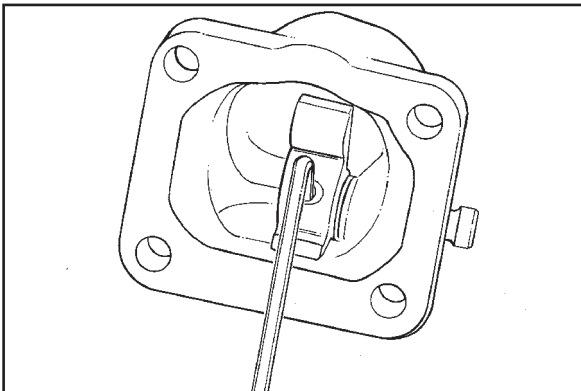


Push the shaft out of the other side of the cover.

Install the other shaft o-ring and apply clean vegetable oil to the o-ring before installation.



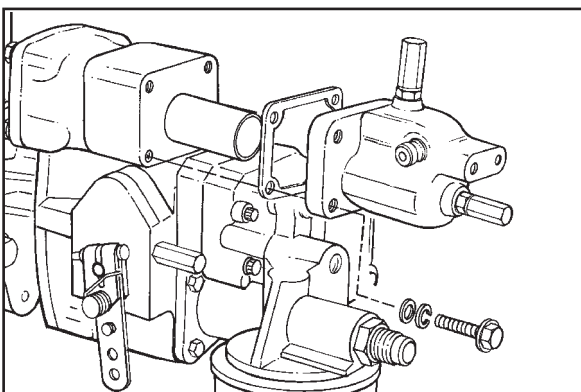
Push the shaft back into the cover.



Align the setscrew hole in the stop with the hole in the shaft.

Install the setscrew into the stop and tighten.

Torque Value: 7 N•m [60 in-lb]

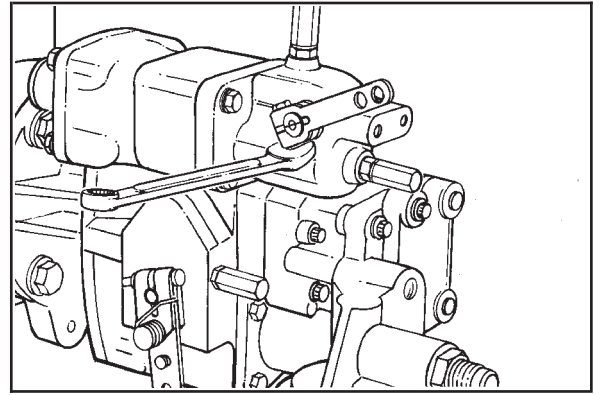


Assemble the cover to the fuel pump with a new gasket.

Align the lever with the mark on the throttle shaft to install the lever.

Tighten the lever retaining nut to secure the lever to the shaft.

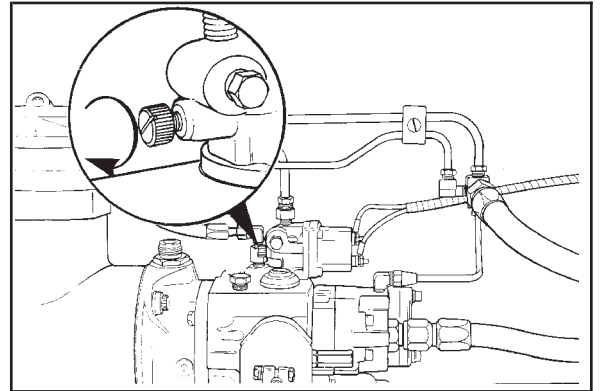
Check the throttle linkage for binding.



Fuel Shutoff Valve (FSOV) (005-043) Inspect for Reuse (005-043-007)

To start a STC engine in case of an electrical failure, turn the knob on the shutoff valve **clockwise** to open the valve.

To shut off a STC engine, turn the shutoff valve knob **counterclockwise**.

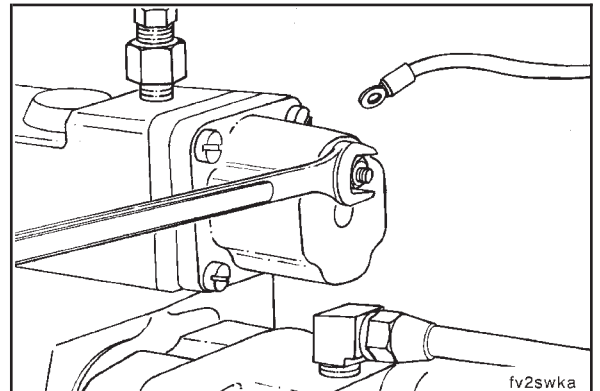


Remove the wire. Make sure the remaining wire connection nut is tight. Tighten the nut.

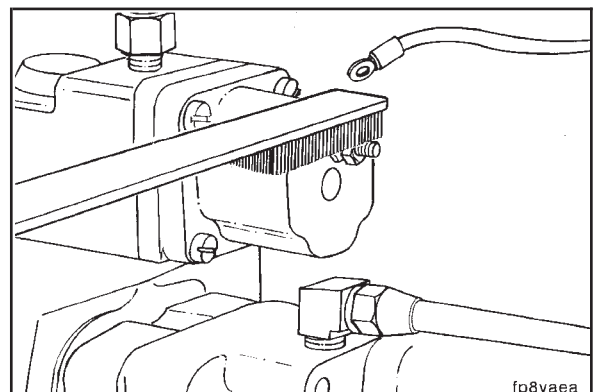
Torque Value: 3 N•m [25 in-lb]

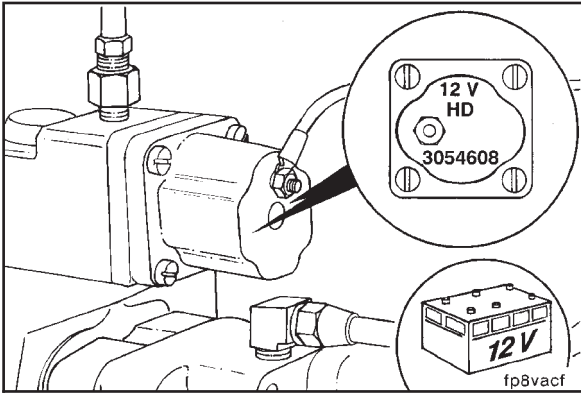
Make sure the post is tight and secure in the coil.

NOTE: Only single post coils can be used on the CELECT™ or CELECT™ Plus fuel system. Two post coils will interfere with the cooling line.



Use a wire brush to clean any corrosion from the coil terminal.



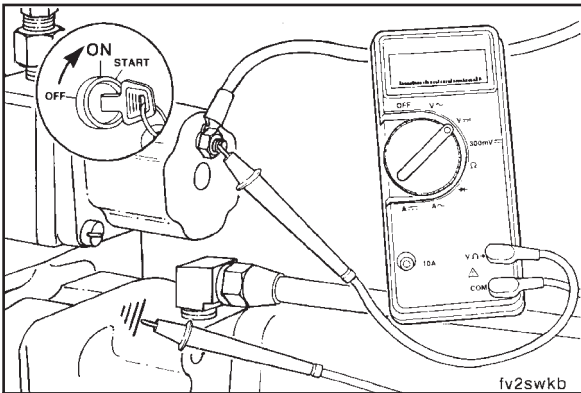


CAUTION

This must be the only wire connected to the shutoff valve.

Connect the wire. Make sure the shutoff valve coil is the correct voltage.

The coil voltage and part number are cast into the terminal connection end of the coil.

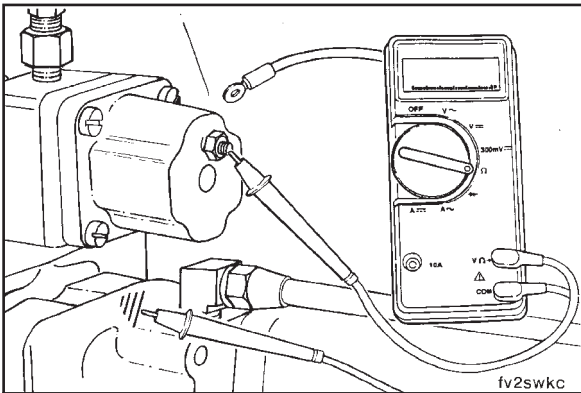


Turn the vehicle key switch to the "ON" position.

Check the DC Voltage to the coil with a volt-ohm meter, Part No. 3377161, or equivalent.

The voltage **must** be the same as the battery voltage.

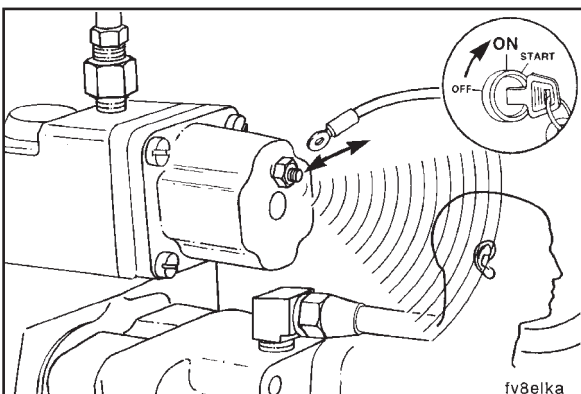
Turn the vehicle key switch to the "OFF" position.



Make sure the coil wire is **not** connected before checking the coil resistance.

Check the coil resistance with a volt-ohm meter. The coil resistance **must** be 7 to 8 ohms for 12 volt solenoids or 28 to 32 ohms for 24 volt solenoids..

Replace the coil if the resistance does **not** meet the specifications.



Turn the vehicle key switch to the "ON" position. Listen for the valve to "click" when the wire is touched to the coil terminal. If the valve does **not** "click", repair or replace the fuel shutoff valve. Refer to the M11 Shop Manual, Bulletin No. 3666075.



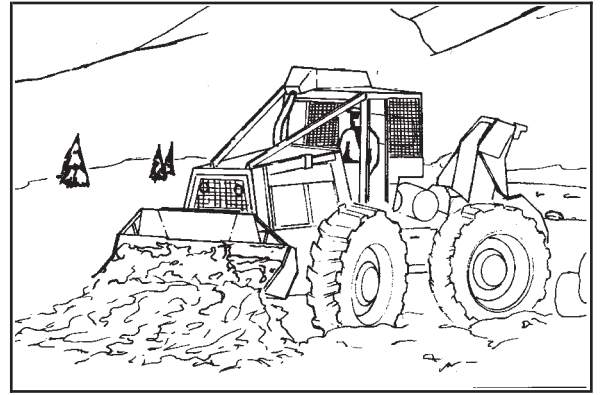
Stall Speed Test (005-054)

Stall Speed Check (005-054-046)

Converter Transmissions Stall Speed

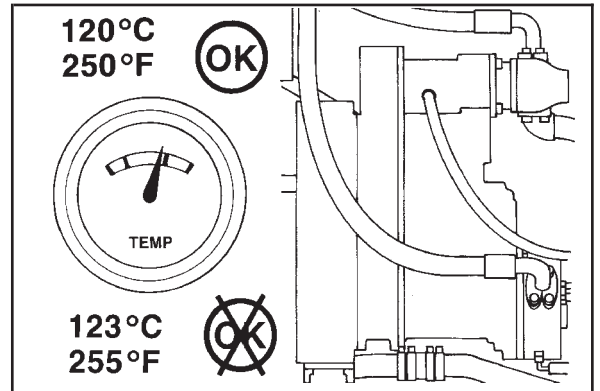
The stall speed is the engine speed (rpm) obtained at full throttle when the converter output shaft is locked.

NOTE: It is possible the vehicle brakes will **not** hold an electronically controlled transmission.



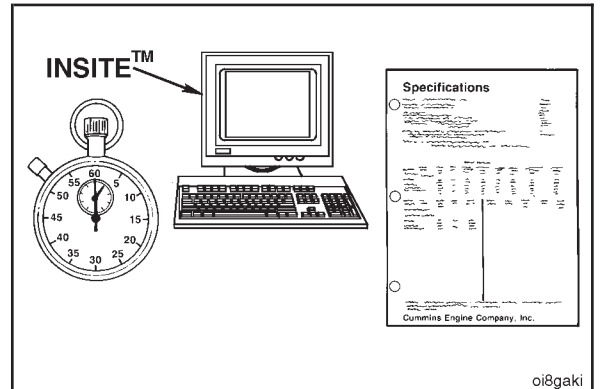
⚠ CAUTION ⚠

Do not exceed 120°C [250°F] converter oil temperature. Overheating which can result and converter damage can occur. If the oil temperature exceeds 120°C [250°F], put the transmission in neutral and operate the engine until the oil temperature is below 120°C [250°F]. Check the converter oil level.

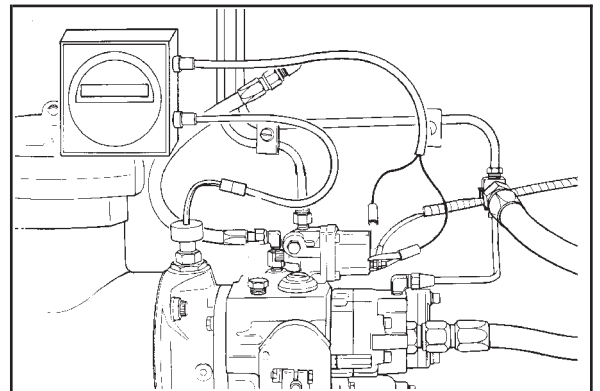


The following equipment is needed for this check:

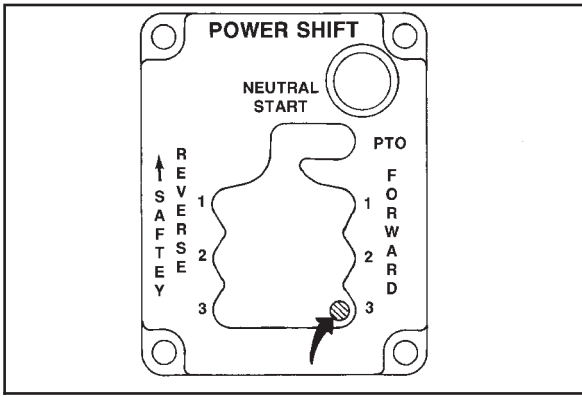
- Stop watch
- Digital tachometer kit, Part No. 3375631, or optical tachometer, Part No. 3377462
- Equipment manufacturer's stall speed and time to stall specifications



Install the tachometer on the fuel pump.

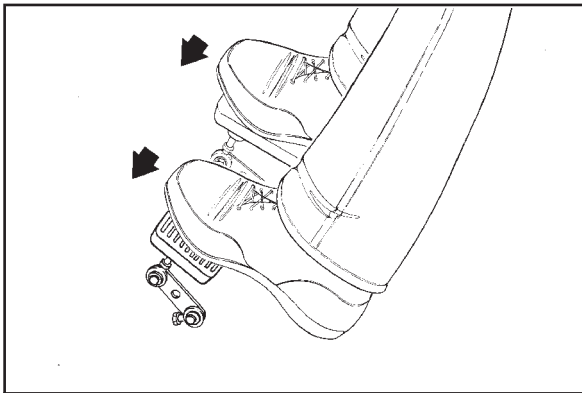


Place the gear selector in the highest gear or full forward.

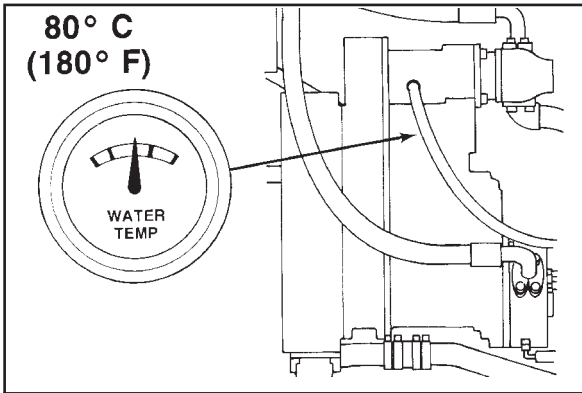


Make sure the vehicle has good brakes and air pressure in the brake system.

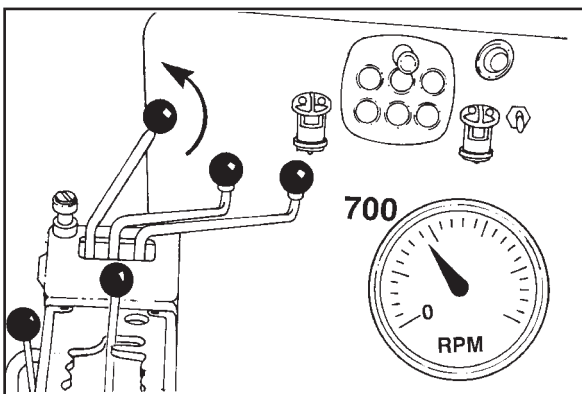
NOTE: The brakes **must** prevent the vehicle from moving when the engine is at full throttle. Engage the vehicle brakes to keep the vehicle from moving.



Operate the engine until the converter temperature is 80°C [180°F] or above.



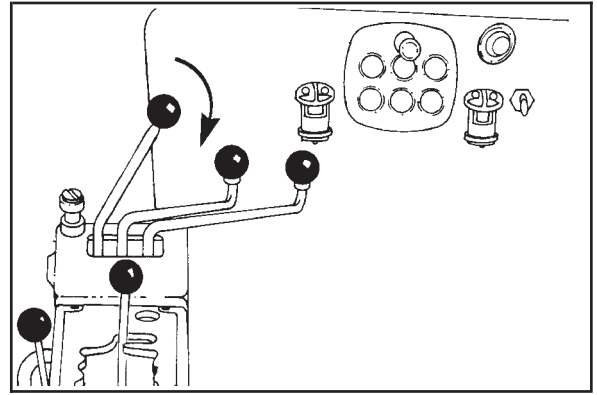
Bring the engine speed back to low idle.



CAUTION

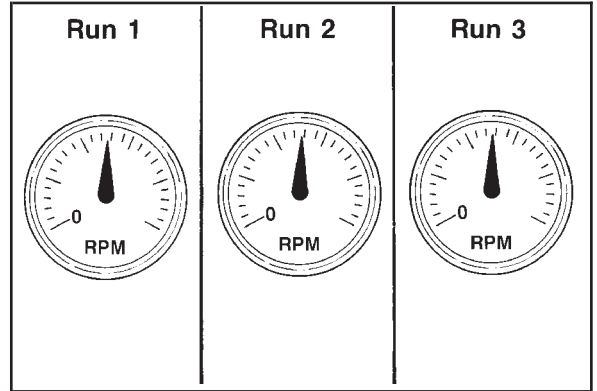
Do not exceed 120°C [250°F] converter oil temperature. Overheating and damage to the converter can occur.

Quickly move the throttle to the full open position.



Check the engine speed (rpm) at the point of stall:

- Always hold the speed until it is stable
- Take several readings
- Make sure the readings are accurate



Check the speed (rpm) against the specifications for the equipment, converter, or automatic transmission.

NOTE: The stall speed for the engine and converter/transmission can vary ± 8 percent from the manufacturer's specifications.



Specifications

Cummins Engine Company, Inc.

$\pm 8\%$

$> \pm 8\%$

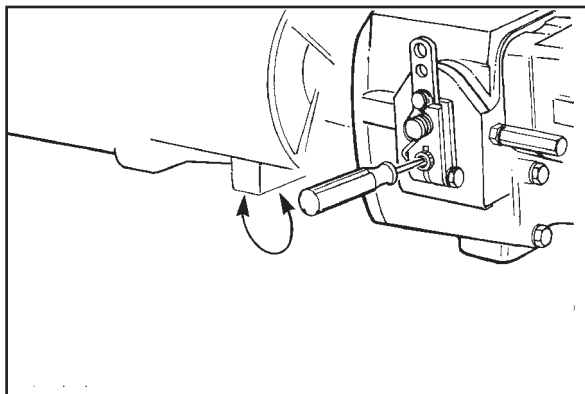
oi800cm

If the stall speed is **not** within the specifications, refer to the stall speed check list at the end of this section.



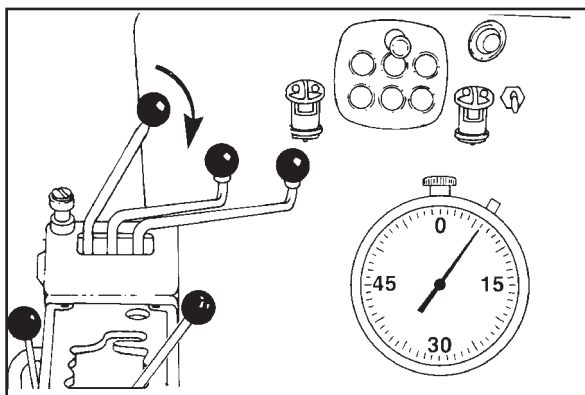
Check the equipment manufacturer's troubleshooting procedures for other reasons for stall speed problems.

STALL SPEED CHECK LIST		
IF THE STALL SPEED IS TOO LOW, CHECK THE FOLLOWING:		
Yes	No	
1.	The tachometer is in error.
2.	The engine is up to or above 70°C [160°F].
3.	The converter oil is up to temperature 80°C [180°F] minimum.
4.	The stall has been held long enough for the engine to accelerate to full power.
5.	The match curve stall speed was recorded correctly.
6.	The converter oil is to the converter manufacturer's recommendation. (SAE 30 instead of SAE 10 for instance)
7.	The engine driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversize compressors, etc. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.	The AFC (Air Fuel Control) is properly adjusted.
9.	The unit is operating at an altitude high enough to affect the engine power.
10.	The converter charging pressure is correct.
11.	The tailshaft governor is interfering with and preventing a full throttle opening. (Disconnect the tailshaft governor.)
12.	The converter blading is interfering or in a stage of failure. Check the sump or filter for metal particles.
13.	The converter stators are free-wheeling instead of locking up.
14.	The engine is set for power other than that specified on the power curve.
..	..	



Adjust the throttle shaft plunger screw, if necessary, to change the stall speed. Refer to Procedure 005-028.

NOTE: Do **not** increase the fuel rate unless it is the true cause for the low stall speed. Overfueling of the engine and poor durability can result.

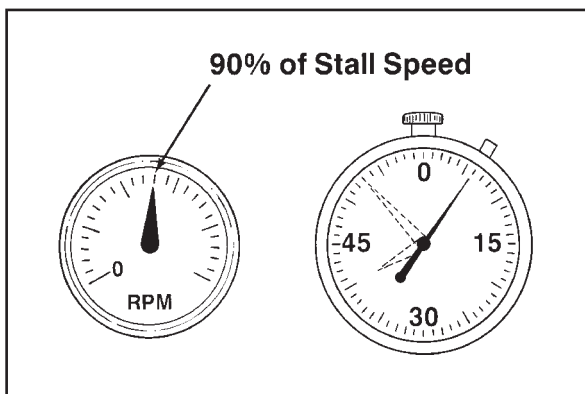


Time Speed Check (005-054-047)

Perform the previous Stall Speed Check procedure through the “check the engine speed (rpm) at the point of stall” step then:



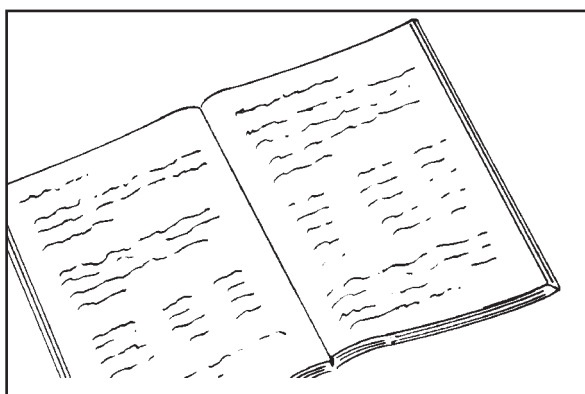
- Quickly move the throttle to the full open position and start the stop watch at the same time



- When the engine speed is 90 percent of the stall speed rpm, stop the stop watch

Example: Stall speed 2089, [2089 X .90 = 1880 rpm]

NOTE: The type of unit and the stall speed rpm can make the stall speed time a maximum of 10 seconds.



Check the equipment manufacturer's specifications for the time to stall or the acceleration time.

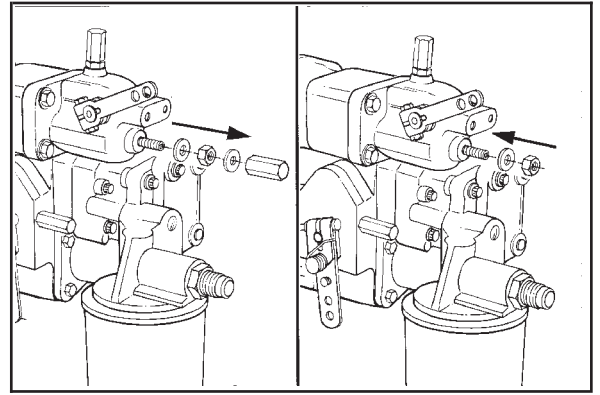


If the time is excessive, check the fuel pump AFC for an air leak. Refer to Procedure 006-047 and the Stall Speed Check List at the end of this procedure.

VS Governor Adjusting Screw Sealing Washers (005-056)

Remove (005-056-002)

Remove the locknuts and jam nuts.
Discard the copper washers.

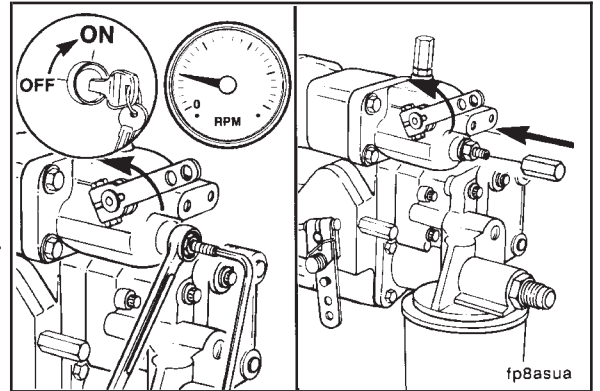


Install (005-056-026)

Install new copper washers between the jam nuts and the locknuts.

Install the jam nuts.

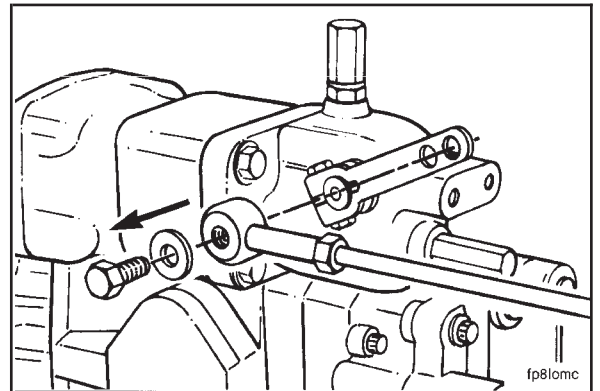
Check the governor speed adjustments. Refer to Procedures 005-028 and 005-029.



VS Governor Idle Spring (005-057)

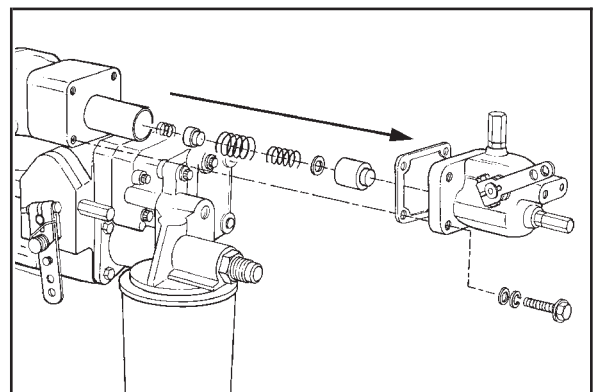
Remove (005-057-002)

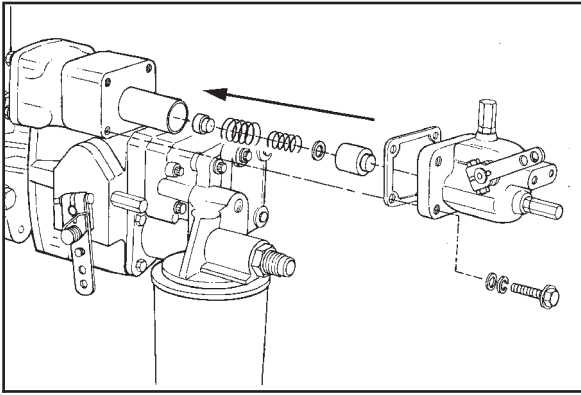
Remove the linkage from the VS throttle lever.



Remove the following parts:

- VS housing cover
- Gasket
- Throttle lever plunger
- High speed spring and the shims
- Plunger assist spring, if required
- Spring guide
- Idle spring

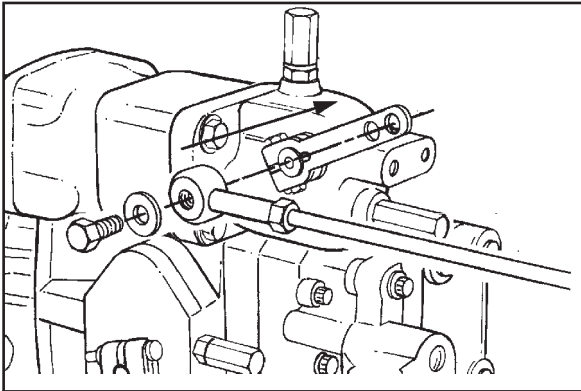




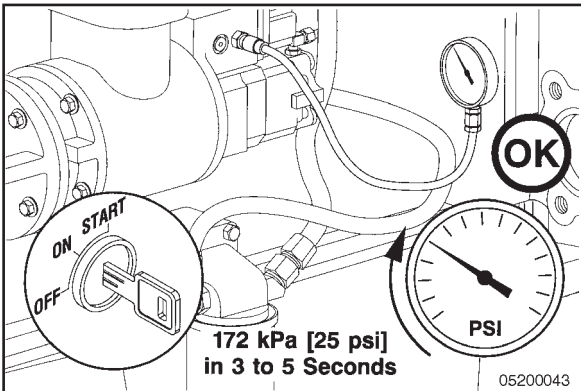
Install (005-057-026)

Install the following parts:

- Spring guide
- High speed spring and the shims
- Plunger assist spring, if required
- Throttle lever plunger
- New cover gasket
- VS housing cover



Install the linkage to the VS throttle lever.



Fuel Pump Pressure Regulator (005-060)

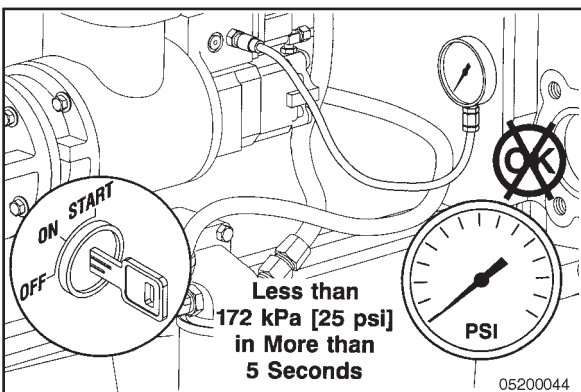
Initial Check (005-060-001)



To check for a sticking pressure regulator, install a pressure gauge on the Compuchek fitting in the side of the fuel shutoff valve.

Start cranking the engine.

The pressure gauge **must** start moving immediately and increase rapidly until the engine fires (approximately 172 kPa [25 psi]). This should take 3 to 5 seconds.



If the pressure gauge does **not** move or increases very slowly for more than 6 seconds, the regulator plunger is stuck open and will **not** let pressure build up quickly for a normal start. This can be caused by dirt, rust, or burrs on the plunger, or burrs on the plunger bore.

If the plunger is sticking, the gear pump **must** be replaced with a new or ReCon® unit. Refer to the Engine Shop Manual, Bulletin No. 3666075.

Stall Speed Check List

If The Stall Speed Is Too Low, Check The Following:

	Yes	No	
1.			The tachometer is in error.
2.			The engine is up to or above 70°C [160°F].
3.			The converter oil is up to temperature 80°C [180°F].
4.			The stall has been held long enough for the engine to accelerate to full power.
5.			The match curve stall speed was recorded correctly.
6.			The converter oil is to the converter manufacturer's recommendation (SAE 30 instead of SAE 10 for instance).
7.			The engine driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversize compressors, and so on. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.			The Air Fuel Control (AFC) is properly adjusted.
9.			The unit is operating at an altitude high enough to affect the engine power.
10.			The converter charging pressure is correct.
11.			The tailshaft governor is interfering with and preventing a full throttle opening. Disconnect the tailshaft governor. Do not exceed the manufacturer's maximum output speed.
12.			The converter blading is interfering, or in a stage of failure. Check the sump or filter for particles.
13.			The converter stators are free-wheeling instead of locking up.
14.			The engine is set for power other than that specified on the power curve.
15.			The converter is wrong due to improper build or rebuild of unit.
16.			The converter is performing to the published absorption curve.
17.			The engine and converter match is correct. Check the engine and converter models for the proper match.
18.			The engine is matched to too large of a converter. If this condition is believed to exist, please report the engine-converter-accessory information to the factory.
19.			The engine power is down. The engine torque rise could be less than shown on the standard engine curve. See the fuel setting adjustments and the turbocharger air manifold pressure check.

It is sometimes easier to change the engine fuel rate than to determine the true cause for low stall speed, but the customer ends up with an over-fueled engine which will also negatively affect durability. Do not increase the fuel rate as a "cure-all".

If The Stall Speed Is Too High, Check The Following:

	Yes	No	
1.			The engine is high in power.
2.			The tachometer is in error.
3.			The accessory power requirements are less than 10 percent of the gross engine power.
4.			The converter oil is aerating or foaming. Check for low oil level, air leaks in suction line, lack of foam inhibitor in the oil, or suction screen or filter. Would be accompanied by a noticeable loss of machine performance.
5.			The converter is being held at full stall. Check for slipping front disconnect clutch or a rotating output shaft. On the converter-transmission package, this can be impossible to check.
6.			The converter turbine element is beginning to fail and losing blades, or the converter was originally built with the wrong size element.
7.			The engine and converter match is correct. Due to a revision in the engine rating or the converter performance.
8.			If the oil level is too high on the transmission-converter units with the oil sump in the transmission, it can cause severe aeration due to parts dipping in the oil.
9.			The converter is performing to the published absorption curve.
10.			The converter charging pressure is correct.

The reasons for abnormal stall speeds listed above are some which have been encountered by Cummins representatives and probably do **not** include all possible causes. The correction of the problem is either covered in the vehicle service manual, the converter service manual, or is self-explanatory.

Section 6 - Injectors and Fuel Lines - Group 06

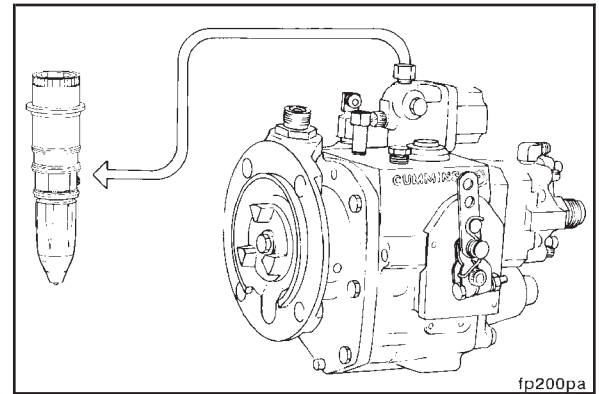
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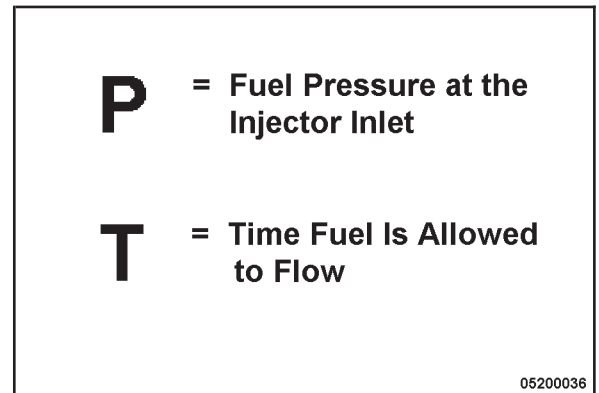
Injectors and Fuel Lines - General Information

Theory of Operation - PT Fuel System

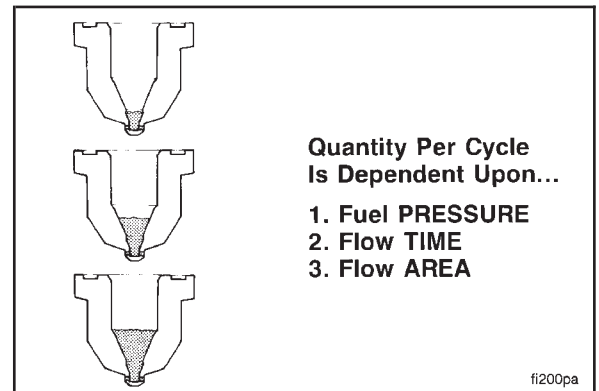
The following is a short description of the theory of operation of the Cummins PT fuel system.



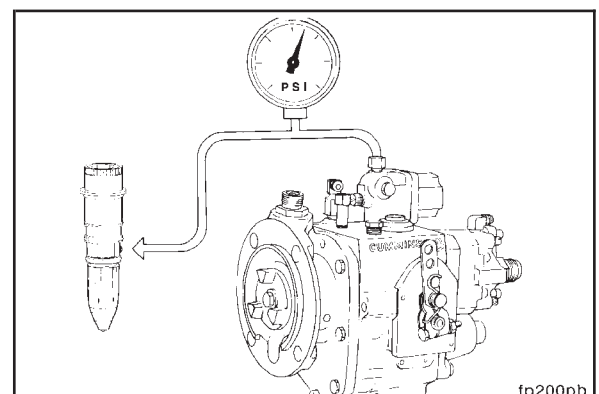
The PT, or Pressure-Time, fuel system derives its name from the two main variables that affect the amount of fuel metered per cycle in the Cummins fuel system. "P" stands for pressure at the inlet of the injectors. It is controlled by the fuel pump. "T" refers to the time that is available for fuel to flow into the injectors. It is controlled by engine speed through the camshaft and injection train.

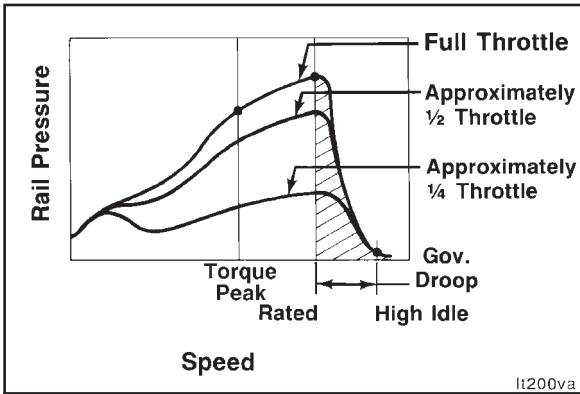


In the PT system, the amount of fuel burned by the engine is the amount that is metered into the injector cup and injected. The quantity metered is dependent on the fuel **pressure** at the injector, the **flow area** of the injector and the **time** the fuel is allowed to flow into the metering chamber of the cup.

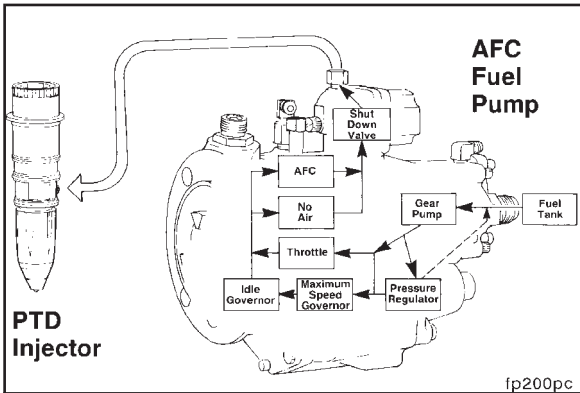


The fuel **pressure** at the injector is controlled by the PT fuel pump. The pressure supplied by the pump varies according to different operating conditions.

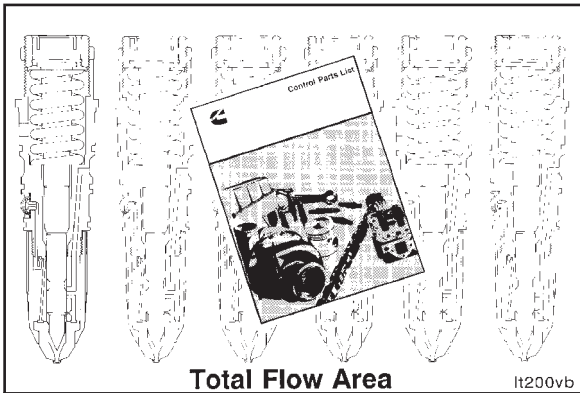




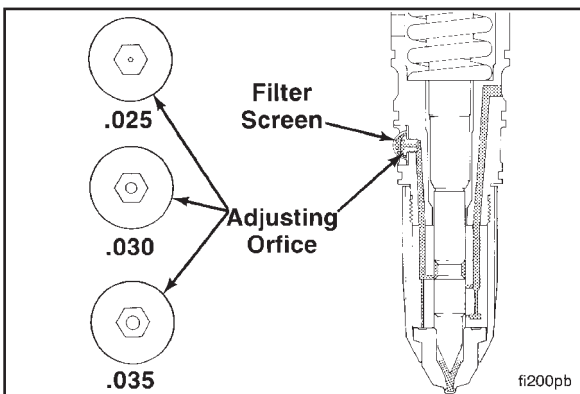
The rail pressure supplied by the fuel pump is dependent on the engine speed. It can also be varied by the operator by changing the position of the throttle.



- The main functions of the fuel pump are to provide:
- Transfer of fuel from tank to engine
 - Rail pressure to injectors
 - Idle speed governing
 - Maximum speed governing
 - Operator control of power output below governed speed (throttle)
 - Control of exhaust smoke during acceleration (AFC — Air Fuel Control)
 - Shutdown of the engine



The **flow area** of the injectors is determined by the calibration of a complete set of injectors. The injector calibration is determined primarily by the parts which make up the injector. The Control Parts List (CPL) manual lists the injector assembly and flow plus the combination of other basic engine parts which are necessary to produce a given level of engine performance.



The calibration flow rate of the injectors is determined by the size of an adjustable orifice. Each injector in the engine is calibrated to the same flow rate. The flow rate adjustment **must** be done by a Cummins Authorized Fuel Systems Location.

M11 Series
Section 6 - Injectors and Fuel Lines - Group 06

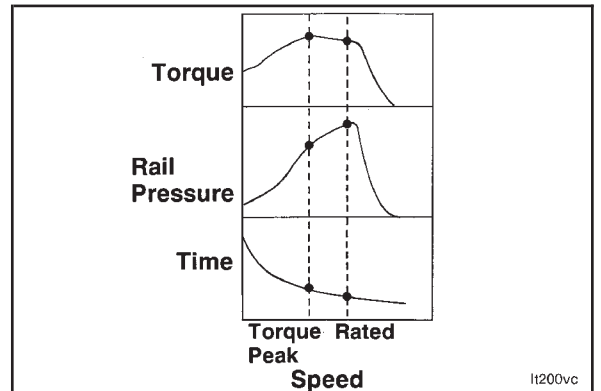
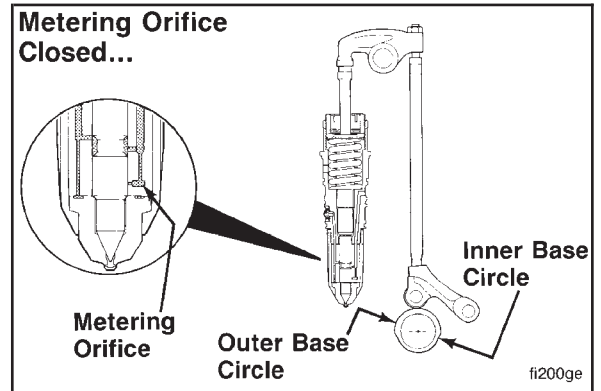
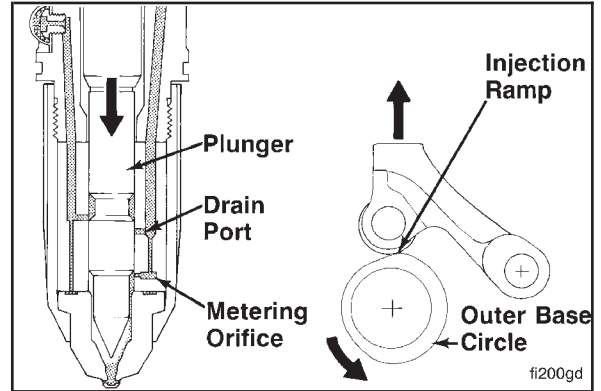
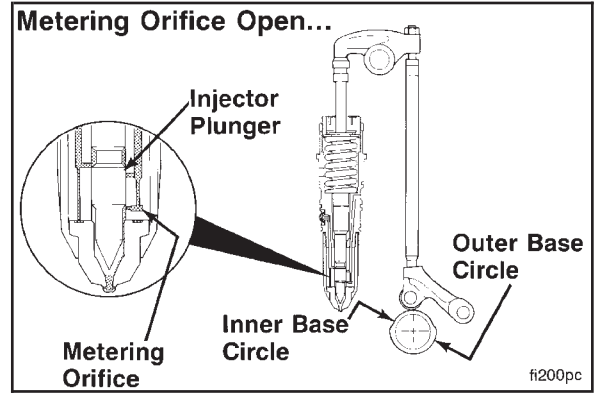
The **time** available for fuel to flow into the cup is determined by the time which the metering orifice in the barrel is uncovered by the plunger. The metering orifice is uncovered while the cam follower roller is on the inner base circle of the cam. The plunger is in the retracted position during this time. The amount of time the metering orifice is uncovered is dependent on engine speed.

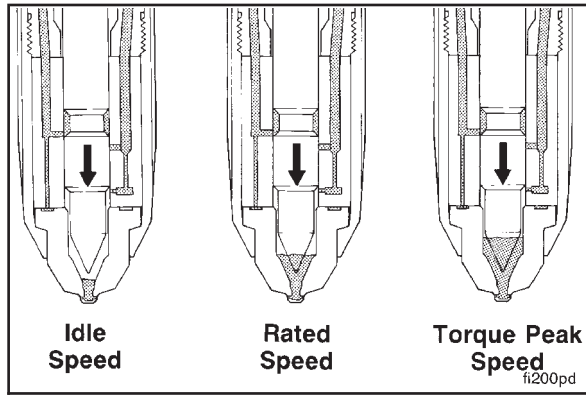
Injection of the fuel in the cup occurs when the cam follower roller travels up the injection ramp of the cam forcing the injector plunger downward. The end of injection occurs when the plunger bottoms in the cup.

The metering orifice is covered while the cam follower roller is on the outer base circle of the cam. The plunger is in the seated position during this time. Fuel supplied to the injector during this time bypasses the plunger through the drain port and is returned to the fuel tank.

The engine will produce more horsepower at rated speed; however, the engine will produce the most torque at the torque peak speed. The rail **pressure** is lower at torque peak speed, but the metering **time** is greater so more fuel is metered per cycle.

Injectors and Fuel Lines - General Information
Page 6-3





Since more fuel is metered per cycle, more fuel is injected per cycle and more torque is produced.



Theory of Operation - STC Fuel System

Step Timing Control, commonly referred to as STC, controls the engine timing in an effort to minimize white smoke at cold engine start-up.

Refer to Step Timing Control Familiarization, Bulletin No. 3387380, for addition information on STC.

STC	
Advanced	Normal
Starting and Light Load	High Load

05200037

STC has two stages of injection timing. The engine operates in the **ADVANCED** mode of injection timing during starting and light engine load conditions and at **NORMAL** timing during medium to high engine load conditions.

- Advanced Timing**
- Improves Cold-Weather Idling Characteristics
 - Reduces Cold-Weather White Smoke
 - Improves Light-Load Fuel Economy
 - Reduces Injector Carboning
- 05200038

STC offers many advantages. During **ADVANCED** injection timing, it:

- Improves cold weather idling characteristics
- Reduces cold weather white smoke
- Improves light load fuel economy
- Reduces injector carboning

During NORMAL injection timing, STC:

- Controls cylinder pressures
- Reduces nitrogen oxide emissions

Normal Timing

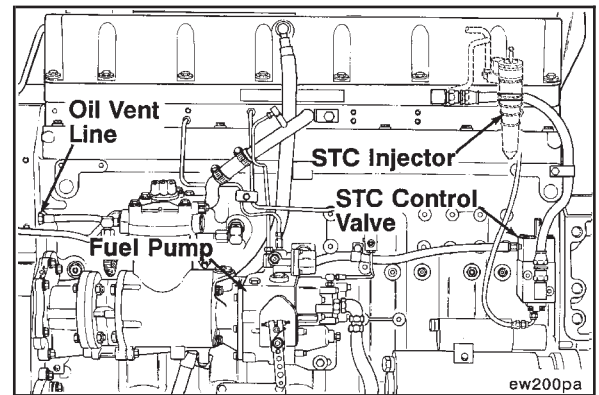
- Controls Cylinder Pressures
- Reduces Nitrogen Oxide Emissions

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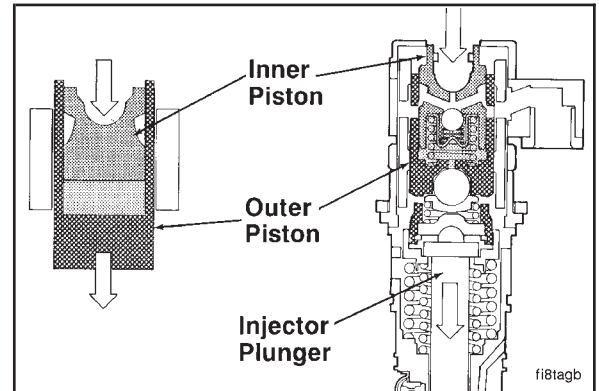
The STC system consists primarily of:

- STC injectors
- STC oil control valve
- STC plumbing and check valve

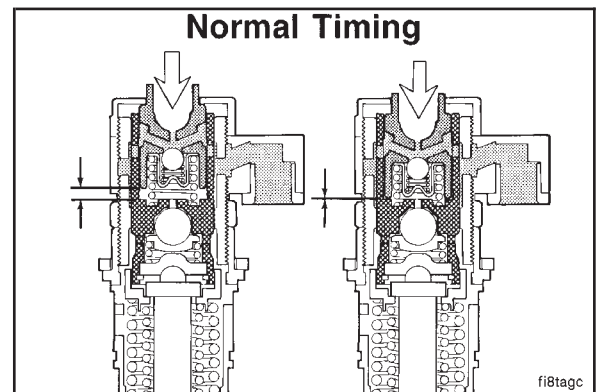
These components control injection timing based on fuel pump rail pressure (engine load).

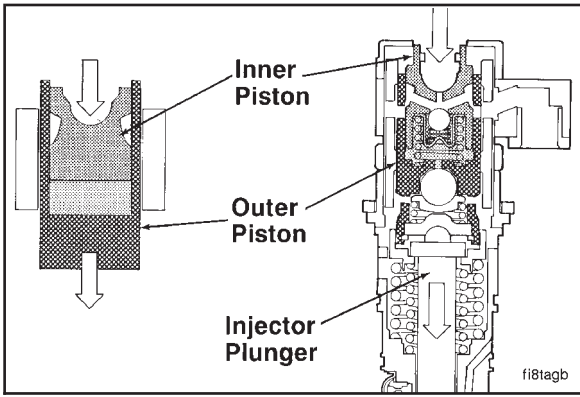


In the injector, injection timing is controlled by the STC hydraulic tappet. The tappet has an inner piston (plunger) and an outer piston (sleeve). These tappet components work together with the injector plunger to control injection timing.

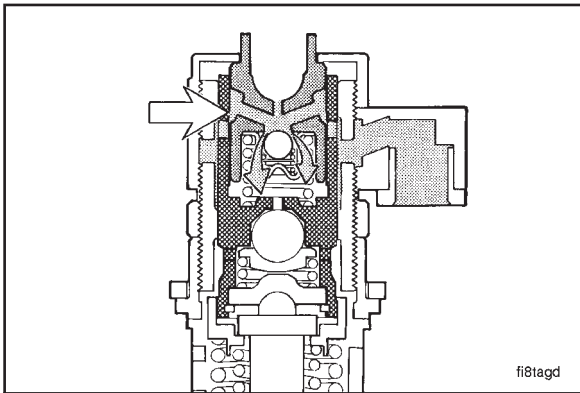


In NORMAL timing, no oil is in the tappet. As the cam follower starts up the camshaft injection ramp, the injector rocker lever begins to force the inner piston downward. Because no oil is in the tappet, the inner piston must make direct contact with the outer piston before the injector plunger can begin its downward travel.

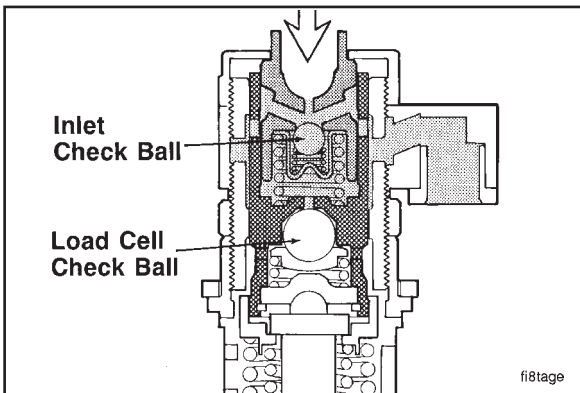




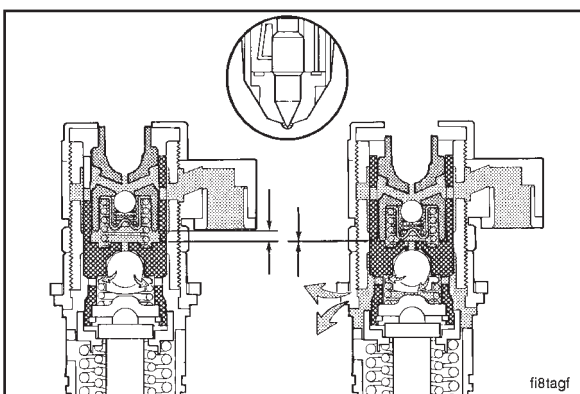
In **ADVANCED** timing, the tappet is filled with oil and the injector is metering fuel. As the cam follower starts up the camshaft injection ramp, the injector lever begins to force the inner piston downward. Since the oil between the pistons forms a solid link, the downward pressure is immediately transmitted to the outer piston and the injector plunger begins its downward travel earlier than it does in **NORMAL** timing. This causes the fuel to be injected earlier.



Engine oil flows from the STC oil control valve through the oil manifold to the tappets. Whenever the oil pressure in the oil manifold exceeds 70 kPa [10 psi], it moves the tappet inlet check ball from its seat and fills the cavity between the inner and outer pistons.



During the injection cycle, the oil is held inside the tappet by the inlet check ball and the load cell check ball. When the rocker lever forces the inner piston downward, the solid link of oil causes the injector plunger to contact the fuel earlier; therefore, the injection timing is in the **ADVANCED** mode. At the end of the injection cycle, injection force increased the oil pressure in the tappet and holds the injector plunger firmly in the cup.

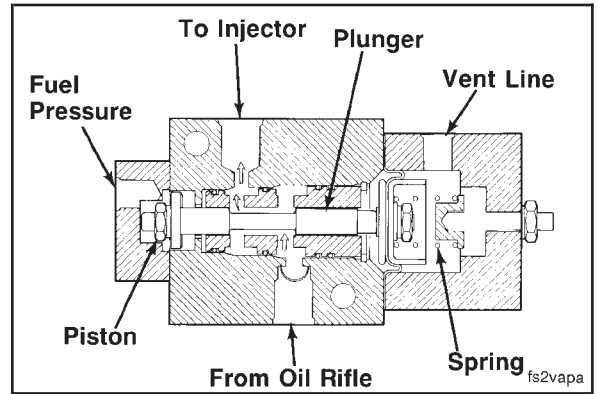


This increased pressure moves the load cell check ball from its seat. The oil drains past the load cell check ball and through the drain holes in the injector adapter and returns to the oil pan through drain passages in the cylinder head and block. Meanwhile, with continued cam lift, the inner piston makes mechanical contact with the outer piston and maintains injector plunger seating force.

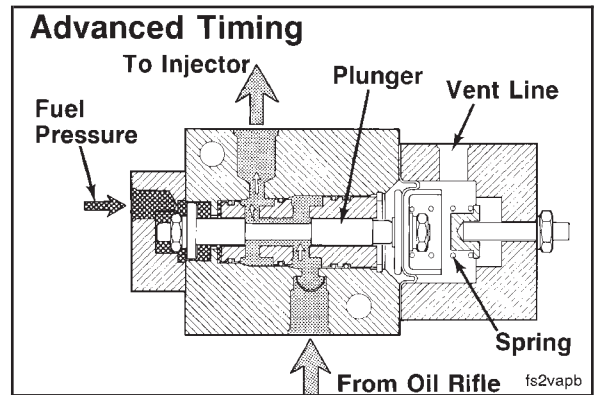
M11 Series
Section 6 - Injectors and Fuel Lines - Group 06

The STC control valve uses fuel pressure and spring force to control the position of an AFC style plunger. The position of the plunger dictates whether the oil passage to the hydraulic tappets is open or closed. Fuel pressure acts on the piston end of the plunger.

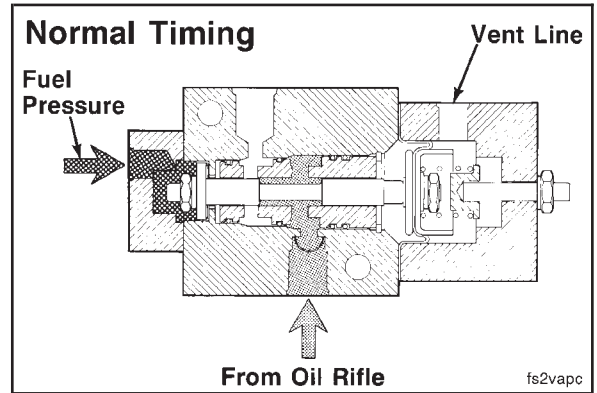
Injectors and Fuel Lines - General Information
Page 6-7



During **ADVANCED** timing (low fuel pressure), the spring opposes the fuel pressure and holds the plunger in the open position. Pressurized lube oil flows to the tappets and initiates **ADVANCED** engine timing. As fuel pressure increases, the spring holds the plunger in the open position until the fuel pressure rises above the certified switching pressure.

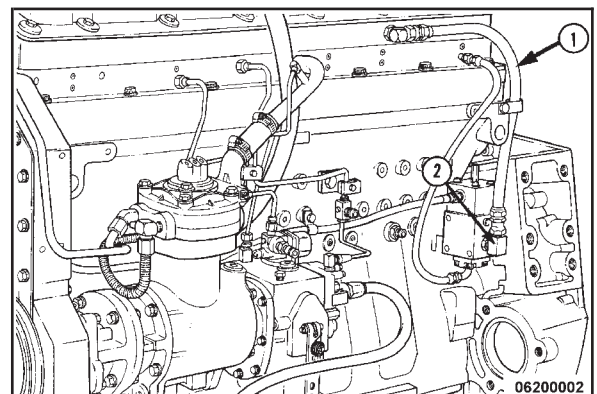


At this certified level, the higher fuel pressure overcomes the spring. This action shifts the plunger and closes the oil passage. The oil supply to the tappets is interrupted and the engine begins to operate in the **NORMAL** timing mode.

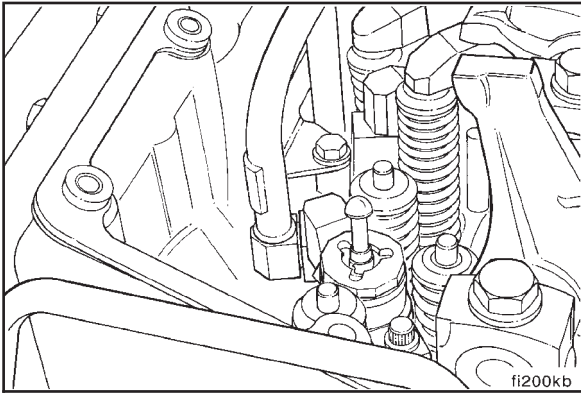


The control valve supplies oil to the STC rocker housing connection through the STC valve oil outlet line (1).

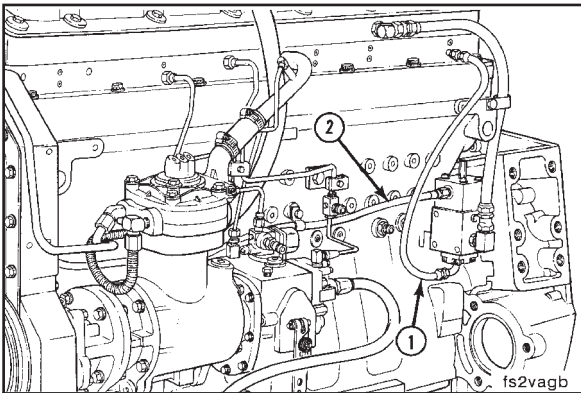
A check valve in the elbow fitting (2) prevents the oil from draining back into the engine when it is shut off. This prevents any delay of oil to the tappets during cold starts.



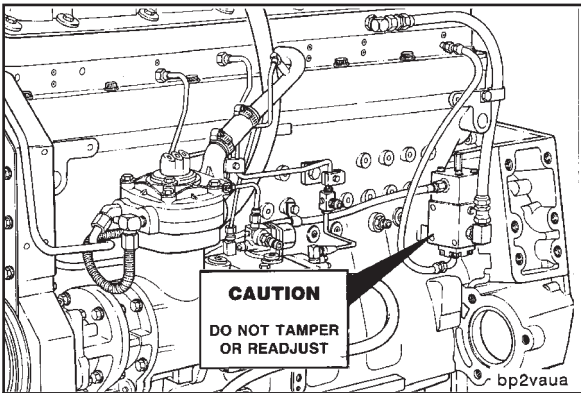
An internal oil manifold connects the oil supply to each STC injector in the rocker housing.



Fuel pressure to the STC valve is provided by a hose (1) between the fuel inlet passages in the cylinder head and the STC valve. The internal spring cavity of the valve is vented to the engine crankcase by the crankcase vent line (2) in order to allow the plunger to cycle freely.

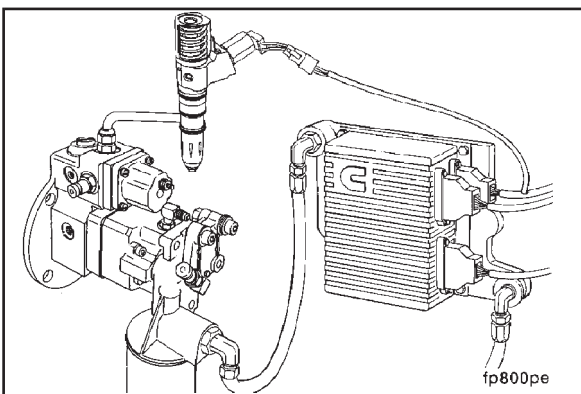


The oil control valve is calibrated to a specific flow and pressure using a fuel pump test stand. Tampering with the valve or plumbing will result in the loss of both fuel economy and engine durability. Correct valve operation is necessary to maintain acceptable cylinder pressures and white smoke levels and to assure optimum fuel economy.



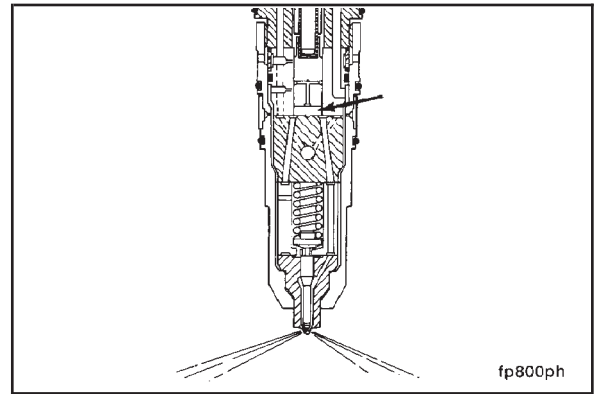
Theory of Operation - CELECT™ and CELECT™ Plus Fuel System

The following is a short description of the theory of operation for the Cummins CELECT™ and CELECT™ Plus™ fuel system.

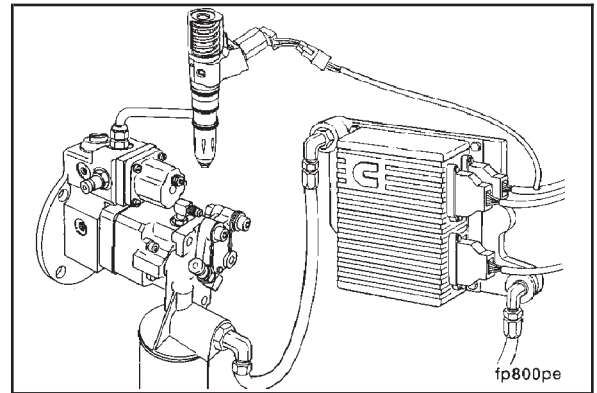


M11 Series
Section 6 - Injectors and Fuel Lines - Group 06

In the CELECT™ and CELECT™ Plus fuel system, the amount of fuel burned by the engine is the amount of fuel injected into the injector metering chamber and injected into the cylinder. The quantity metered is dependent only on the time that fuel is allowed to flow into the metering chamber.

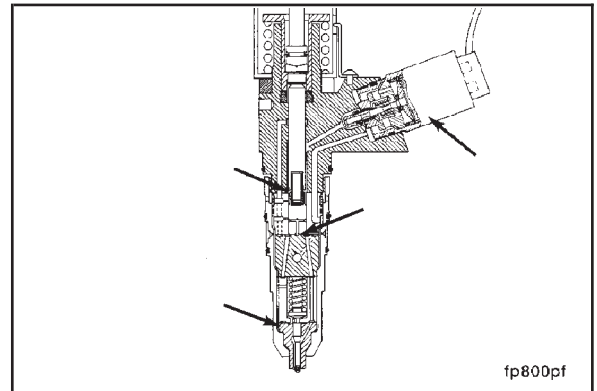


The fuel pump provides a constant fuel flow at a relatively constant pressure to the injectors. The electronic control module (ECM), controls the time of fuel metering.



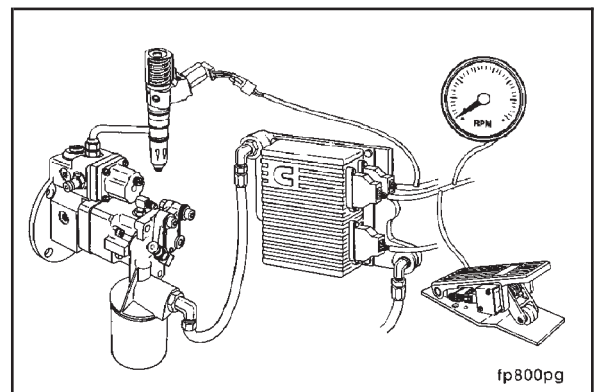
The main functions of the injector are to provide:

- Metered fuel for injection
- Injection timing control
- Inject fuel into the cylinder



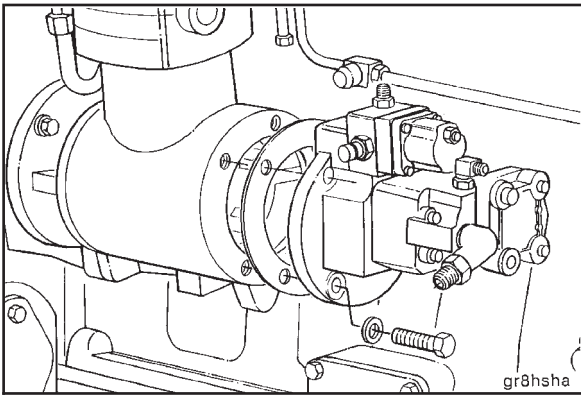
The main functions of the ECM are to provide:

- Idle speed governing
- Maximum speed governing
- Operator control of power output below governed speed (throttle, PTO, Cruise)
- Control of exhaust smoke during acceleration (AFC- Air Fuel Control)
- Control fuel metering time
- Determine injection timing



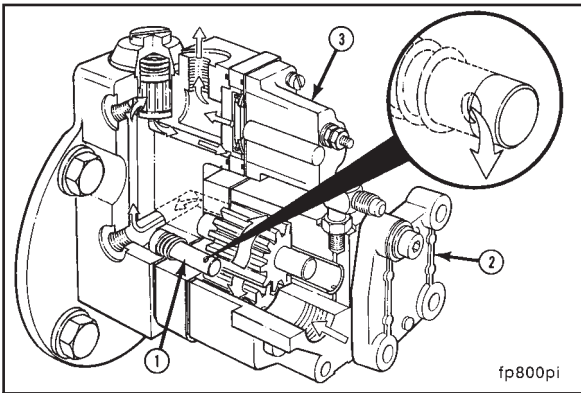
Hydromechanical Subsystem

The fuel pump is located in the same location as a PT fuel pump.

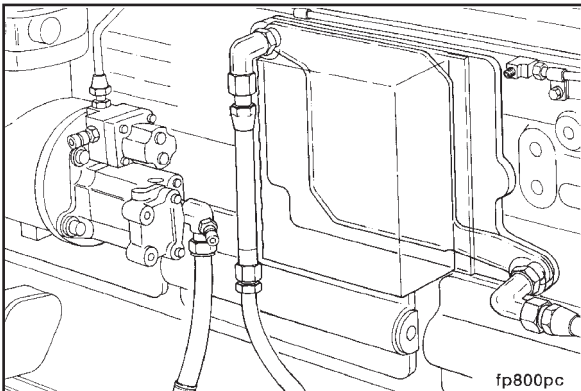


The fuel pump is a gear type pump. The assembly includes, a pressure regulator, pulsation damper and a solenoid valve.

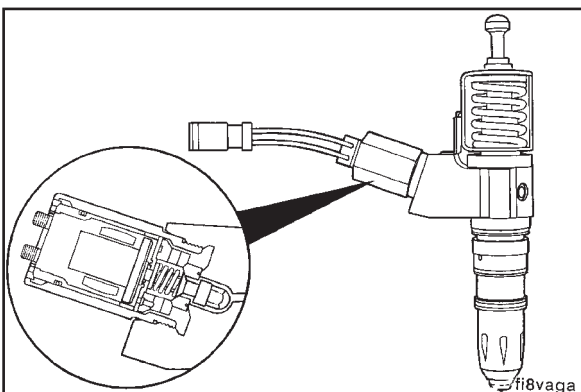
1. Pressure regulator
2. Pulsation damper
3. Solenoid valve



The ECM mounts on a cooling plate. During engine operation, fuel circulates through the cooling plate to absorb heat generated by the ECM.



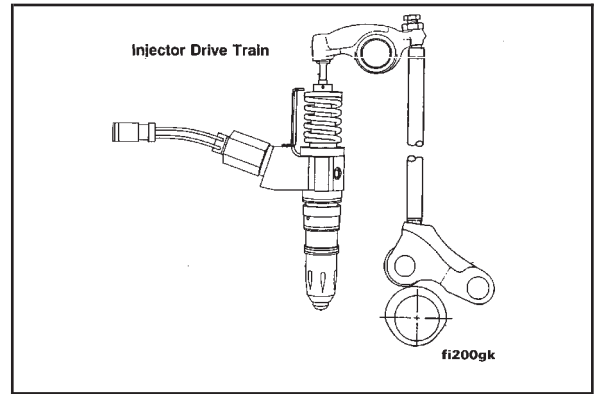
The injector assembly includes a solenoid valve, which controls the end of the fuel metering and the beginning of injection. The solenoid valve is normally open. An electronic signal from the ECM closes the valve as required.



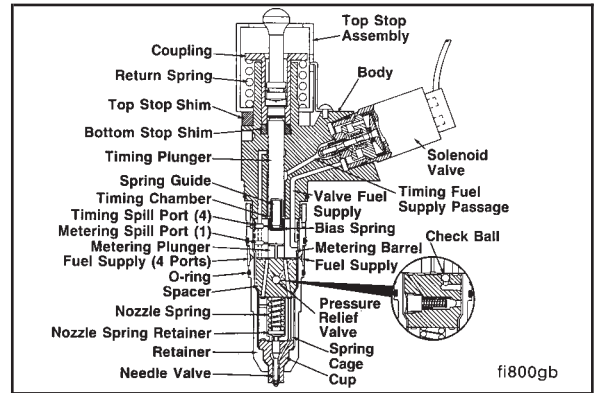
M11 Series
Section 6 - Injectors and Fuel Lines - Group 06

As in the PT fuel system, the CELECT™ and CELECT™ Plus fuel systems use the camshaft to create adequate pressure for injection.

Injectors and Fuel Lines - General Information
Page 6-11

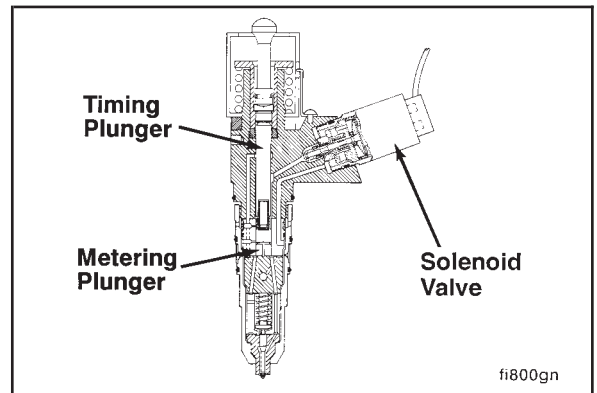


Here is a cutaway view of the electronic controlled injector with the internal components identified.



Injection Cycle

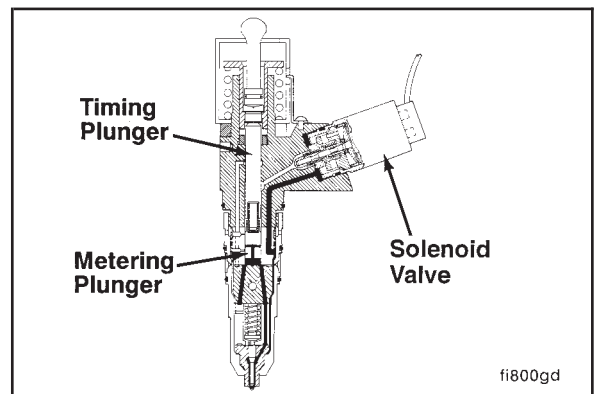
At the start of metering, the metering plunger and the timing plunger are at the lower limits of their travel. The injector control valve is closed.



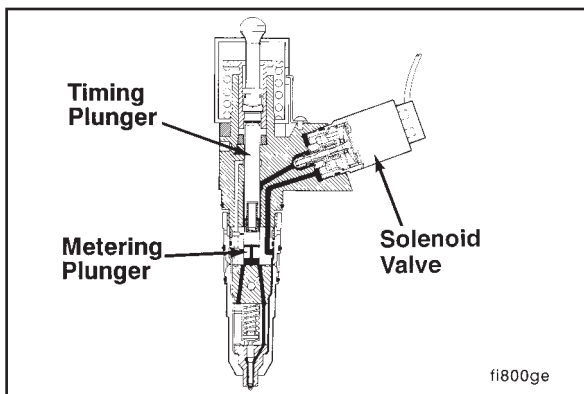
As the camshaft rotates, the timing plunger return spring forces the timing plunger upward.

Fuel flows past the metering check ball and into the metering chamber. This flow continues as long as the timing plunger is moving **upward**, and the injector control valve is **closed**.

Supply pressure, acting on the bottom of the metering piston, forces it to maintain contact with the timing plunger.



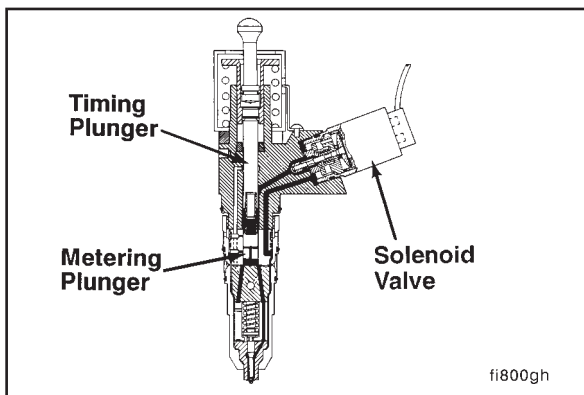
The ECM determines the end of the metering by signaling the injector control valve to **open**.



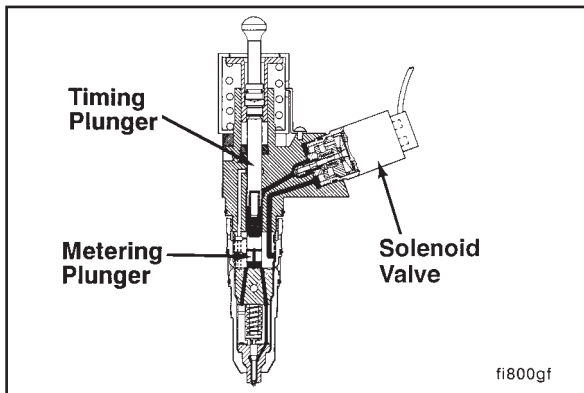
Fuel at supply pressure then flows into the **timing** chamber, thereby stopping metering piston travel.

During this time, the bias spring makes sure the metering plunger remains stationary, that it does **not** drift upward as the timing plunger moves upward. This same force against the metering plunger results in enough fuel pressure **below** the piston to keep the metering check ball seated.

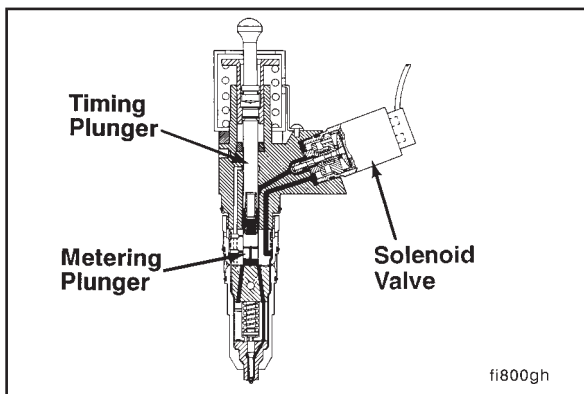
A precisely metered quantity of fuel is now trapped in the metering chamber. This determines the quantity of fuel that will be injected.



The timing plunger continues to move upward, and the timing **chamber** fills with fuel.

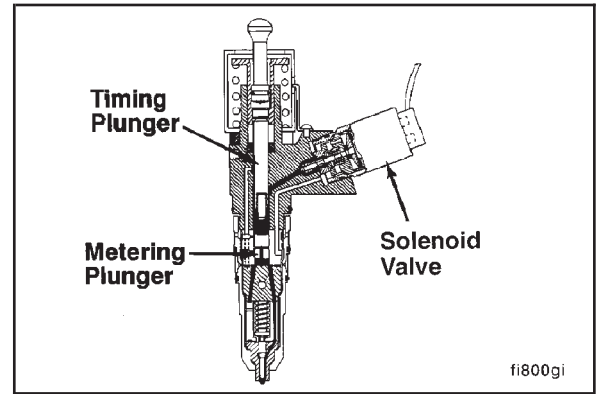


Now the timing plunger begins its **downward** travel. Initially, the injector control valve remains open, allowing fuel to flow from the timing chamber, through the injector control valve, to the fuel supply passage.



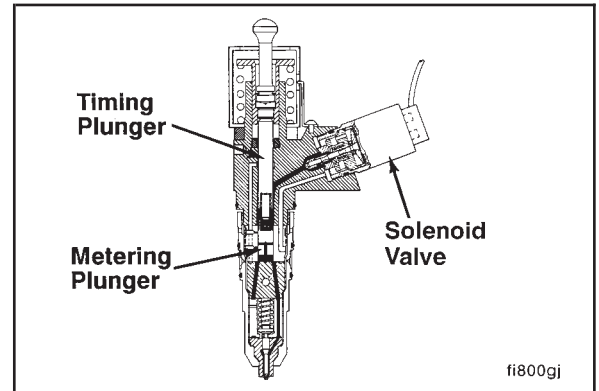
M11 Series
Section 6 - Injectors and Fuel Lines - Group 06

At the appropriate time, as determined by the ECM, the injector control valve closes, trapping fuel in the timing chamber. This trapped fuel creates a solid, hydraulic link between the timing plunger and metering plunger.



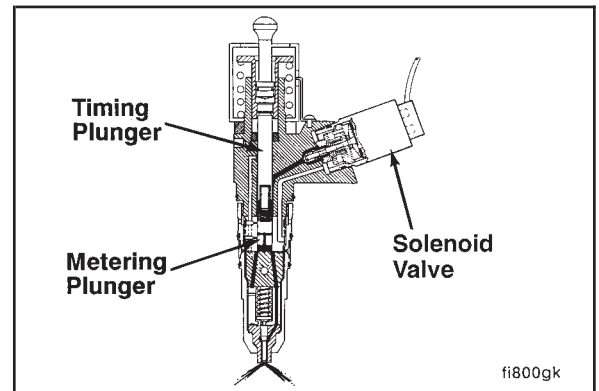
As a result, the metering plunger is forced to move downward with the timing plunger.

Because the fuel is trapped, the downward force on the timing plunger is transferred to the metering plunger, thereby increasing pressure in the metering chamber.



When this pressure reaches approximately 5000 psi, the needle valve begins to be forced upward.

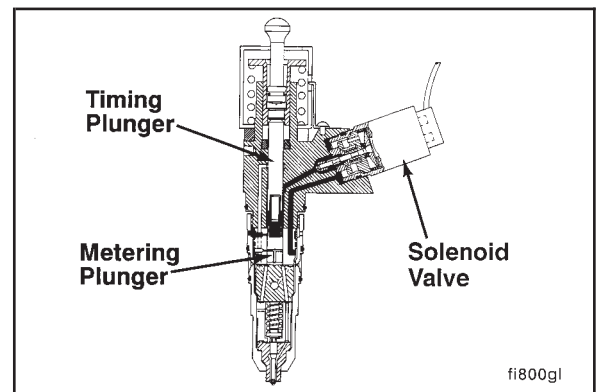
Continued downward movement of the timing plunger and metering plunger results in steadily increasing fuel pressure. The result is that fuel is forced past the needle valve, through the spray holes, and into the combustion chamber.



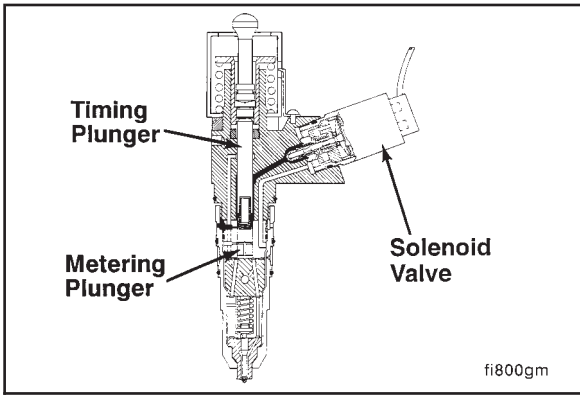
Injection continues until the spill passage of the metering plunger passes the metering spill port.

Metering chamber pressure drops rapidly, allowing the needle valve to close abruptly. This action results in a positive end of injection. The positive end of the injection prevents dribble, and results in cleaner burning.

It is also at this point that the pressure relief valve "pops off", thereby reducing the effects of the high pressure "spike" that occurs at the time of metering spill.

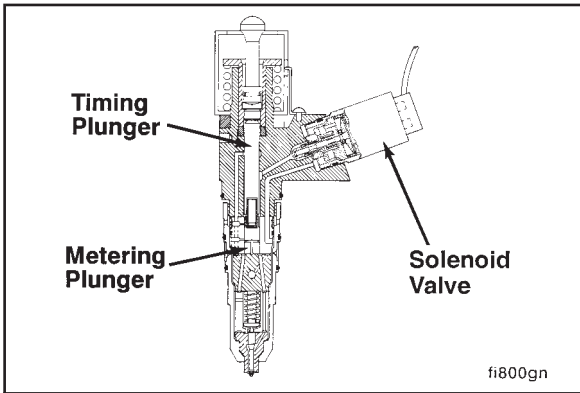


Immediately **after** the metering spill port is opened, the upper edge of the metering plunger passes the timing spill port.



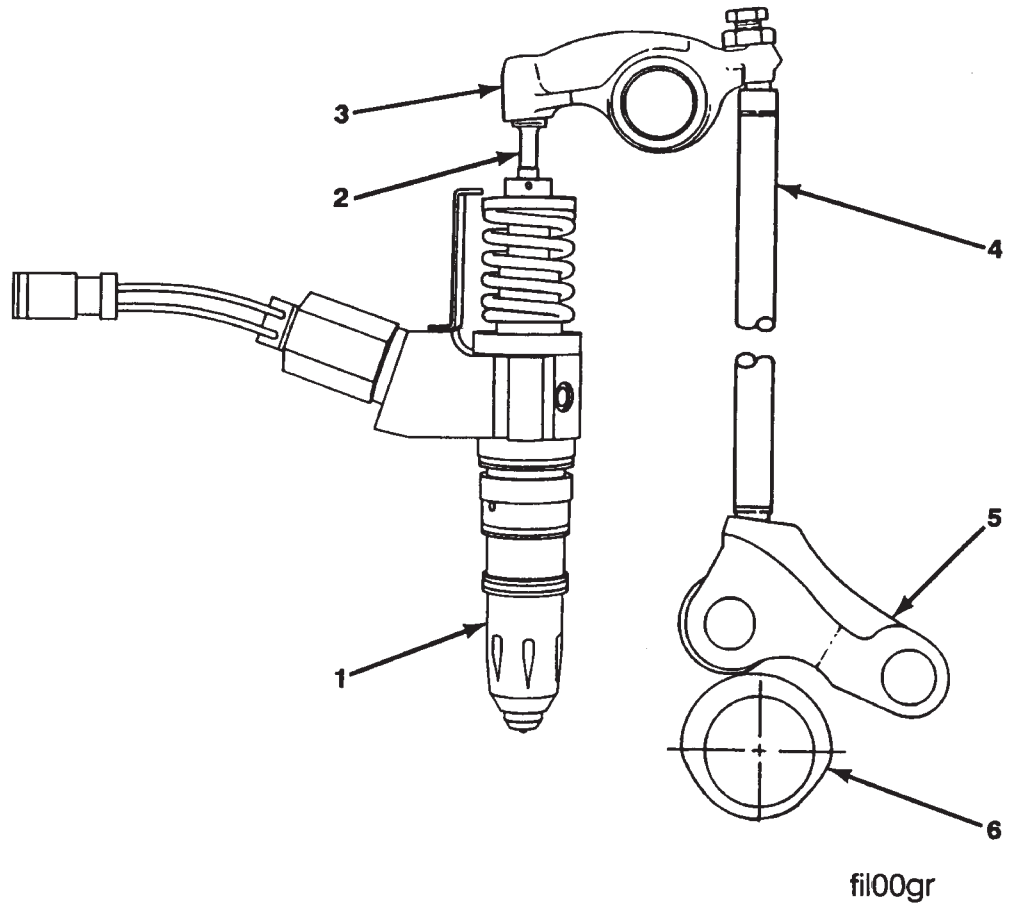
This action allows the fuel in the timing chamber to be spilled back to the fuel drain as the timing plunger completes its downward movement.

This completes the injection cycle.



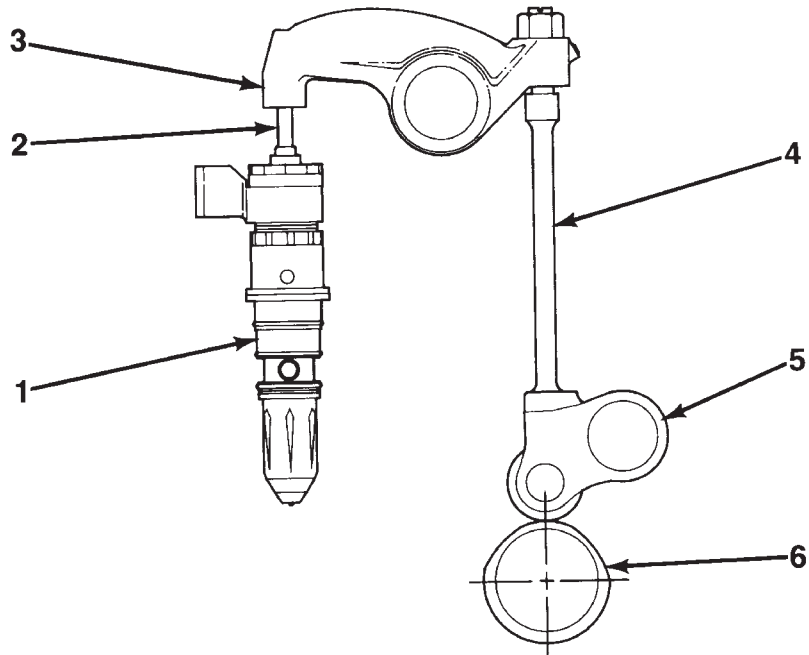
INJECTOR DRIVE TRAIN — CELECT™ AND CELECT™ PLUS

1. Injector
2. Injector Link
3. Rocker Lever
4. Push Rod
5. Cam Follower
6. Camshaft



INJECTOR DRIVE TRAIN — PT (TYPE D) STC

1. Injector
2. Injector Link
3. Rocker Lever
4. Push Rod
5. Cam Follower
6. Camshaft


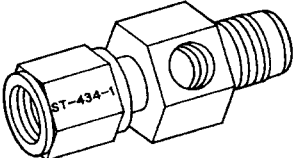
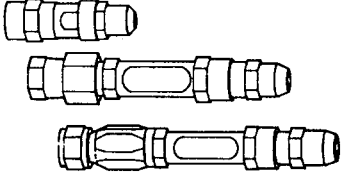
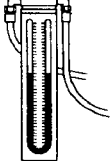
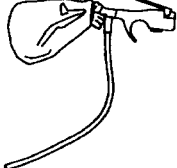
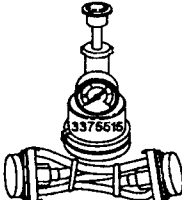


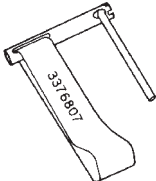
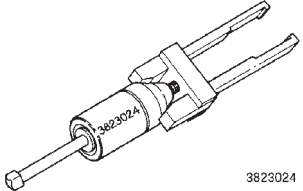
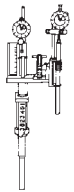
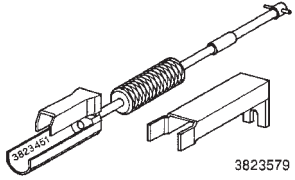
f1200gg

Service Tools

Injectors and Fuel Lines

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

Tool No.	Tool Description	Tool Illustration
ST-434	<p>Vacuum Gauge (0-30 in. Hg)</p> <p>Used to check fuel inlet restriction. Fuel restriction adapters, Part No's. ST-434-1, 3375845 and 3376922, are required and must be ordered separately</p>	 <p style="text-align: right; font-size: small;">eg8togc</p>
ST-434-1 ST-434-2	<p>Hose Adapter</p> <p>Used with vacuum gauge, Part No. ST-434. Use Part No. ST-434-1 with No. 8 hose. Use Part No. ST-434-2 with No. 10 hose.</p>	 <p style="text-align: right; font-size: small;">st-434-1</p>
ST-998 3375362 3375808	<p>Sight Glass</p> <p>Used to check for air in the fuel suction line. Use Part No. 3375362 with No. 12 hose, and Part No. 3375808 with No. 16 hose.</p>	 <p style="text-align: right; font-size: small;">3375362</p>
ST-1111-3	<p>Mercury Filled Slack Tube Manometer</p> <p>Used to measure fuel drain line restriction.</p>	
ST-1272-11 or 3823461	<p>Chip Removing Unit</p> <p>Used to remove carbon from the top of the piston. Refer to capscrew salvage thread kit, Part No. 3376208. Chip unit, Part No. 3823461, is a vacuum tool.</p>	 <p style="text-align: right; font-size: small;">st-1272-11</p>
3375515	<p>Control Pressure Pump</p> <p>Check AFC setting.</p>	

Tool No.	Tool Description	Tool Illustration
3376807	<p>Filter Wrench Used to remove or tighten spin on fuel filters.</p>	 <p>3376807</p>
3823024	<p>Injector Puller — STC Engines Used to remove STC injectors from the engine.</p>	 <p>3823024</p>
3823451	<p>Static Injection Timing Tool Used to measure static timing.</p>	 <p>3823451</p>
3823579	<p>CELECT™ Injector Puller and Driver Assembly Used to remove and install CELECT™ injectors.</p>	 <p>3823579</p>

Air in Fuel (006-003)

Test (006-003-012)

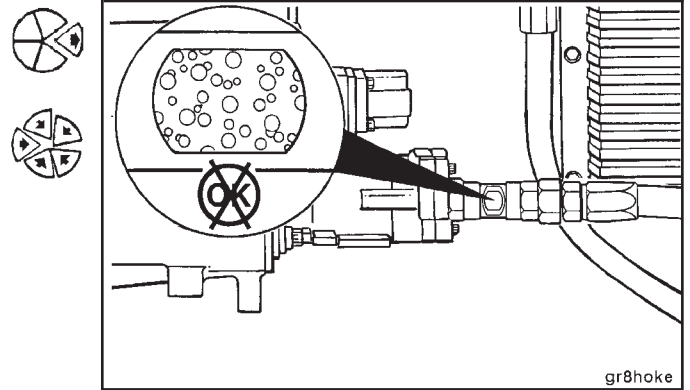
Sightglass Method

Remove the fuel suction line.

Install a sight glass, Part No. 3375362, in the line.

Operate the engine.

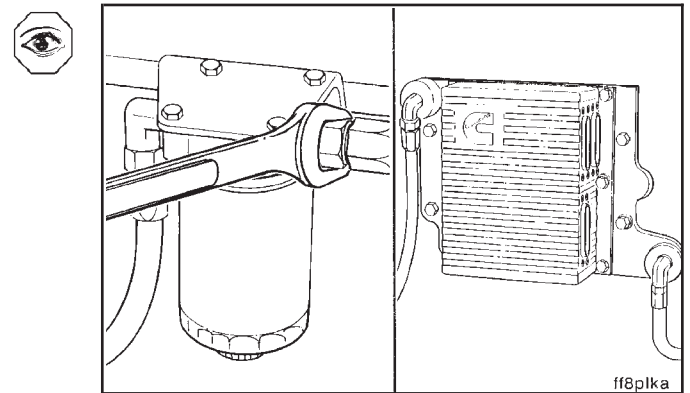
NOTE: A small air leak will have a “milky” appearance. A large air leak will look like bubbles in the fuel.



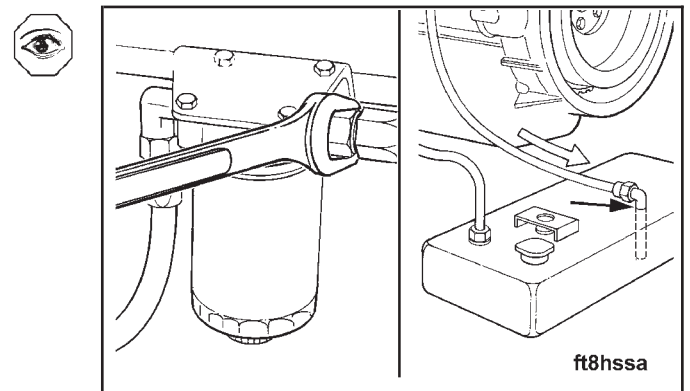
If an air leak is found, visually inspect the fuel lines, o-rings, and fittings for damage. Check for loose connections.

Replace the damaged lines or tighten the loose connections.

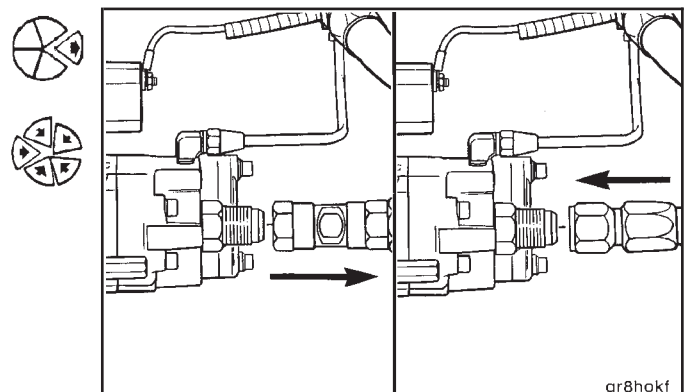
Operate the engine at high idle with no load and check the sight glass.

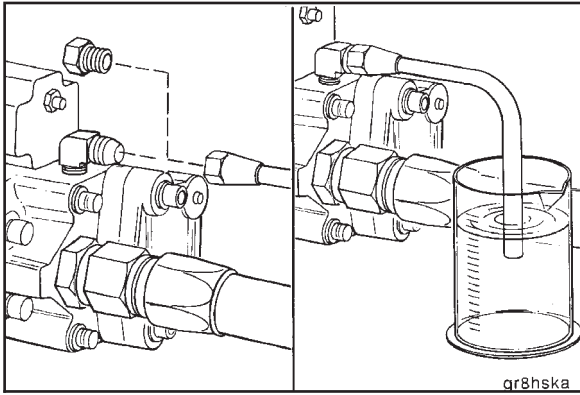


Tighten the hose connections and the fuel filter.
Check the drop tube in the fuel tank for damage.



Replace any defective parts as required.
Remove the sight glass and install the suction hose.
Test the engine again for other air leaks.





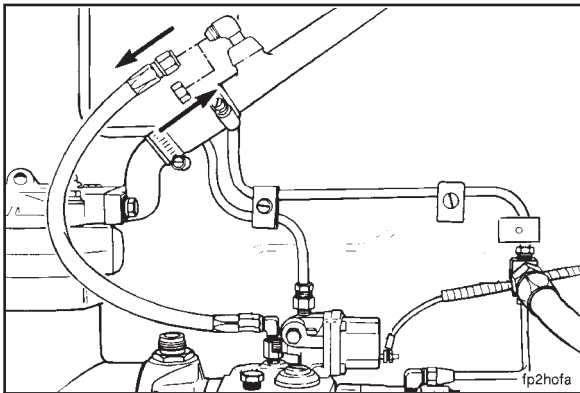
Gear Pump Drain Method

STC

Remove the gear pump cooling drain line from the check valve and install a plug in the line.



Install a hose on the check valve and place the other end of the hose in a container.

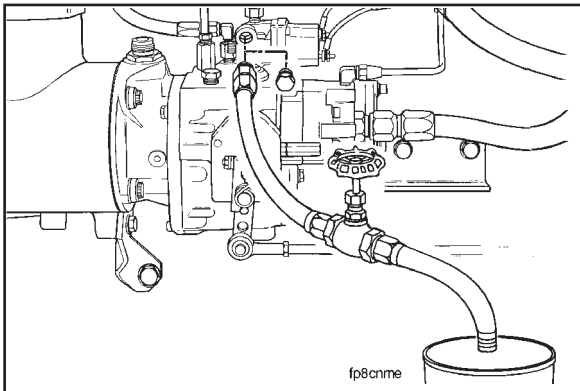


Remove the AFC air supply line from the air intake manifold or the compressor air tube. Install a plug or a cap in the air manifold hole.



Apply air pressure to the AFC air supply line.

Air Pressure 172 kPa [25 psi]



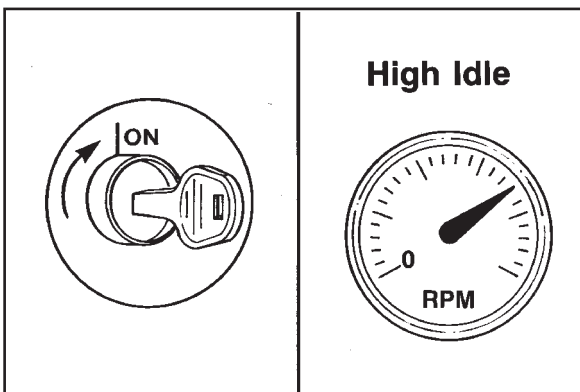
Remove the Compuchek® fitting, if equipped, from the fuel shutoff valve.



Install a fuel hose with a needle valve in it to the shutoff valve.

Close the needle valve.

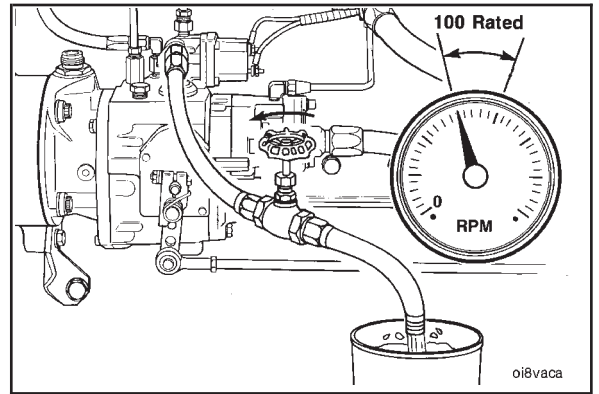
Place the end of the hose in a bucket.



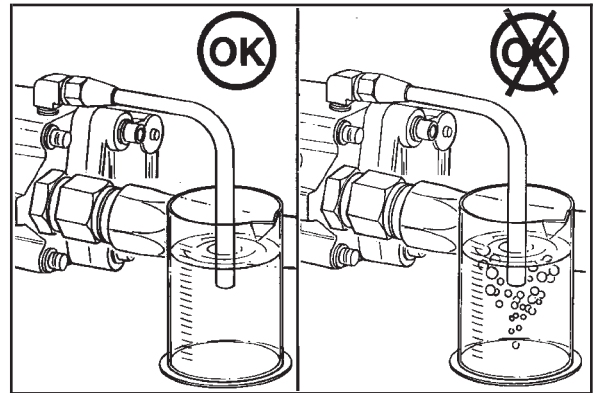
Operate the engine at high idle with **no** load.

M11 Series
Section 6 - Injectors and Fuel Lines - Group 06

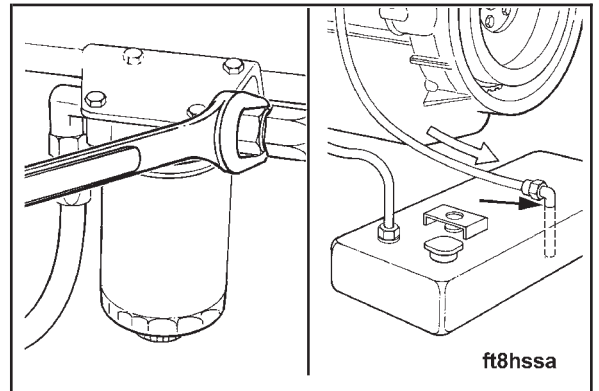
Open the needle valve and allow fuel to drain into the bucket until the engine speed drops to 100 rpm below rated speed.



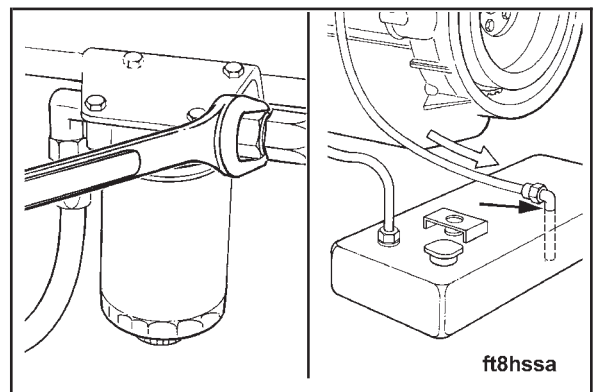
If air is entering the fuel pump suction line, bubbles will be visible in the container of fuel.

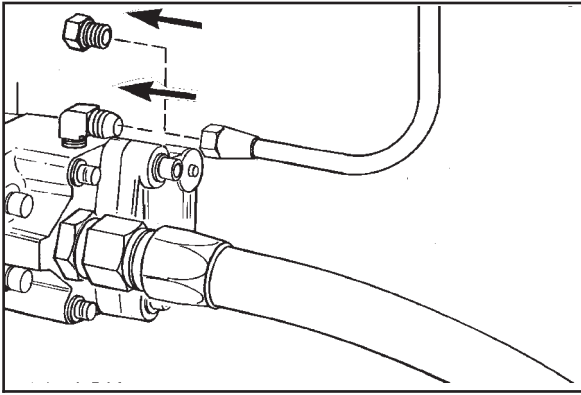


Tighten the hose connections and the fuel filter.
Check the drop tube in the fuel tank for damage.



Correct the air leak and test again for other leaks.

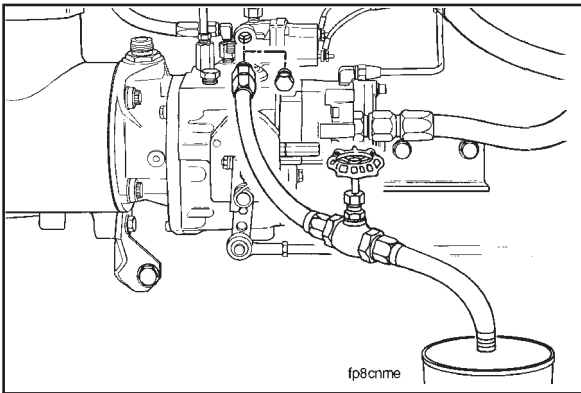




Remove the hose from the check valve elbow and the plug from the cooling drain line.



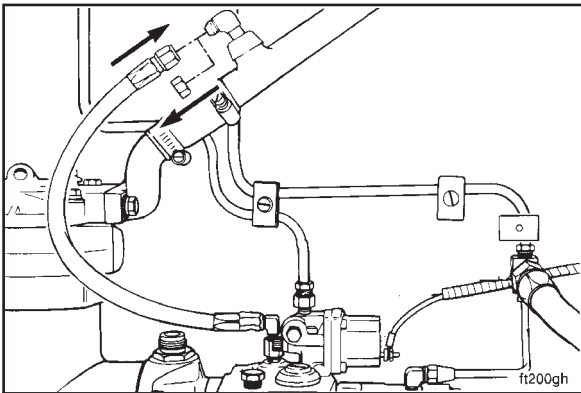
Install the drain line on the check valve.



Remove the fuel hose and needle valve from the fuel shutoff valve.



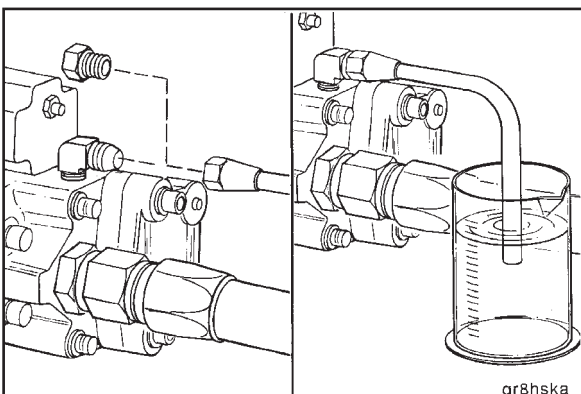
Install the Compuchek® fitting, if equipped, in the fuel shutoff valve.



Remove the plug or cap from the compressor air tube or the air intake manifold.



Install the AFC air supply line to the compressor air tube or the air intake manifold.



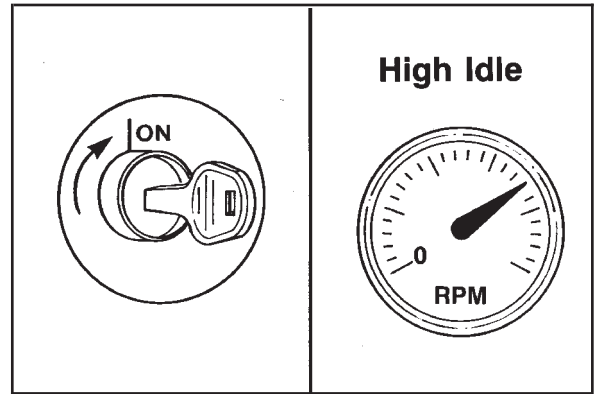
CELECT™ and CELECT™ Plus

Remove the gear pump cooling drain line from the check valve and install a plug in the line.

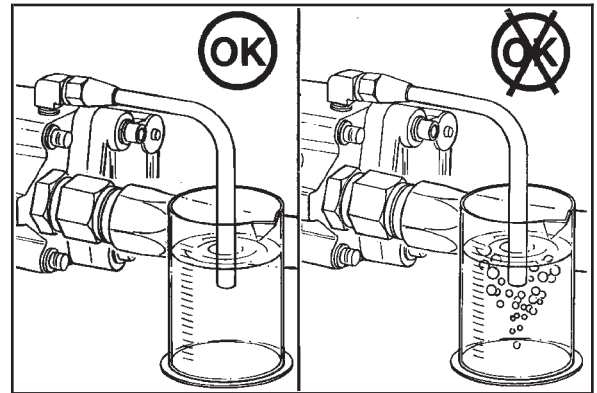


Install a hose on the check valve and place the other end of the hose in a container.

Operate the engine at high idle with **no** load.

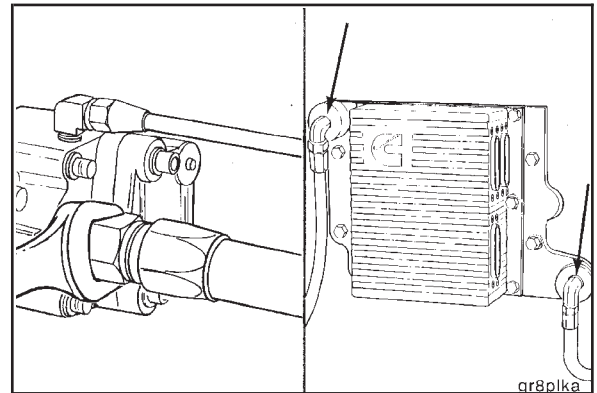


If air is entering the fuel pump suction line, bubbles will be visible in the container of fuel.

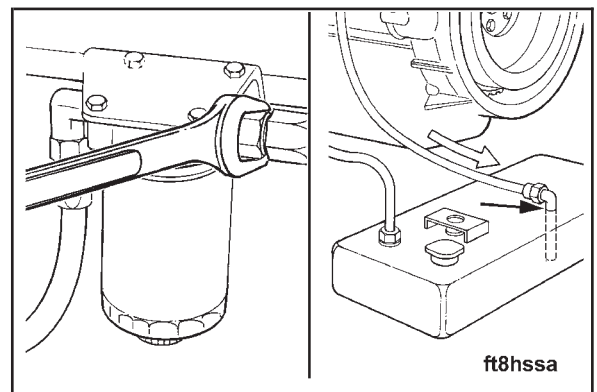


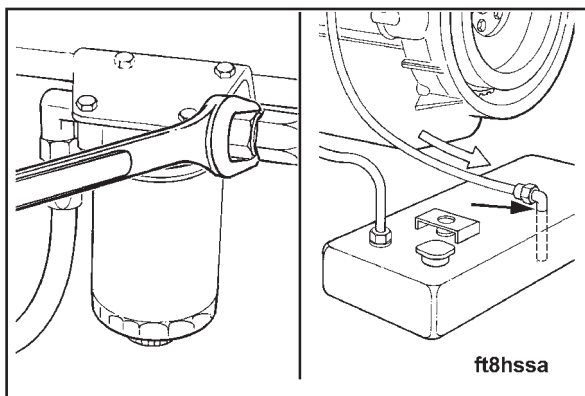
If bubbles are visible, tighten the fuel supply pump inlet fitting.

Tighten the cooling plate inlet and outlet fittings.

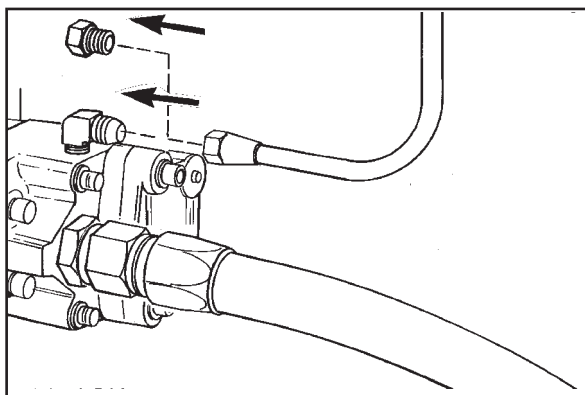


Tighten the hose connections and the fuel filter.
Check the drop tube in the fuel tank for damage.



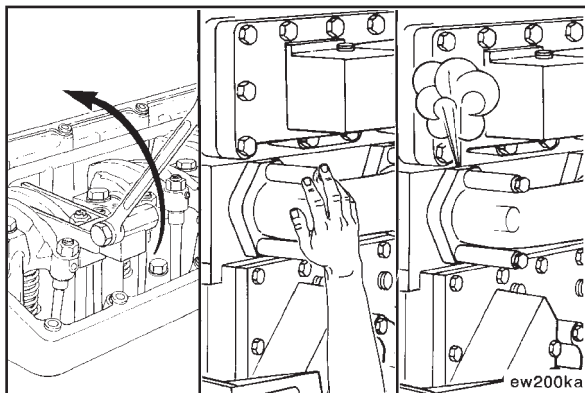


Correct the air leak and test again for other leaks.



Remove the hose from the check valve elbow and the plug form the cooling drain line.

Install the drain line on the check valve.



Cylinder Misfires or Smokes (006-005) General Information



WARNING

Due to the stroke of the CELECT™ and CELECT™ Plus injectors on M11 engines, DO NOT use the mechanical method to perform a cylinder cutout test. When an injector on a CELECT™ or CELECT™ Plus engine is mechanically shorted (barred), the push rods can be thrown free causing personal injury. Refer to the Automated Cylinder Performance Test to perform the test on CELECT™ or CELECT™ Plus engines.

The following methods can be used to find the cylinder(s) causing misfire/white smoke.

- Mechanical cylinder cutout test (STC engines only)
- Exhaust manifold temperature
- Tilting back exhaust manifold
- Automated cylinder performance test (CELECT™ and CELECT™ Plus only)

Automated Cylinder Performance Test (006-005-057)

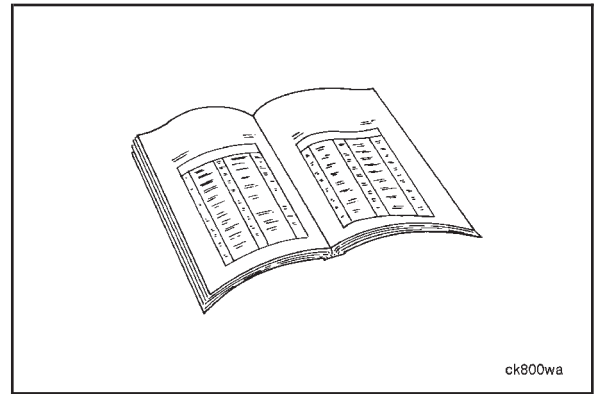
CELECT™ or CELECT™ Plus

NOTE: Do **not** run the automated Cylinder Performance Test on engines that are smoking at idle.

Perform the Automated Cylinder Performance Test at least twice.

Refer to the appropriate electronic service tool manual.

Minimum cylinder contribution is 71%.



Cylinder Cutout Test (006-005-058)

CELECT™ or CELECT™ Plus



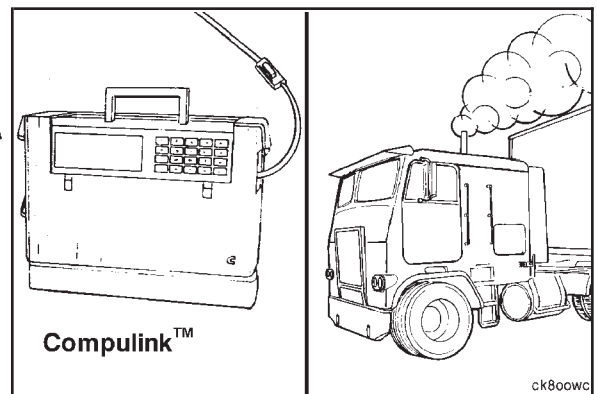
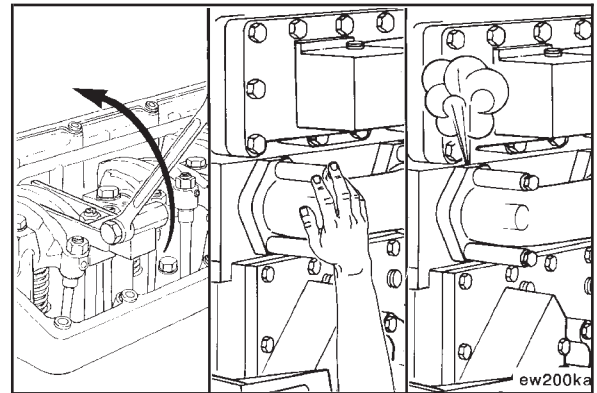
Due to the stroke of the CELECT™ and CELECT™ Plus injectors on M11 engines, **DO NOT** use the mechanical method to perform a cylinder cutout test. When an injector on a CELECT™ or CELECT™ Plus engine is mechanically shorted (barred), the push rods can be thrown free causing personal injury. Refer to the appropriate electronic service tool manual.

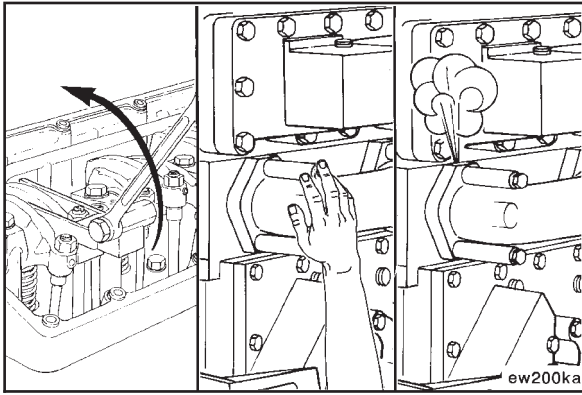
The following methods can be used to find the cylinder(s) causing misfire/white smoke.

- Mechanical cylinder cutout test (STC engines only)
- Exhaust manifold temperature
- Tilting back exhaust manifold
- Automated cylinder performance test (CELECT™ and CELECT™ Plus only)

Cut out each cylinder while watching the exhaust smoke. Refer to the appropriate electronic service tool manual.

Replace the injector in the cylinder that causes a reduction in smoke when cut out.





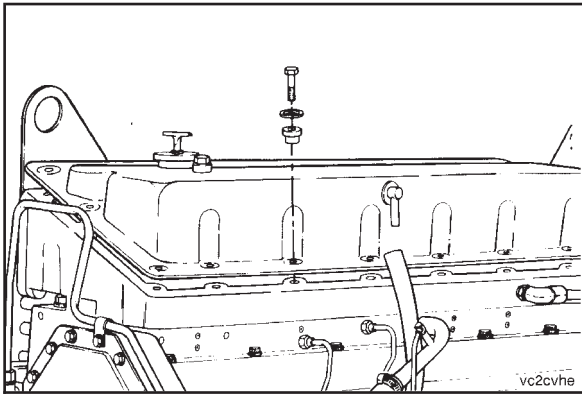
STC

▲ WARNING ▲

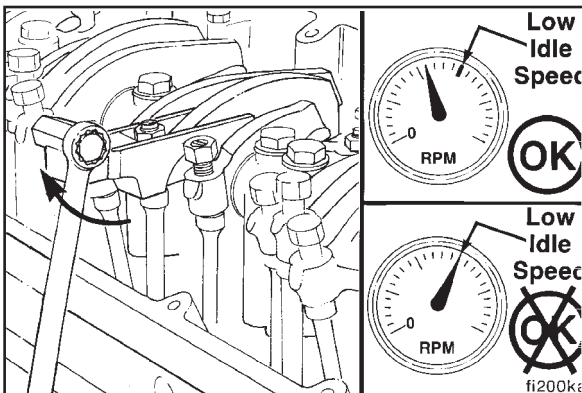
Due to the stroke of the CELECT™ and CELECT™ Plus injectors on M11 engines, DO NOT use the mechanical method to perform a cylinder cutout test. When an injector on a CELECT™ or CELECT™ Plus engine is mechanically shorted (barred), the push rods can be thrown free causing personal injury. Refer to the Automated Cylinder Performance Test to perform the test on CELECT™ or CELECT™ Plus engines.

The following methods can be used to find the cylinder(s) causing misfire/white smoke.

- Mechanical cylinder cutout test (STC engines only)
- Exhaust manifold temperature
- Tilting back exhaust manifold
- Automated cylinder performance test (CELECT™ and CELECT™ Plus only)



Remove the rocker lever cover. Refer to Procedure 003-011-002.



Hold the injector plunger down while the engine is running at low idle. This will stop the fuel flow to that injector.

If the smoke disappears when an injector is cutout, this is the cylinder causing the smoke.

Replace the injector in the cylinder(s) that causes a reduction in smoke when cut out.

Exhaust Manifold Temperature Test (006-005-059)

To locate a smoking cylinder, use a pyrometer or infrared temperature gun to measure the exhaust manifold surface temperature at each cylinder port.

The maximum exhaust manifold surface temperature at idle is 143°C [290°F].

A cylinder is smoking if:

- The exhaust manifold surface temperature at that exhaust port exceeds the above specification.
- The exhaust manifold surface temperature at that port is significantly higher than that for the other cylinder ports.

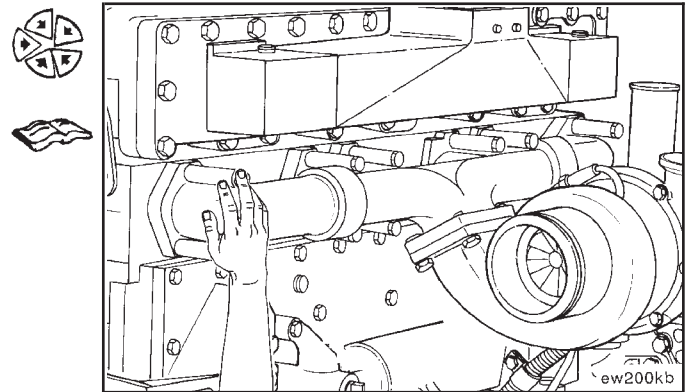
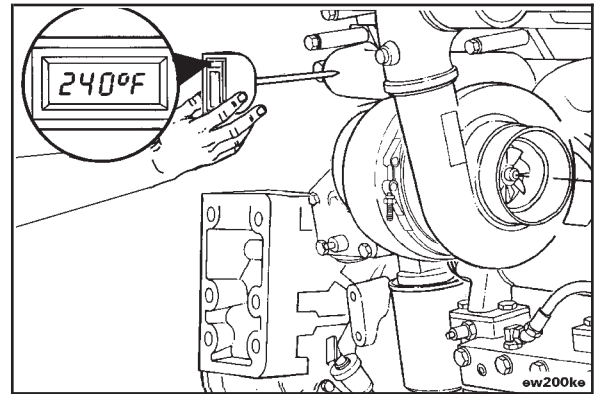
NOTE: If this test is inconclusive, tilt back the exhaust manifold to visually locate the smoking cylinder.



Do not place hand on the exhaust manifold if the engine is hot or heavily black smoking.

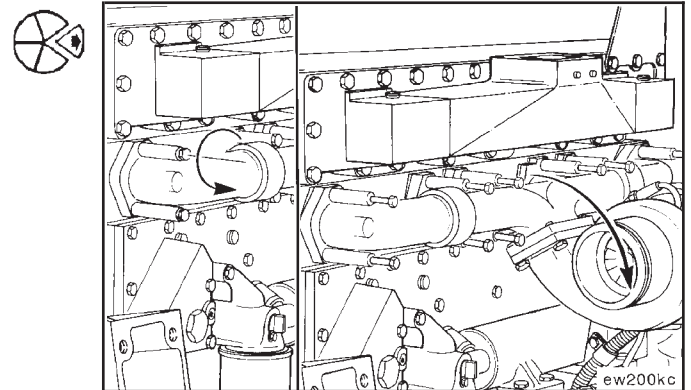
An alternate method is to place your hand on the exhaust manifold at each cylinder port. A smoking cylinder will feel hot.

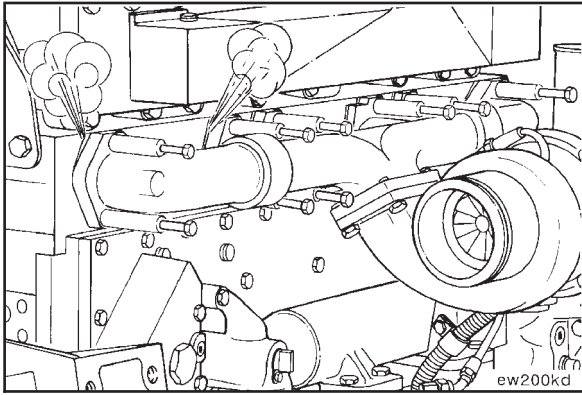
Replace the injector in the cylinder that is producing the smoke. Refer to Procedure 006-026.



Exhaust Manifold Tilt-back Method (006-005-060)

Loosen the exhaust manifold capscrews, and tilt the exhaust manifold back.



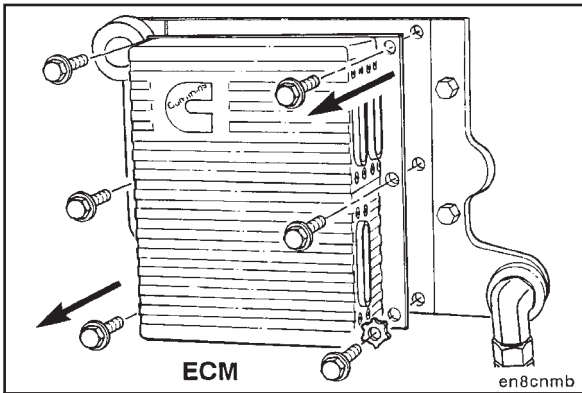


Idle the engine.

Observe the smoking cylinder.



Replace the injector in the cylinder that is producing the smoke. Refer to Procedure 006-026.



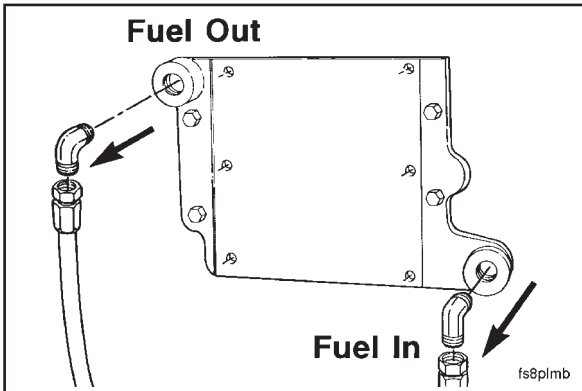
ECM Cooling Plate (006-006)

Remove (006-006-002)

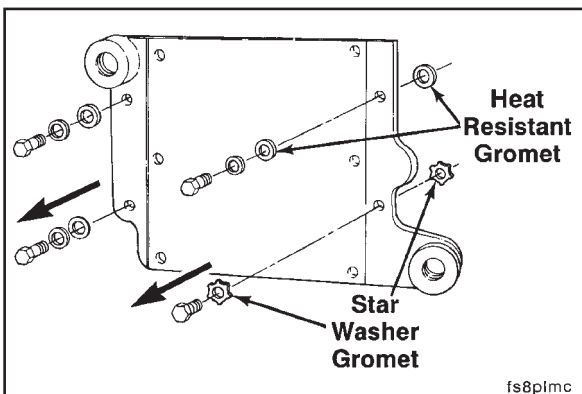
NOTE: This procedure applies to CELECT™ and CELECT™ Plus engines only.

Disconnect the engine wiring harness from the ECM.

Remove the six ECM mounting capscrews. These capscrews are metric. Remove the ECM from the cooling plate.



Remove the inlet and outlet fuel hoses from the cooling plate.



Remove the four cooling plate mounting capscrews. Do **not** lose any of the heat resistant grommets. The heat resistant grommets are on both sides of the cooling plate. One of the mounting locations has heat resistant star washer grommets on both sides of the cooling plate.

Remove the cooling plate

Install (006-006-026)

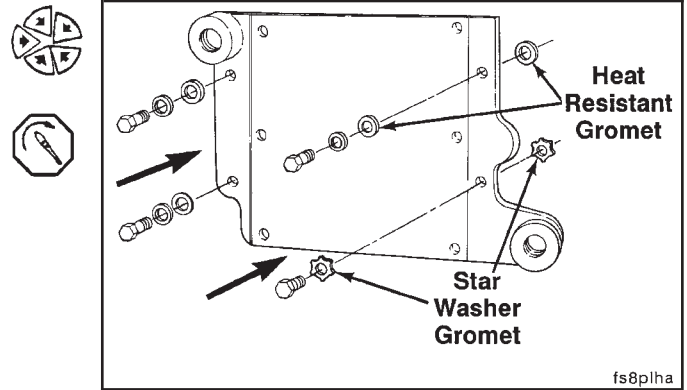
Install a new cooling plate.

Install the heat resistant grommets on both sides of the cooling plate.

Install the two heat resistant star washer grommets at the same mounting location.

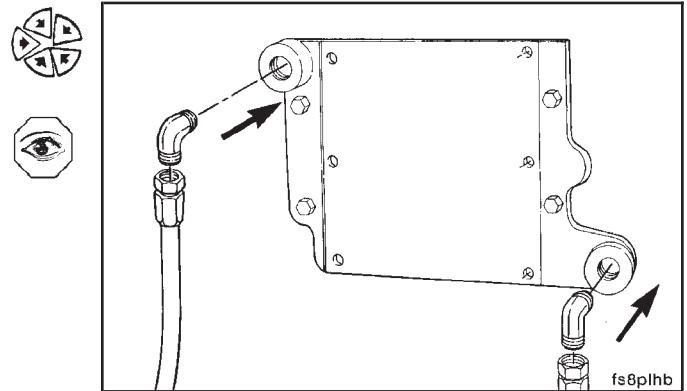
Tighten the four capscrews.

Torque Value: 40 N•m [30 ft-lb]



Connect and tighten the inlet and outlet hoses to the cooling plate.

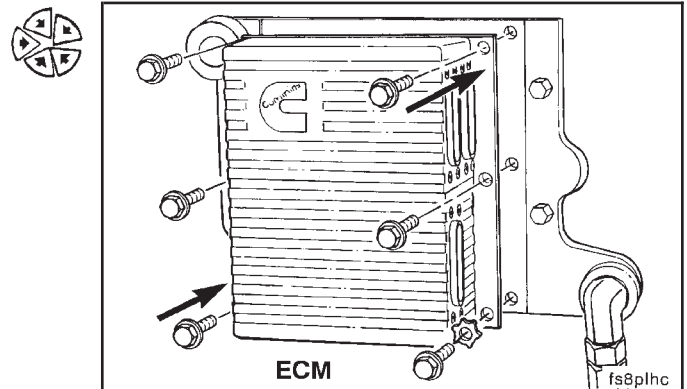
Inspect for paint or grease on the cooling plate.



⚠ CAUTION ⚠

Do not paint the cooling plate. Make sure there is no grease or dirt between the ECM and the cooling plate.

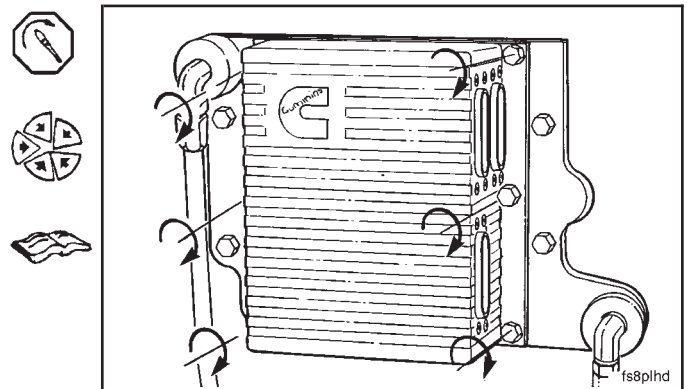
Install the ECM on the cooling plate. Install the six capscrews. Install the star washer under one of the capscrews.

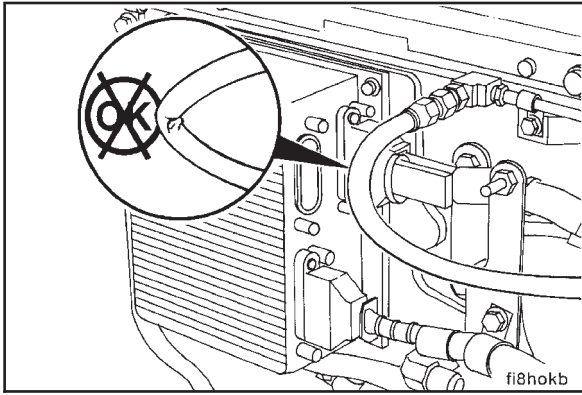


Tighten the six capscrews.

Torque Value: 7 N•m [65 in-lb]

Connect the engine harness and OEM harness connectors to the ECM. Refer to Procedure 019-031-026 in the Troubleshooting and Repair Manual CELECT™ Plus System, Bulletin No. 3666130.

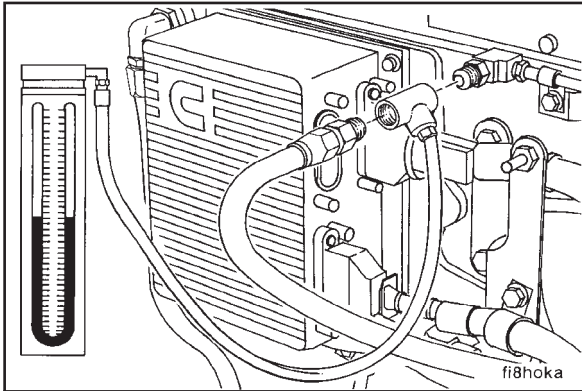




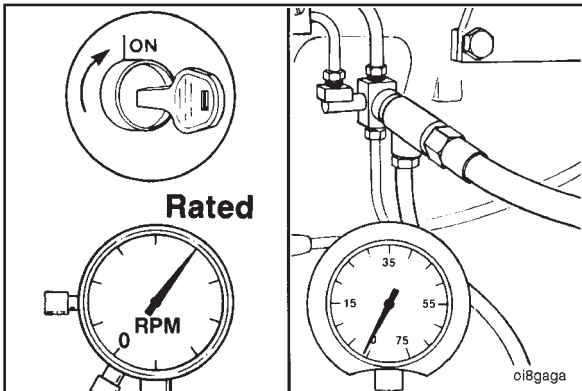
Fuel Drain Line Restriction (006-012)

Measure (006-012-010)

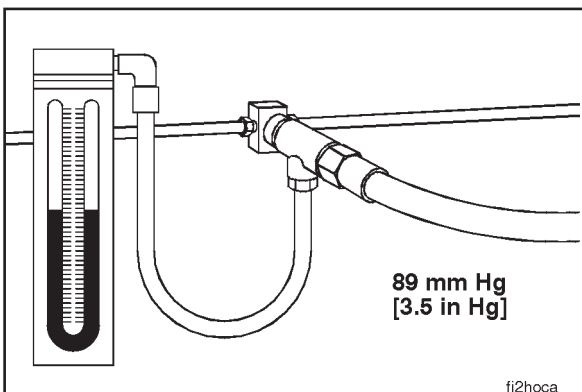
Inspect the drain lines and make sure the lines do **not** have any loops and are **not** crimped.



Remove the fuel drain line and install the Mercury Manometer, Part No. ST-1111-3



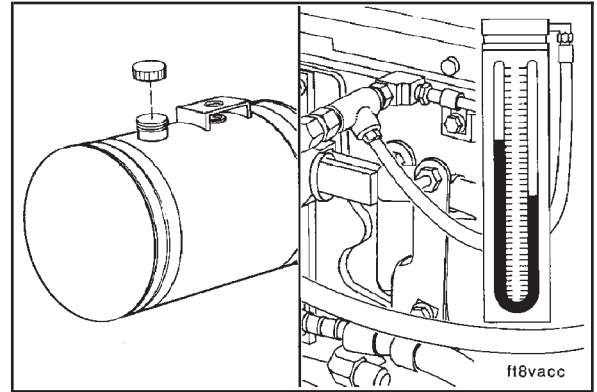
Operate the engine at rated speed and no load.



Observe the reading on the manometer. Hold the manometer at the same level as the connection.

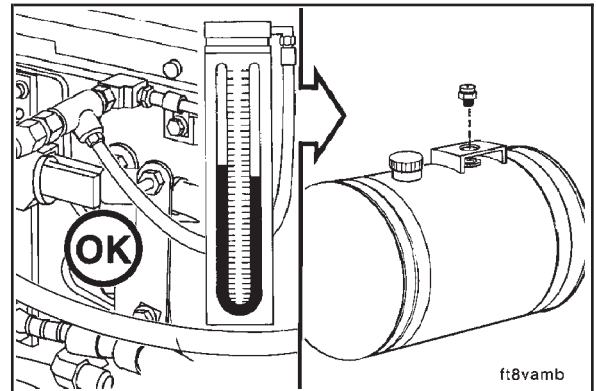
Fuel Drain Line Restriction CELECT™ and CELECT™ Plus			
mm Hg			in Hg
89	MAX		3.5
Fuel Drain Line Restriction — STC			
	mm Hg		in Hg
Without Check Valves	63	MAX	2.5
With Check Valves	165	MAX	6.5

If the restriction is above the maximum specifications, remove the fuel tank fill cap and check again.



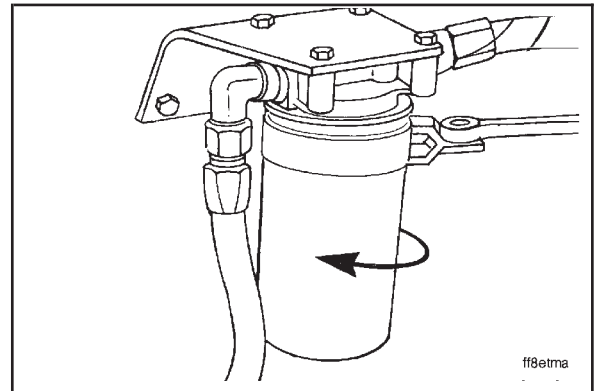
If the restriction is below the specifications when the cap is removed, replace the tank vents.

If the restriction is still above the specifications, inspect the drain lines for restrictions.

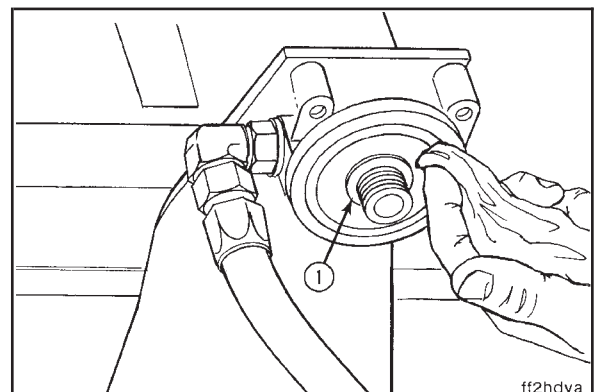


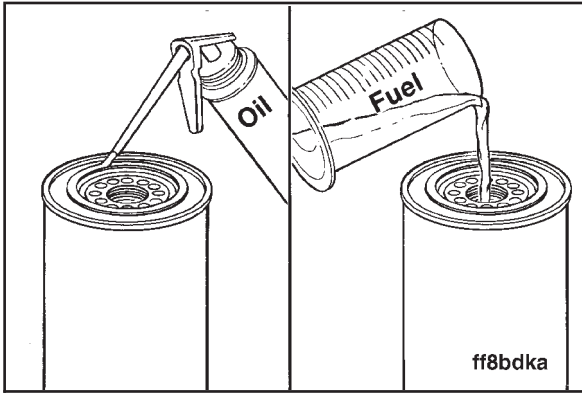
Fuel Filter (Spin-On Type) (006-015)
Remove (006-015-002)

Clean the area around the fuel filter head and filter.
Remove the fuel filter with filter wrench, Part No. 3376807.



Remove the thread adapter sealing ring (1).
Use a clean, lint-free towel to clean the filter head gasket surface.





Install (006-015-026)

Use the correct filter(s) for your engine. Cummins Engine Company, Inc. requires a fuel-water separator be installed in the fuel supply system.

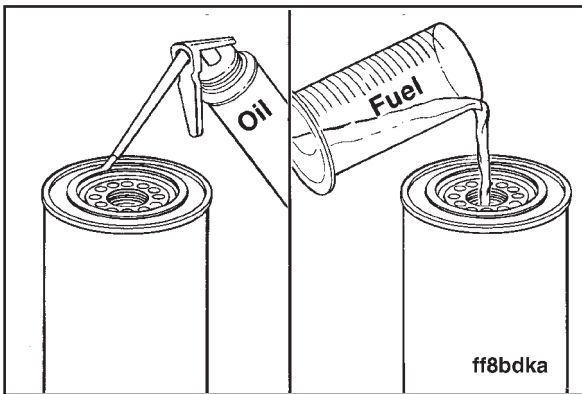


Fuel Filter Specifications (Cummins Engine Company, Inc. Standard No. 14,223)

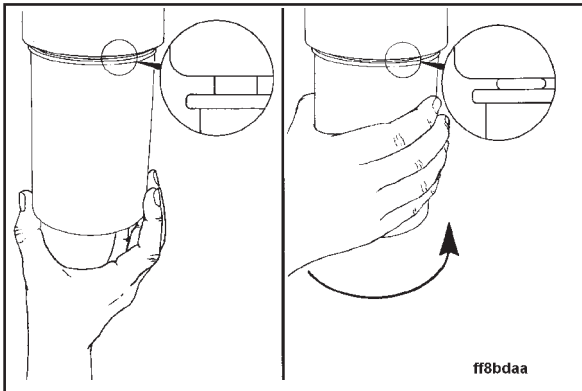
Efficiency:	98.7% at 10 microns 96% at 8 microns 86% at 5 microns
Water Removed:	Free = 95% Emulsified = 95%

Fuel-Water Separator (Superfilter)

Cummins, Part No. 3889716
Fleetguard®, Part No. FS 1000



Install a new thread adaptor sealing ring supplied with the new filter. Apply a light coating of clean engine oil to the filter gasket surface. Fill the filter(s) with clean fuel.



⚠ CAUTION ⚠

Mechanical overtightening of the filter can distort the threads or damage the filter element seal.

Install the filter on the filter head. Turn the filter until the gasket contacts the filter head surface.

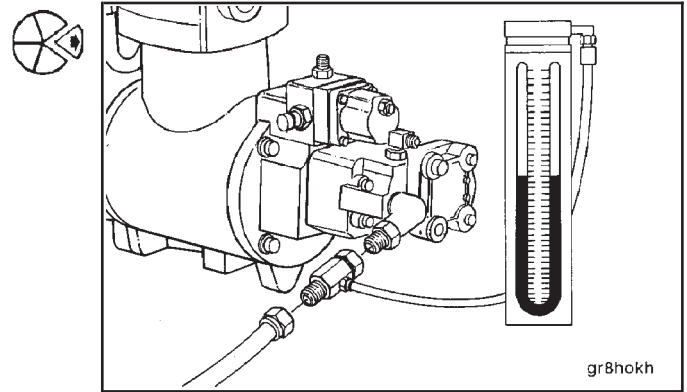
Tighten the filter an additional one-half to three-fourths of a turn after the gasket contacts the filter head surface, or as specified by the filter manufacturer.

Fuel Inlet Restriction (006-020)

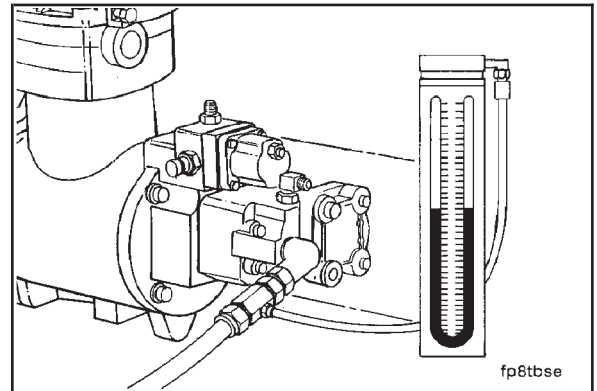
Measure (006-020-010)

Remove the fuel supply hose to the gear pump and install the manometer, Part No. ST-1111-3. Use the appropriate hose adapter for the specific engine as described in the Service Tools list.

NOTE: If the gear pump inlet fitting has a Compuchek® fitting, the manometer can be installed there.



Hold the manometer at the same level as the gear pump connection.



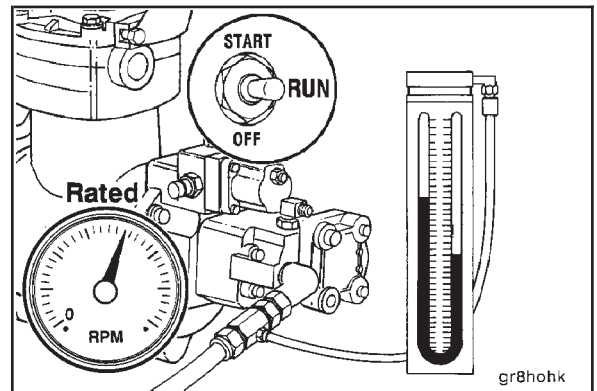
Operate the engine at rated speed and **no** load.

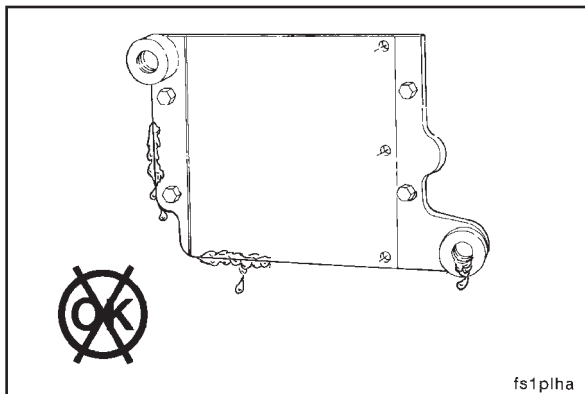
Observe the reading on the manometer.

Fuel Inlet Restriction CELECT™ and CELECT™ Plus			
	mm Hg		in Hg
Clean Filter	152	MAX	6
Dirty Fiter	254	MAX	10
Fuel Inlet Restriction — STC			
	mm Hg		in Hg
Clean Filter	102	MAX	4
Dirty Fiter	204	MAX	8

Correct the restriction or replace the fuel filter.

NOTE: The cooling plate on CELECT™ and CELECT™ Plus engines has about 25.4 mm Hg [1 in Hg] restriction.



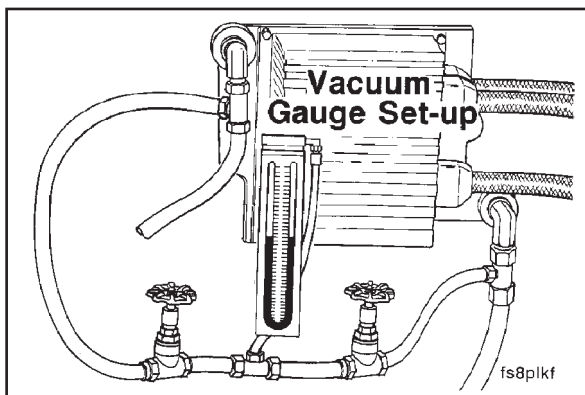


Cooling Plate Inspection

NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

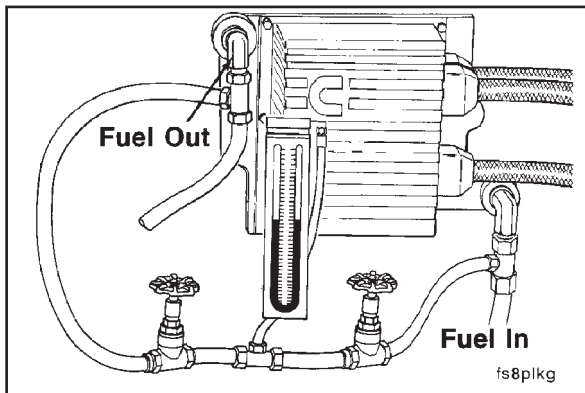


Inspect the cooling plate for restriction, porosity, and leakage. To inspect for porosity and leakage, visually examine the cooling plate for fuel leaks. If any leaks are found replace the cooling plate. Refer to Procedure 006-006.



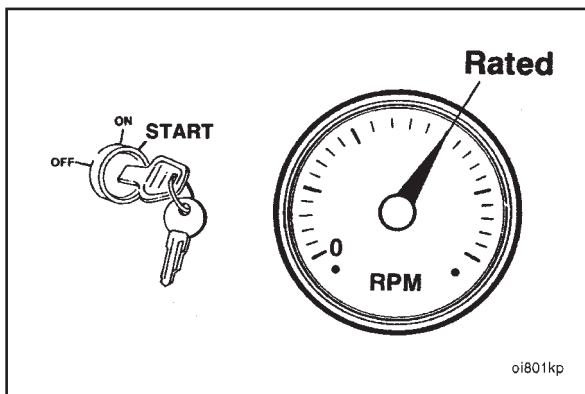
NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Install the mercury manometer, Part No. ST-1111-3, line to a tee fitting. Connect one on and off valve at either side of the tee. Attach the hose and appropriate fittings.



NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Remove the fuel line from the rear of the cooling plate (fuel in). Install one side of the manometer hose into the fuel line. Connect the line to the cooling plate. Connect the other side of the manometer hose into the line from the front of the cooling plate (fuel out). Make sure both valves are closed.

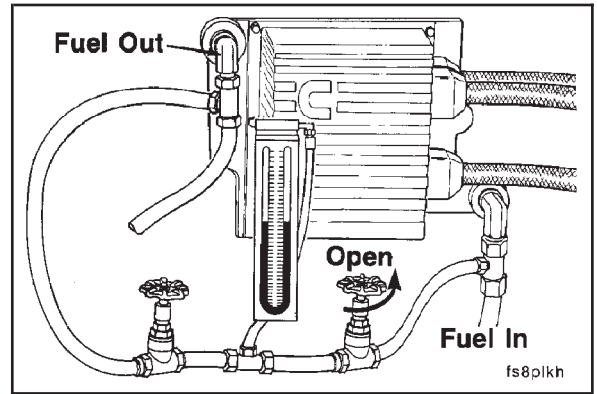


NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Start the engine and operate it at rated rpm and no load.

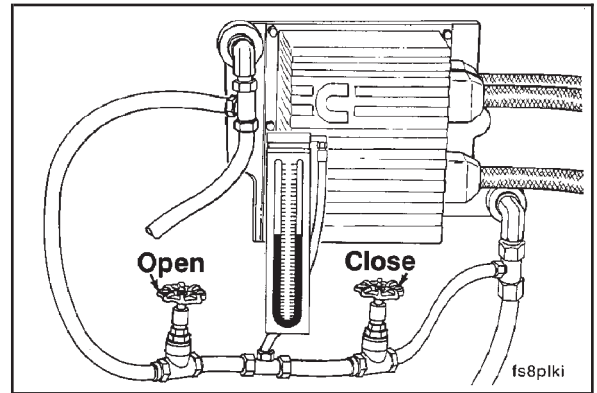
NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Open the valve on the inlet side of the manometer and read the vacuum on the manometer. Record the vacuum reading.



NOTE: This action applies to CELECT™ and CELECT™ Plus engines only.

Close the valve on the inlet side of the manometer. Open the valve on the outlet side of the manometer. Record the vacuum reading on the manometer.



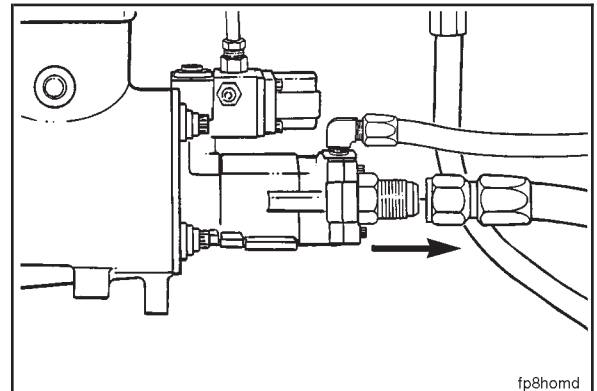
Cooling Plate Restriction		
mm Hg		in Hg
25	MAX	1

If the restriction is greater than the value given, clean or replace the cooling plate.

Fuel Supply Lines (006-024)

Remove (006-024-002)

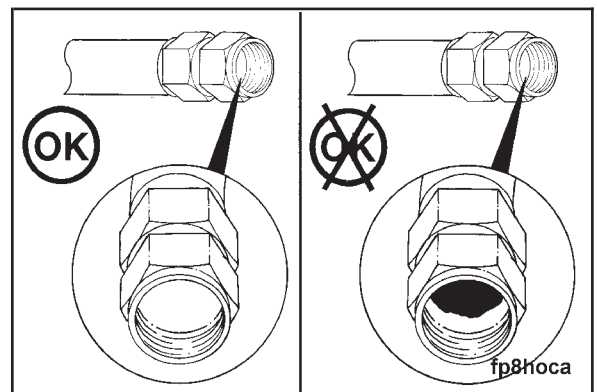
Remove the fuel line or fuel hose.

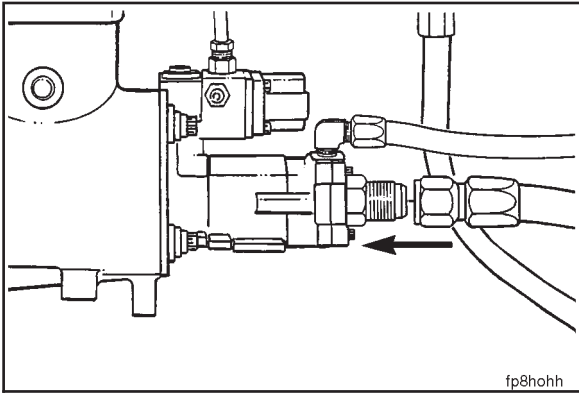


Inspect for Reuse (006-024-007)

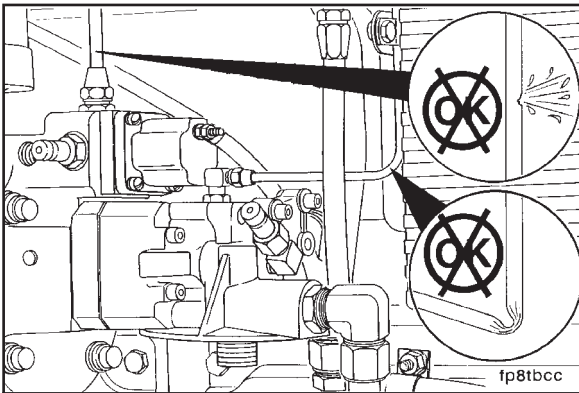
Visually inspect the inside of the fuel hose.

- The inner lining of the hose can separate from the center hose section
- A separation or flap can cause a restriction in the fuel flow



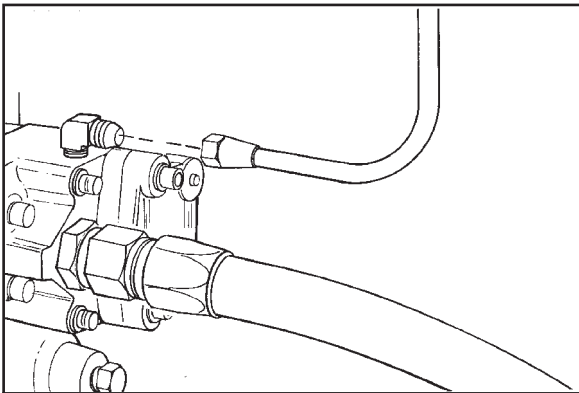


Replace the fuel hose if damage is found.

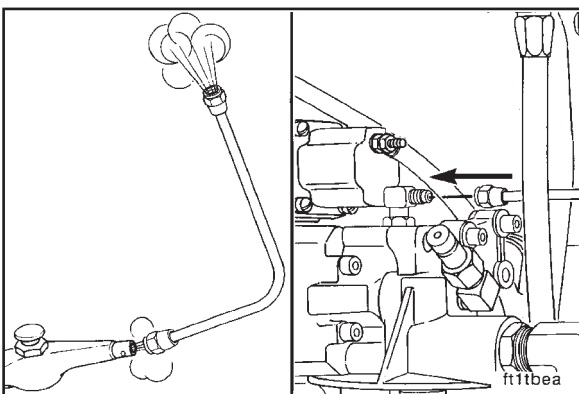


Check for cracks which can cause a pressure loss.

Check the metal fuel lines for sharp bends which can cause a pressure restriction.



If a line(s) is damaged, replace the line(s).



Use compressed air to flush the lines and remove any loose dirt particles.

Install the fuel lines.



Install any brackets that were in place on the fuel plumbing.

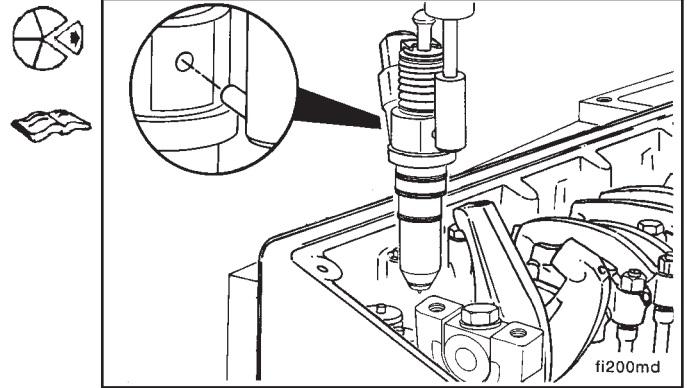
Static Injection Timing (006-025)

Setup (006-025-011)

Remove the rocker lever cover. Refer to Procedure 003-011-002.

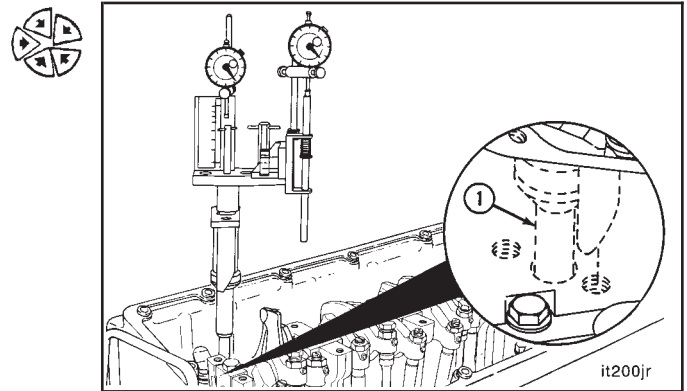
Remove the injector from cylinder No. 1. Refer to Procedure 006-026-002.

NOTE: It is **not** necessary to remove all injectors; however, engine rotation will be easier with all injectors removed.



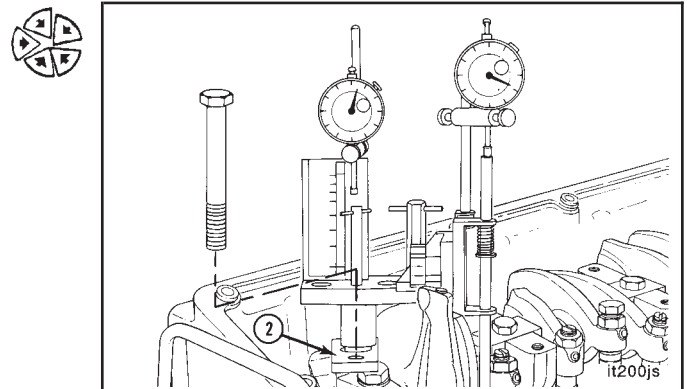
The timing tool, Part No. 3823451, can be installed without removing the rocker housing.

Install the piston plunger rod (1) in the injector bore of the number one cylinder.



Align the swivel bracket (2) with the injector hold down capscrew hole.

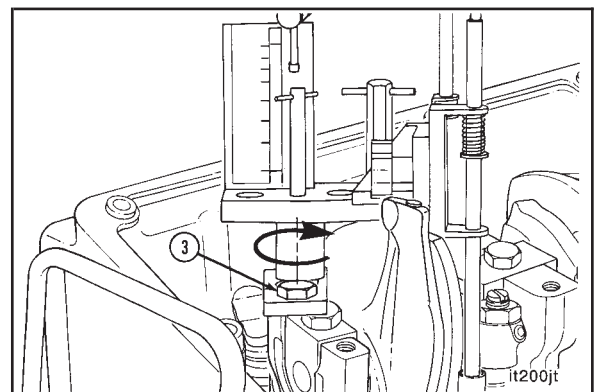
Install capscrew, Part No. 3823600, through the swivel bracket. The capscrew is included with timing tool kit.

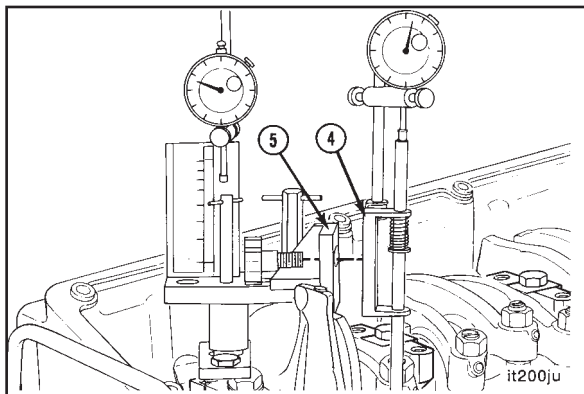


⚠ CAUTION ⚠

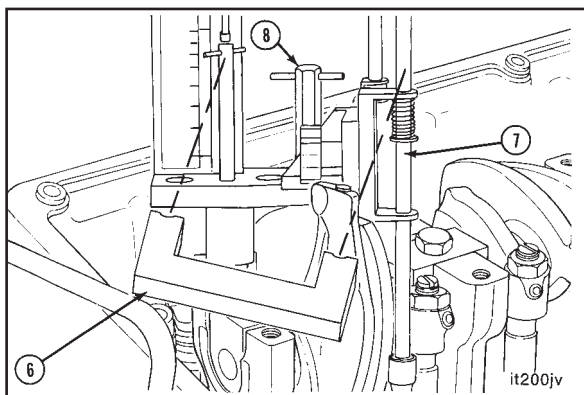
Do not tighten the capscrew too tight. The capscrew can be damaged.

Tighten the capscrew (3) enough to hold the timing fixture rigid.



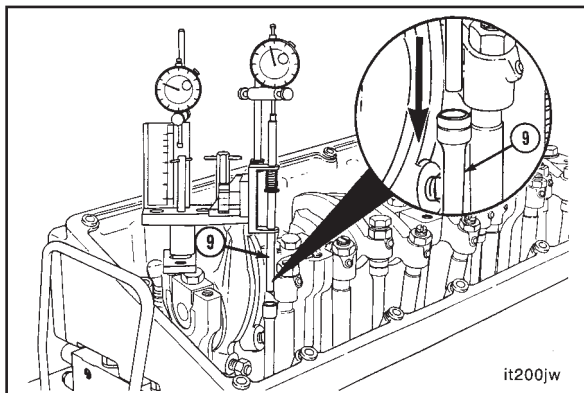


Position the timing tool push tube plunger bracket (4) on the back side of the center bracket (5).



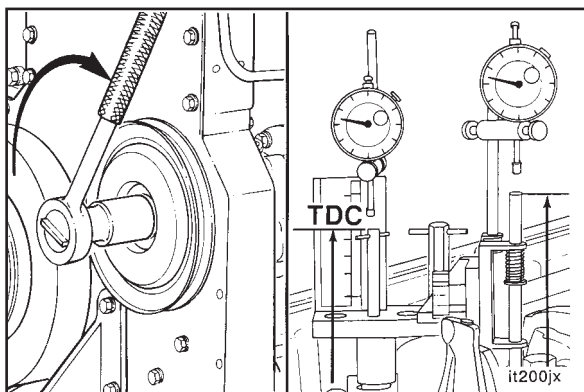
Use the alignment tool (6), Part No. 3376180, to align the push rod plunger rod (7).

Be sure to tighten the clamp handle (8) after the plunger rod is aligned, and remove the alignment tool.



Install the injector push rod (9) between the injector camshaft follower and the plunger rod.

The push rod (9) **must** be vertically aligned with the plunger rod. If it is **not**, incorrect timing values will result. Be careful **not** to drop the push rod into the engine.



Measure (006-025-010)



Use the accessory drive shaft to rotate the crankshaft. If another method is used, the injection timing will not be correct, or the engine can be damaged.

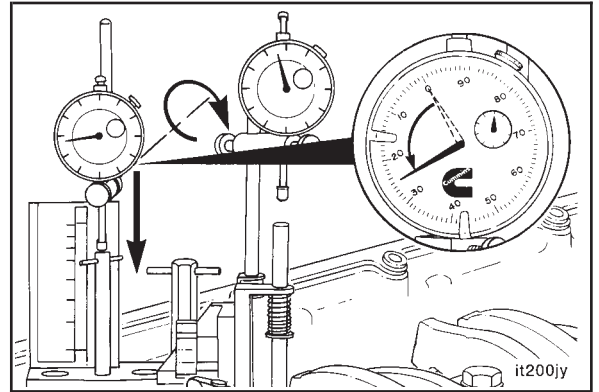
Determine the piston top dead center (TDC) on the compression stroke by rotating the accessory drive shaft **clockwise**.

The piston is on the compression stroke when both plungers move in an upward direction at the same time. TDC is indicated by the maximum **clockwise** indicator position of the piston travel indicator pointer.

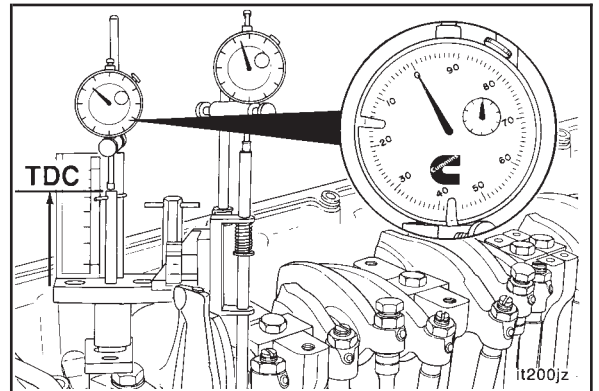
CAUTION

Both indicators must have a travel range of at least 6.35 mm [0.250 inch], or the indicators will be damaged.

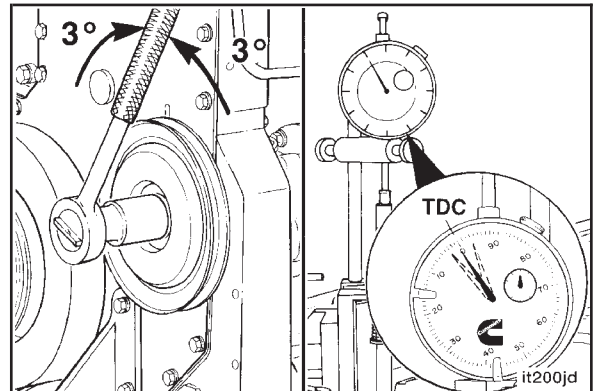
Position the gauge contact tip in the center of the plunger rod and lower the gauge to within 0.63 mm [0.025 inch] of the fully compressed position.



Set the dial indicator over the piston plunger rod to zero "0" when the piston plunger rod has reached maximum upward movement (TDC).

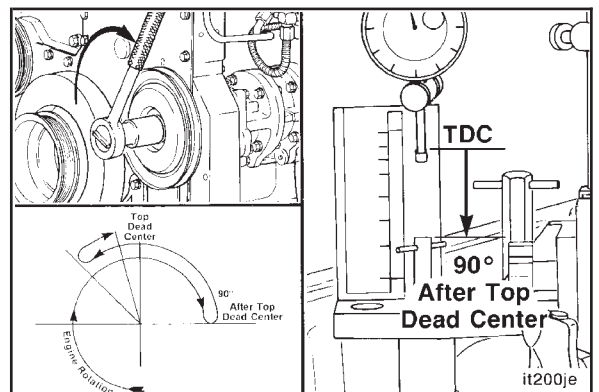


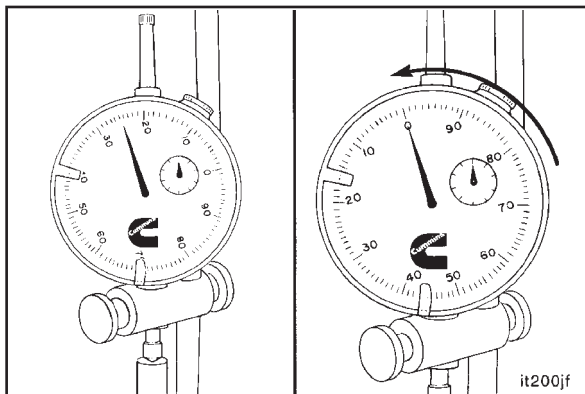
Rotate the accessory drive shaft back and forth, before and after the zero "0" indicator reading, for approximately 3 degrees to be sure the piston is at TDC.



Rotate the accessory drive shaft **clockwise** to 90 degrees after top dead center (ATDC).

The piston plunger will be at the "L10 90 degree" mark on the timing fixture.

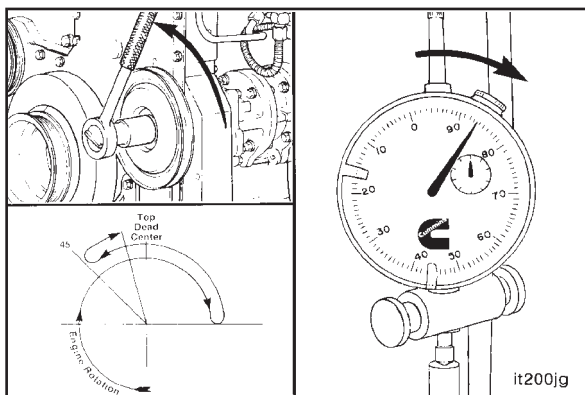




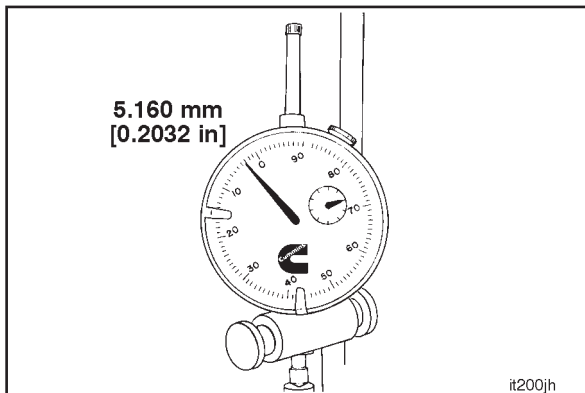
Position the push rod dial indicator contact tip in the center of the plunger rod and lower the gauge to within 0.63 mm [0.025 inch] of the fully compressed position.

Set the push rod dial indicator to zero "0".

Rotate the accessory drive shaft **counterclockwise** to TDC.

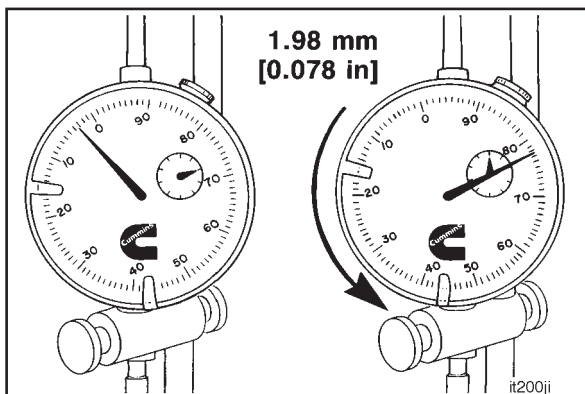


Continue to rotate the accessory drive shaft **counterclockwise** until the crankshaft is at 45 degrees before top dead center (BTDC). This step is necessary to remove gear backlash in the engine.



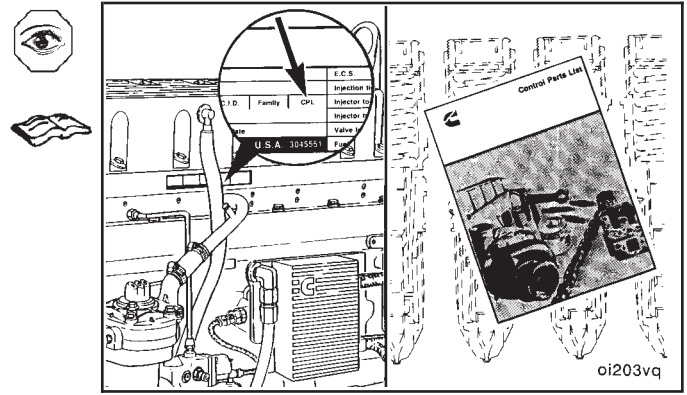
Rotate the accessory drive shaft **clockwise** slowly until the piston travel gauge is at 5.160 mm [0.2032 inch] BTDC.

If the crankshaft is rotated beyond the 5.160 mm [0.2032 inch] BTDC position, the crankshaft **must** be rotated **counterclockwise** back to the 45 degrees BTDC mark.



Read the push rod travel gauge **counterclockwise** from zero "0". This travel represents the injection timing value. In the example shown, the value is 1.98 mm [0.078 inch].

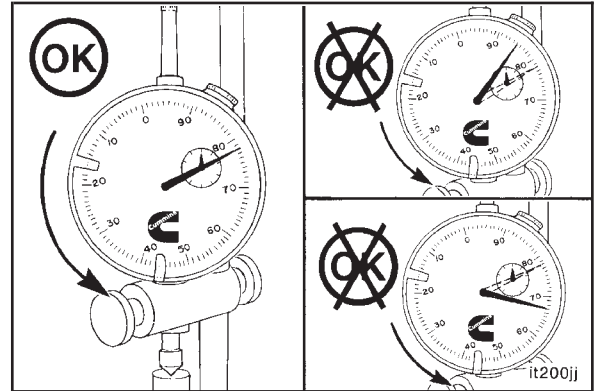
To verify the correct injection timing for a particular engine, check the Control Parts List (CPL) number on the engine dataplate then refer to the CPL Manual, Bulletin No. 3379133. Timing codes are listed as two letter alpha characters.



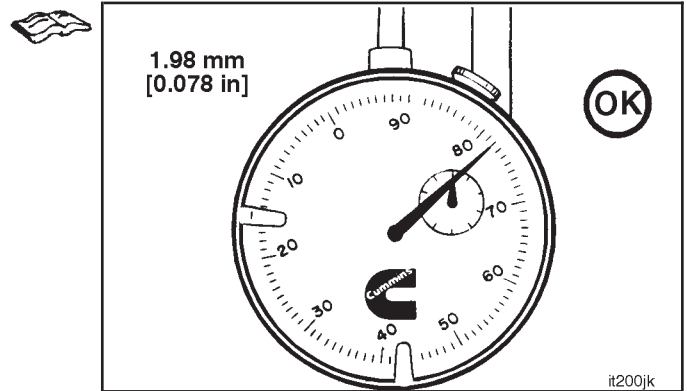
If the indicator reading is lower than the specification, the timing is advanced.

If the indicator reading is higher than the specification, the timing is retarded.

NOTE: The push rod **must** be vertically aligned with the plunger, or incorrect timing values will result. Repeat the procedure if in doubt.



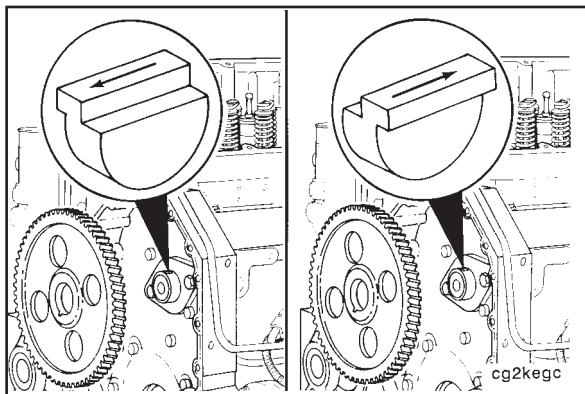
Injection timing can be changed by removing the camshaft gear and installing an offset key. Refer to Procedure 001-012.



The accompanying table lists offset keys by part number and degree of offset.

Never advance injection timing beyond the specification limits. The engine durability will be affected.

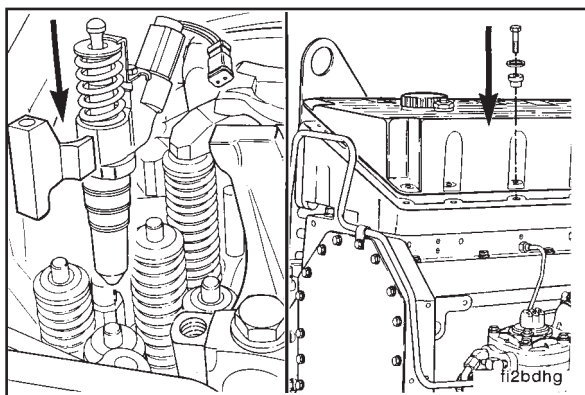
Key Part No.	Degree of Offset (To the Camshaft)	Change in Push Rod Travel	
		mm	in.
3009953	0.00	0.000	0.0000
3030893	0.25	0.051	0.0020
3009948	0.50	0.102	0.0040
3030894	0.75	0.152	0.0060
3009949	1.00	0.203	0.0080
3030895	1.25	0.254	0.0100
3009950	1.50	0.305	0.0120
3030896	1.75	0.356	0.0140
3009951	2.00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



If the arrow on the key is pointing towards the engine, the timing is retarded.

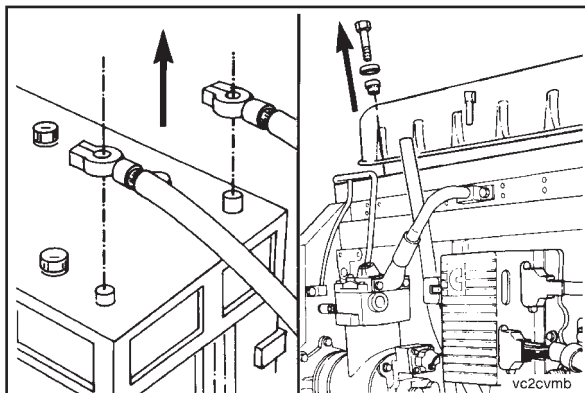
If the arrow is pointing away from the engine, the timing is advanced.

After installing a new timing key, always recheck the timing to be sure the timing is within the specifications.



Install the injector(s). Refer to Procedure 006-026-026.

Install the rocker lever cover. Refer to Procedure 003-011-026.



Injector (006-026)

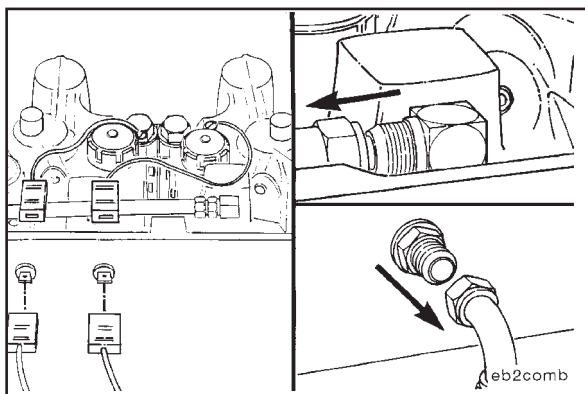
Remove (006-026-002)

CELECT™ or CELECT™ Plus

Disconnect the battery cables before removing or installing the injectors.

Remove the air piping from the charge air cooler to the intake manifold. Remove the hose from the crankcase breather.

Remove the rocker lever cover. Refer to Procedure 003-011-002.



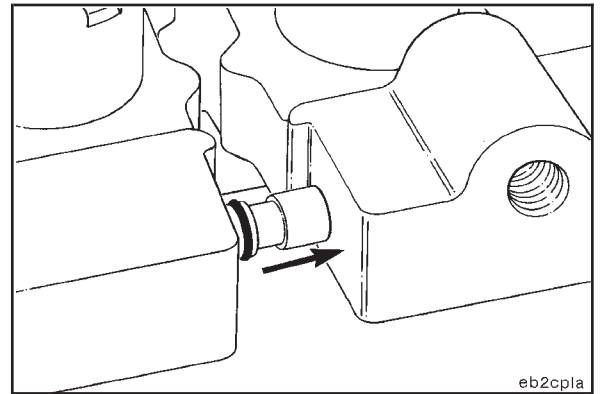
If the engine is equipped with engine brakes, the brakes **must** be removed to remove the injectors.

Disconnect the two electrical connections from the terminals on the inside and outside of the engine brake spacer housing.

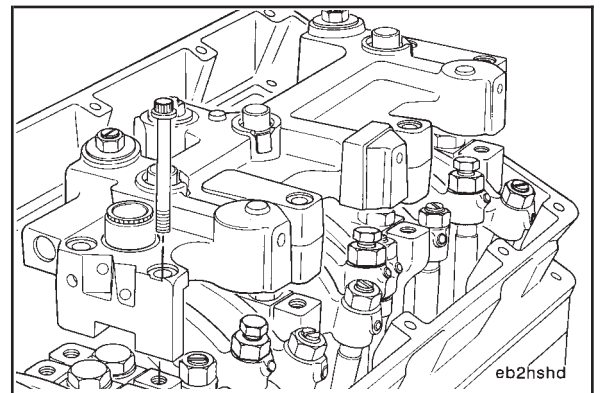
Disconnect the oil supply hose connection.

Remove the oil supply hose.

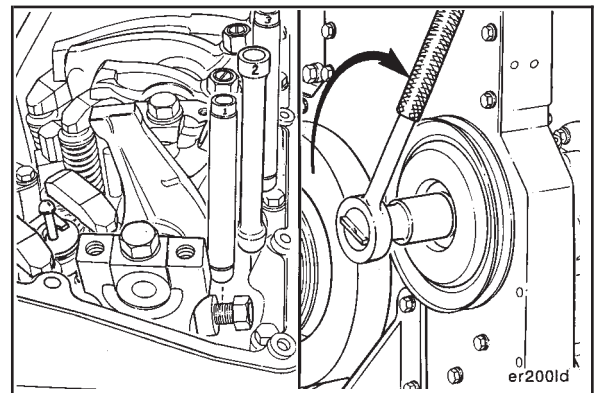
Use your fingers or a screwdriver to press the engine brake housing oil connector into the front brake housing to allow clearance for the housing removal.



Remove the 16 engine brake mounting capscrews and both engine brake housings.



Loosen the injector and valve adjusting screws and remove the push rods and push tubes on the cylinder requiring injector replacement.

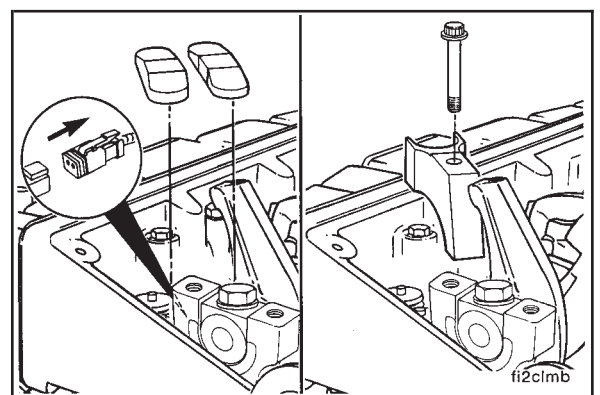


Some push rods are under compression due to the valves being open. Rotate the crankshaft **clockwise** with the accessory drive pulley to relieve the spring tension.

Mark the position of the push rods and push tubes as they are removed. Due to wear patterns on the cam follower sockets and adjusting screws, the push rods and push tubes **must** be installed in the same position as from which they are removed.

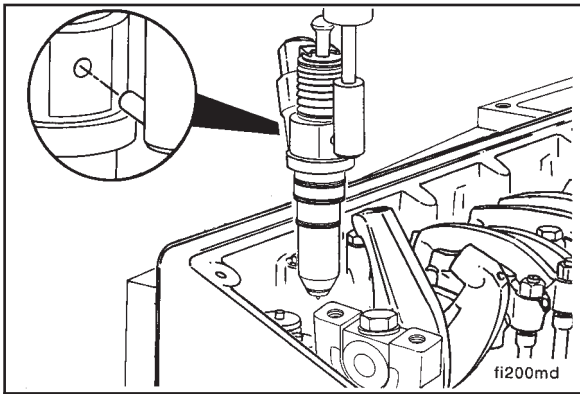
Hold the push rod with one hand to prevent it from falling into the engine. Loosen each adjusting screw and remove the push rod.

Remove the crossheads. Mark the position and orientation of the crossheads as they are removed. Due to wear patterns, they **must** be installed in the same position as from which they were removed.

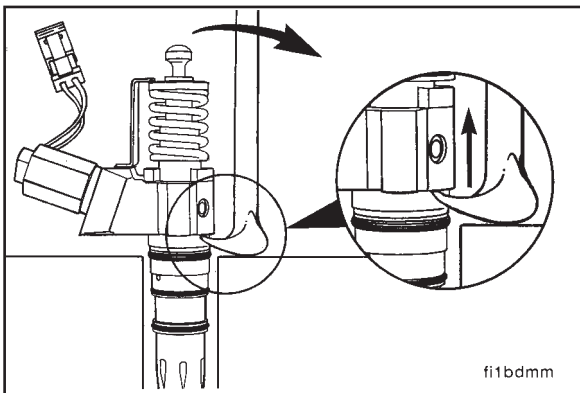


Disconnect the injector wires. Number the injector electrical connections as they are removed. They **must** be connected to the same cylinder when they are installed.

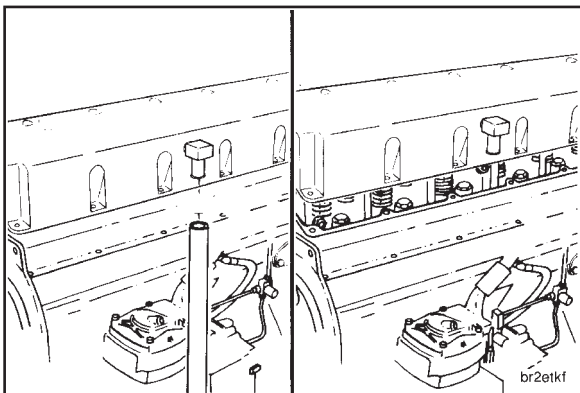
Remove the clamp capscrew and injector hold down clamp.



Remove the injectors using injector tool, Part No. 3823579. Insert the pin of the tool into the hole provided in the body of the injector.



If injector puller, Part No. 3823579, is **not** available, carefully use a pry bar. Pry upward on the injector against the cylinder head.

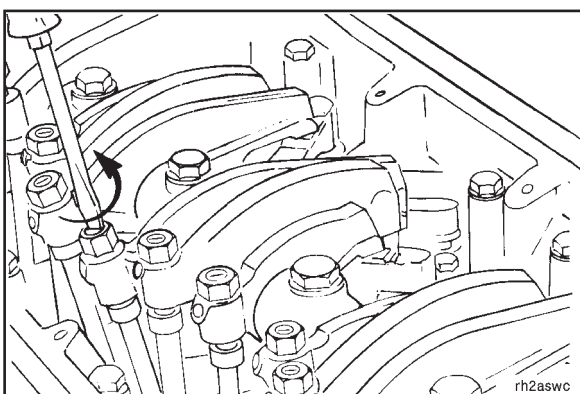


STC

Remove the hose from the crankcase breather.

Remove the 16 capscrews, isolators and spacers from the rocker lever cover assembly.

Remove the cover and gasket.



Loosen the locknut and turn out the adjusting screw on each injector and valve rocker lever.

Some push rods are under compression due to the valves being open. Rotate the crankshaft **clockwise** with the accessory drive pulley to relieve the spring tension.

NOTE: Mark the position of the push rods as they are removed. Due to wear patterns on the cam follower sockets and adjusting screws, the push rods **must** be installed in the same position as from which they are removed.

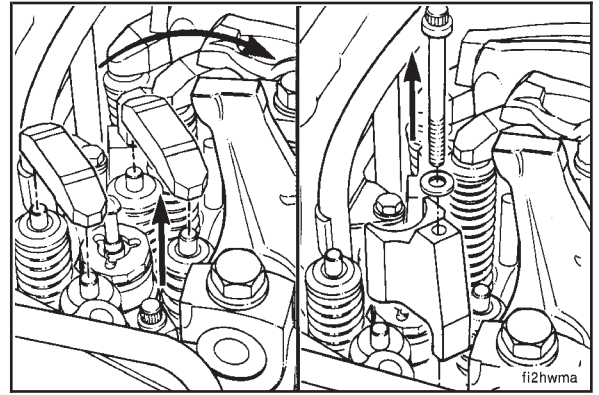
Hold the push rod with one hand to prevent it from falling into the engine. Loosen each adjusting screw and remove the push rod.

NOTE: Do **not** remove the links from STC injectors.

Rotate the injector and valve rocker levers up on each cylinder.

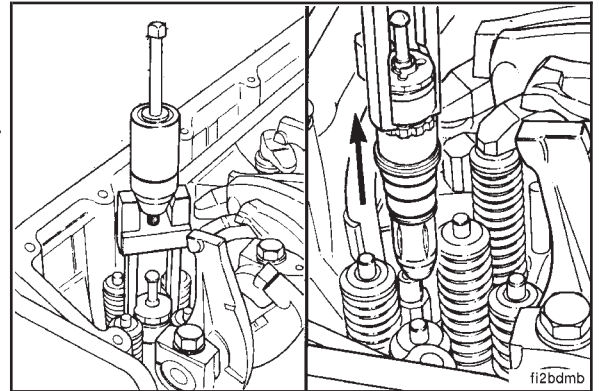
Remove the crossheads. Mark the position and orientation of the crossheads as they are removed. Due to wear patterns, they **must** be installed in the same locations from which they were removed.

Loosen the injector hold down capscrew and remove the hold down.



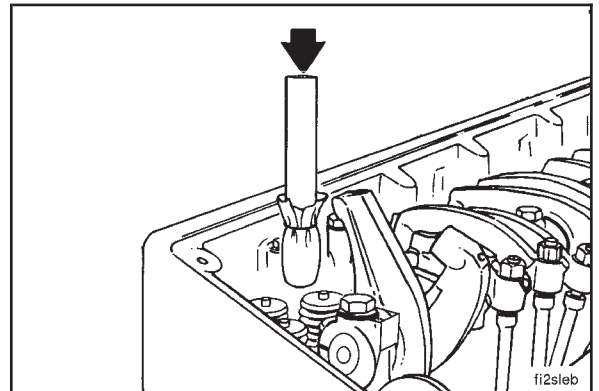
Use injector puller, Part No. 3823024, to remove the injectors.

Take the injectors to a Cummins Authorized Repair Location.



Do **not** use anything metal to scrape the injector copper sleeves. Damage to the injector sleeve can occur.

Use a clean wooden stick with a clean cloth wrapped around the end to remove all of the carbon from the injector copper sleeves in the cylinder head.



Install (006-026-026)

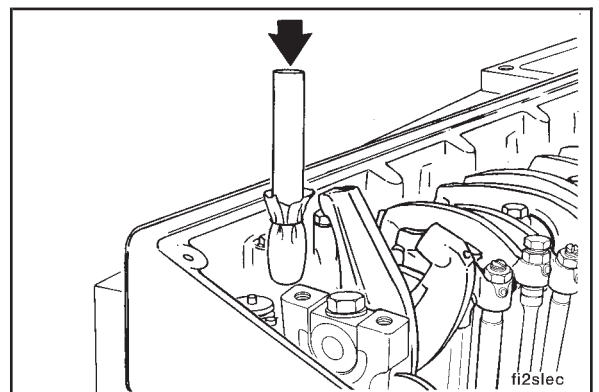
CELECT™ or CELECT™ Plus

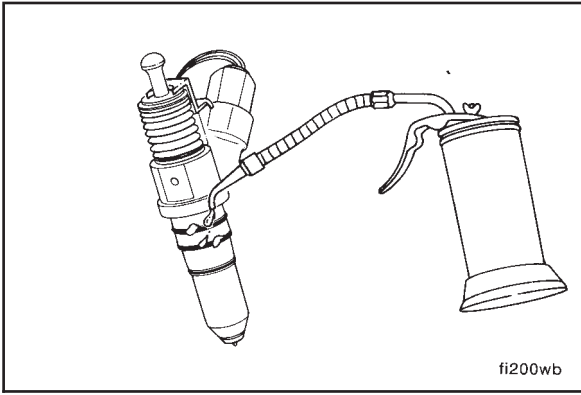


Do not use anything metal to scrape the copper injector sleeves.

Use a clean wooden stick with a clean cloth wrapped around the end to remove all the carbon from the copper injector sleeves in the cylinder head.

Use chip removing unit, Part No. 3823461 or ST-1272-11, to remove the carbon from the top of the piston.





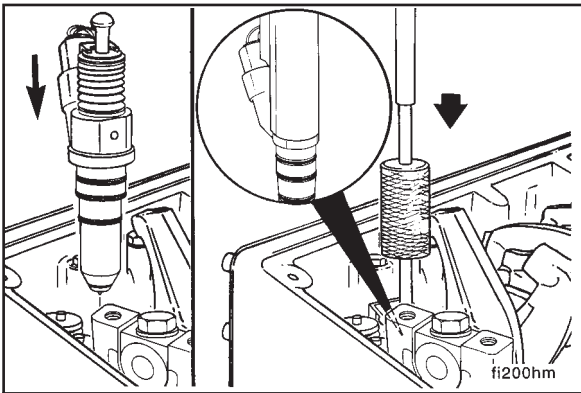
NOTE: It is important that three new o-rings be installed and oriented correctly on the injector when installing the injectors.



Install three new o-rings on each injector. Do **not** twist the o-rings.

Part No.	Location	Color Code
3070136	Top	Red
3070137	Middle	White
3070138	Bottom	Blue

Lubricate the o-rings with clean 15W-40 lubricating oil just before installation.

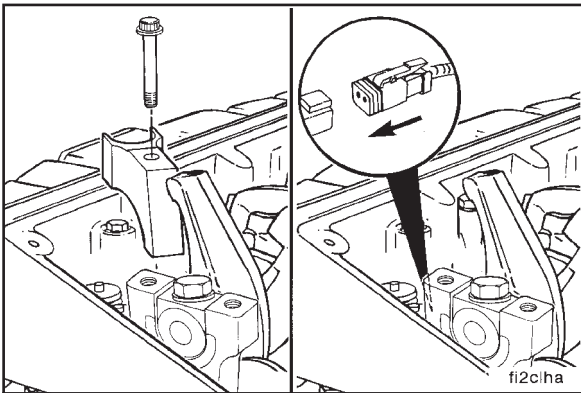


Place the injector in the cylinder head injector bore with the injector solenoid valve toward the intake port. Align the injector equally between the valve springs.

⚠ CAUTION ⚠

Do not drive the injector in by striking the solenoid valve area. This can damage the solenoid or cause the injector to be out of alignment in the bore which will result in o-ring damage.

Use injector tool, Part No. 3823579, to seat the injector in the bore.



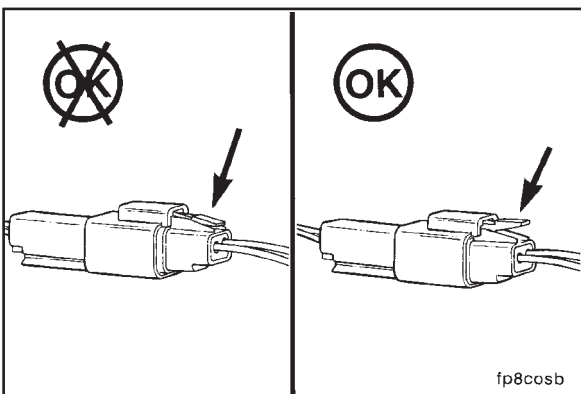
⚠ CAUTION ⚠

The injector must be fully seated before installing the hold down clamp. The hold down clamp can not pull the injector into the bore. Engine damage can occur if the injector is not fully seated.

Install the injector hold down clamp capscrew.

Torque Value: 75 N•m [55 ft-lb]

Connect the injector wires. Make sure the wires are connected to the same cylinder they were removed from.



Check the wire connector to make sure the connector is properly locked in position.



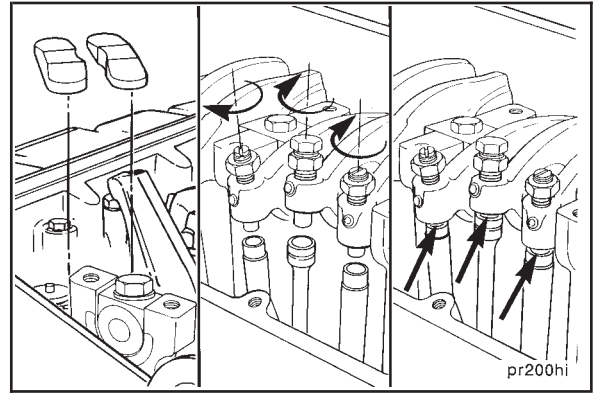
If the wire connector will **not** properly lock into position, refer to the Troubleshooting and Repair Manual CELECT™ Plus System, Bulletin No. 3666130.

Install the crossheads on the intake and exhaust valves.

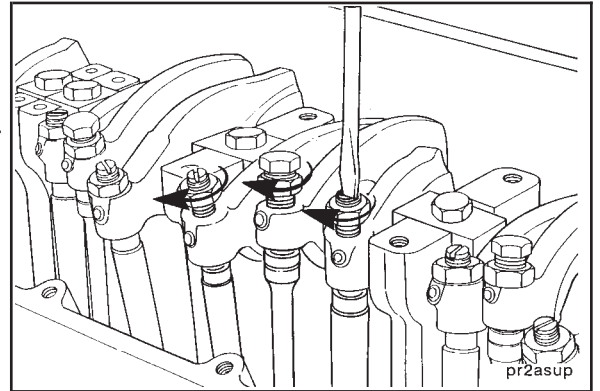
NOTE: The crossheads **must** be installed in the same position as from which they were removed.

Rotate the rocker levers down and install the push rods and push tubes.

NOTE: It is necessary to bar the engine over and install the push rods and push tubes as camshaft position allows.

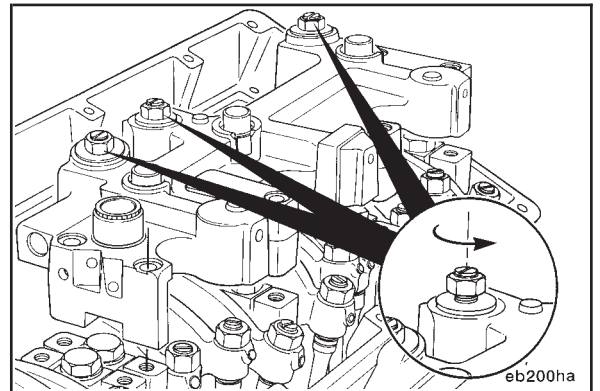


Adjust the valves and injectors. Refer to Procedure 003-004-029.



Loosen the locknuts on the engine brake slave piston. Make sure the slave pistons are fully retracted.

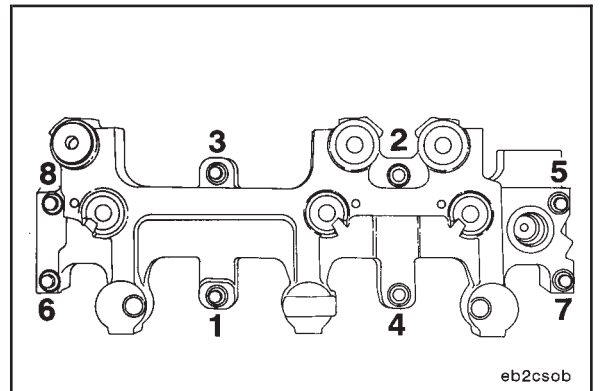
Install the engine brake housing on the rear rocker lever supports.

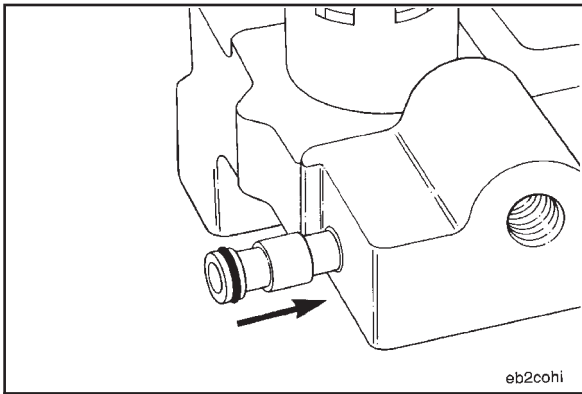


Use clean 15W-40 oil to coat the bottom side of the capscrew heads and the threads.

Install the capscrews in the rocker lever supports. Tighten the capscrews in the sequence shown.

Torque Value: 81 N•m [60 ft-lb]





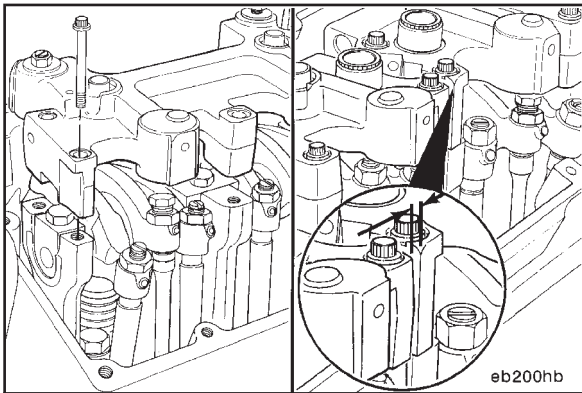
Install new o-rings on the brake oil connector.

Use clean 15W-40 oil to lubricate the o-rings on the oil connector.



Press the connector all the way into the front housing by hand.

NOTE: When installing the front housing, be sure the oil connector and o-ring are in position to be pushed into the rear housing.



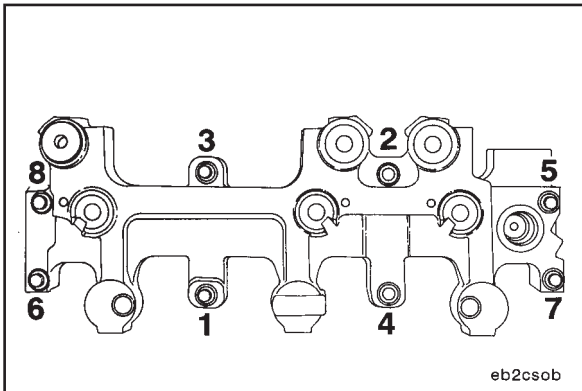
Install the front engine brake housing on the front rocker lever supports.

Center the oil connector between the front and rear housings before tightening the capscrews.



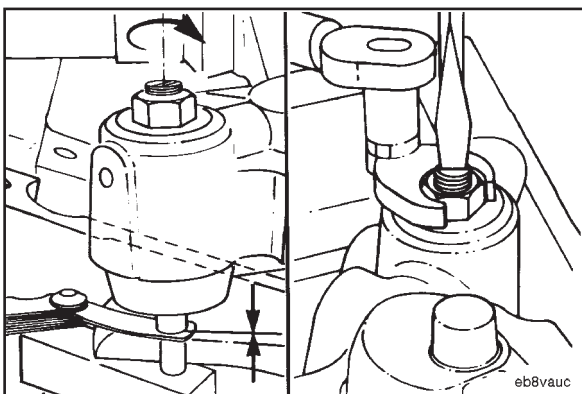
Use clean 15W-40 oil to coat the bottom side of the capscrew heads and the threads.

Install the capscrews in the rocker lever supports.



Tighten the capscrews in the sequence shown.

Torque Value: 81 N•m [60 ft-lb]

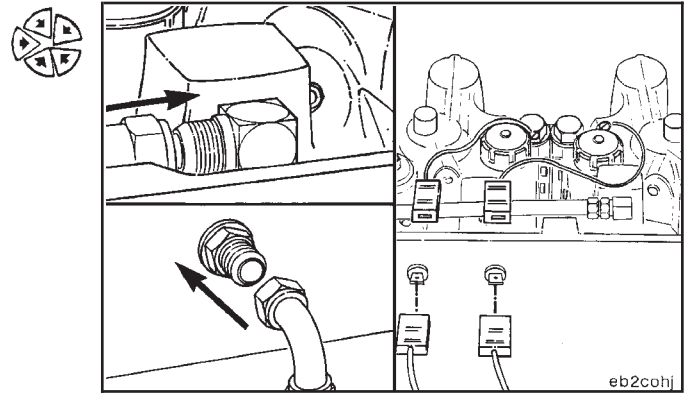


Adjust the engine brakes. Refer to Procedure 003-004-029.

Install and tighten the oil supply hose fitting to the front brake housing.

Install the engine brake terminal electrical leads on the outside of the spacer.

Connect the two solenoid electrical wires to the terminals on the inside of the spacer.



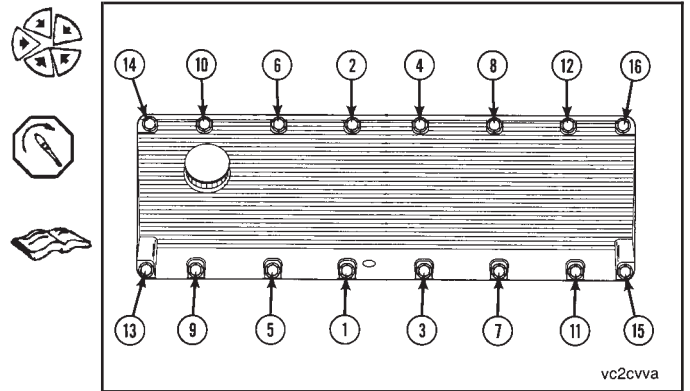
Install the rocker housing cover.

Install the 16 isolaters and capscrews. Tighten the capscrews in the sequence shown.

Torque Value: 15 N•m [130 in-lb]

Install the crankcase breather tube. Install the air piping from the charge air cooler to the intake manifold. Refer to the manufacturer's specifications for the correct hose clamp torque value.

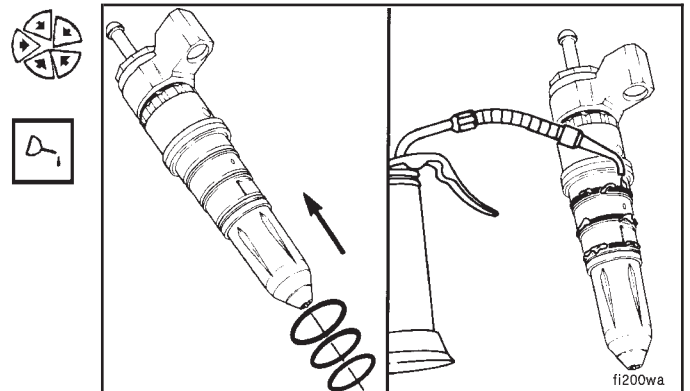
Connect the battery cables.



STC

Install three new o-rings over the injector into the retaining grooves. Do **not** twist the o-rings.

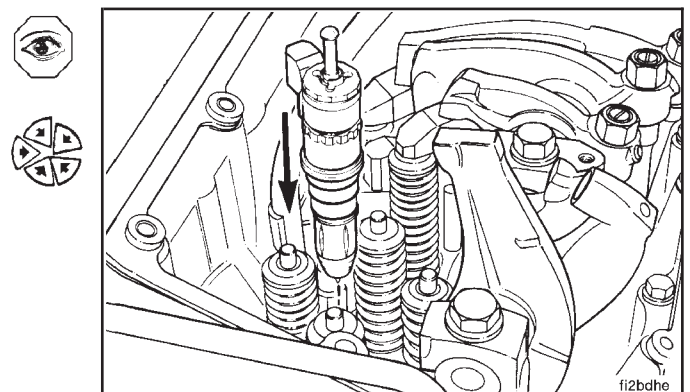
Lubricate the o-rings with clean 15W-40 oil just before installation.

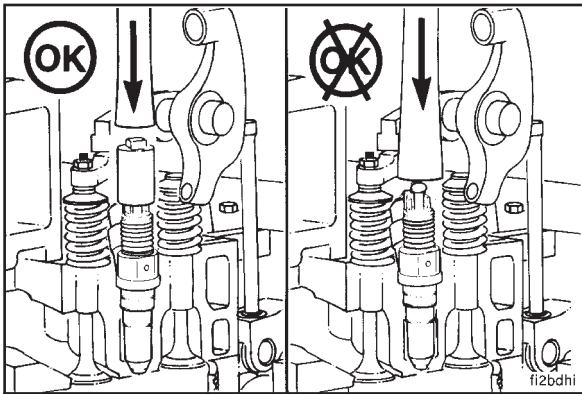


Check the bores in the cylinder head for burrs or sharp edges which can damage the o-rings. Repair damaged injector bores.

Install new o-rings on the STC oil manifold connections.

Align the injector with the oil manifold connections and install the injector into the cylinder head injector bore.



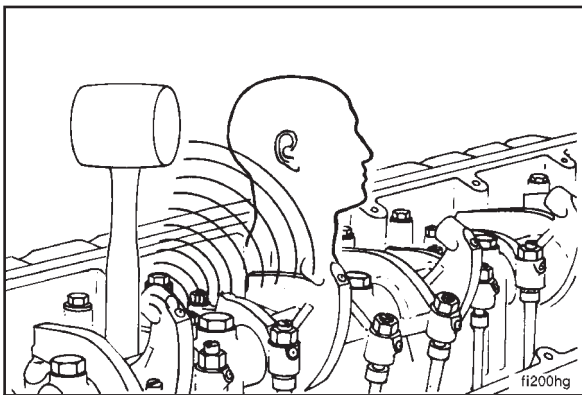


⚠ CAUTION ⚠

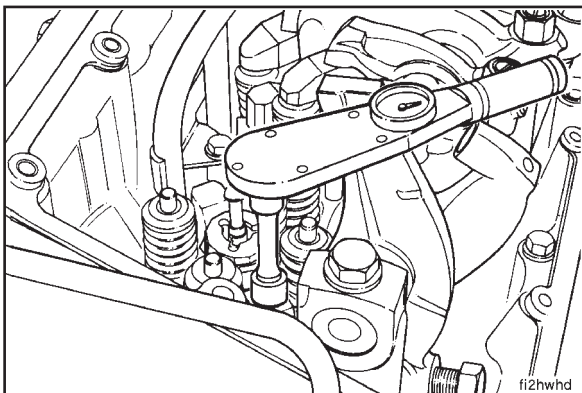
Be sure to place the instrument used to install the injectors on the top cap of the injector, not on the plunger or link. The plungers will be damaged.

Install a deep well socket 27 mm [1 1/16 in] over the top link of the injector. Use the socket so it will still rest completely on the top surface of the injector top cap to avoid bending the inner part of the top cap.

Use a clean, blunt instrument to seat the injector in the bore.



A “snap” will be heard and felt as the injector is seated. If the injector does **not** seat, remove it and check the o-rings for damage. Replace damaged o-rings.

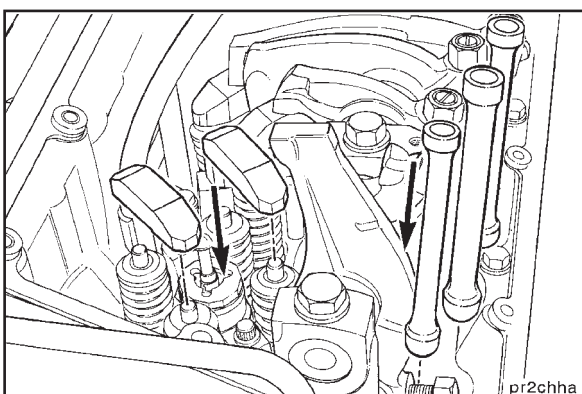


⚠ CAUTION ⚠

The injector must be fully seated before installing the hold down clamp. The hold down clamp can not pull the injector into the bore. Engine damage can occur if the injector is not fully seated.

Install the injector hold down clamp and capscrew.

Torque Value: 75 N•m [55 ft-lb]



Install the crossheads on the valves.

NOTE: The crossheads **must** be installed in the same position as from which they were removed.

Rotate the rocker levers down and install the push rods and push tubes.

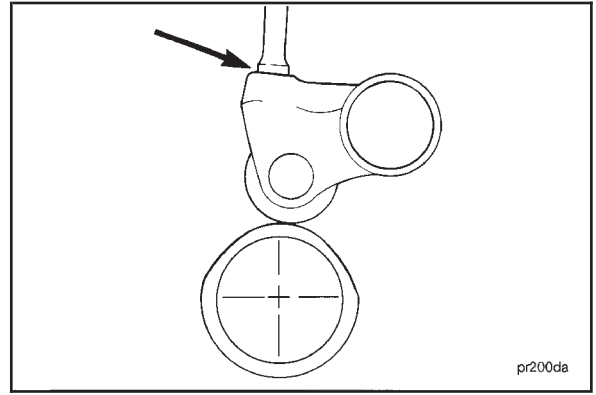
NOTE: It is necessary to bar the engine over and install the push rods and push tubes as camshaft position allows.

M11 Series
Section 6 - Injectors and Fuel Lines - Group 06

Make sure the push rods are properly seated in the cam follower sockets.



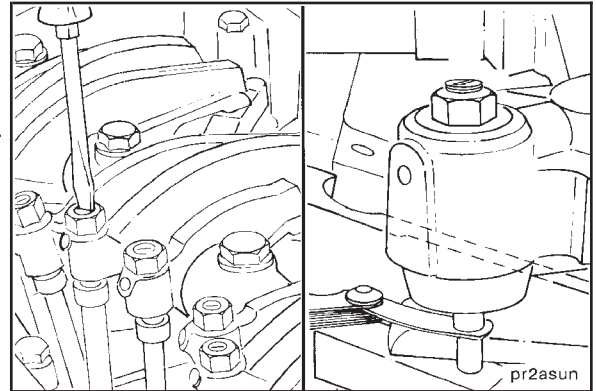
STC Oil Control Valve (Mechanical) (006-037)
Page 6-51



pr200da

Turn the adjusting screw for each rocker lever in until it is properly seated in the push rod socket.

Adjust all valves and injectors. Refer to Procedure 003-004-029.



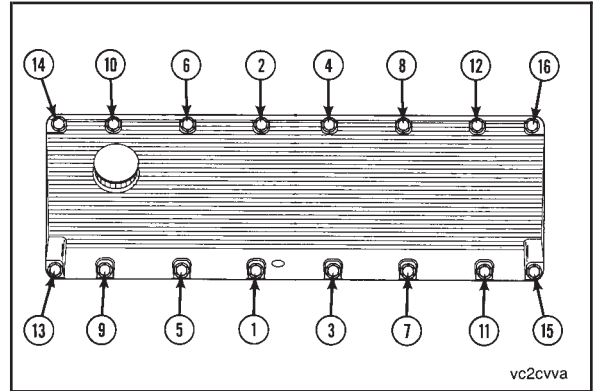
pr2asun

Inspect the rocker lever cover gasket for cuts or damage. If necessary, install a new gasket.

Install the rocker lever cover.

Install the 16 isolators and capscrews. Tighten the capscrews in the sequence shown.

Torque Value: 15 N•m [130 in-lb]



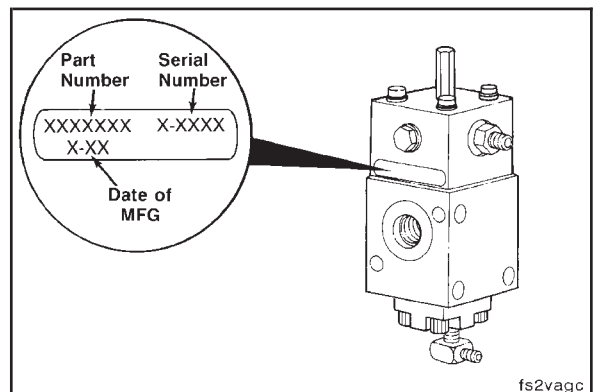
vc2cvva

STC Oil Control Valve (Mechanical)
(006-037)

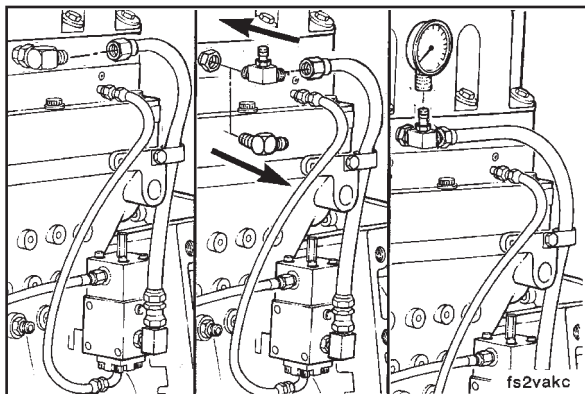
Initial Check (006-037-001)

Record the part number of the STC control valve from the data tag on the valve.

Record the upper and lower shift-point values for the valve.



fs2vagc



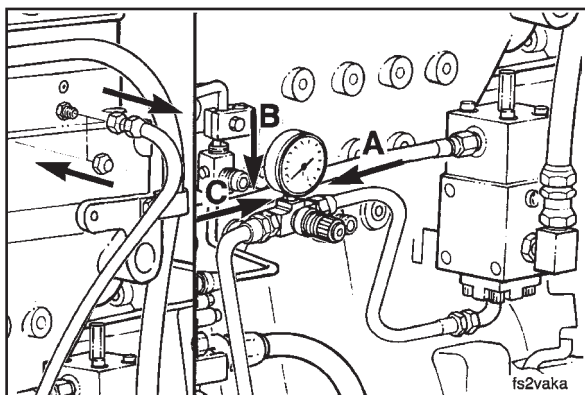
Disconnect the STC oil outlet line from the rocker lever housing.

Remove the elbow fitting from the rocker lever housing.



Install a fitting between the rocker housing and oil outlet line.

Connect a 0–300 psi pressure gauge, Part No. 3375932, to the fitting.



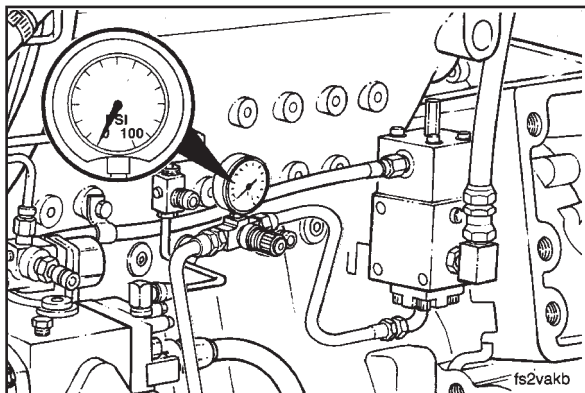
Disconnect the STC fuel pressure sensing line from the fuel inlet passage of the cylinder head. Plug the hole in the cylinder head with a pipe plug.



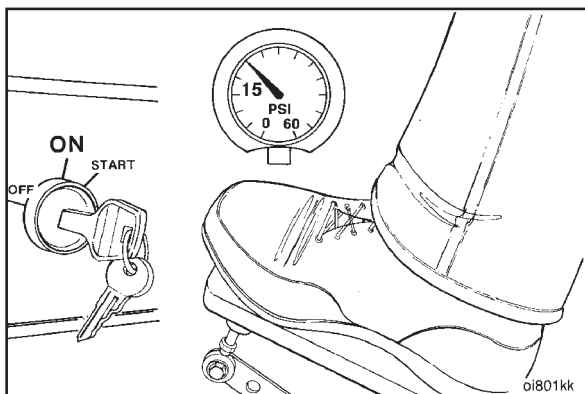
Connect the STC fuel pressure line (A) to the outlet side of the air pressure regulator, Part No. ST-990–40.

Connect a 0–160 psi pressure gauge (B), Part No. 3375275, to the air pressure regulator.

Connect a shop air pressure line (C), capable of providing 100 psi, to the inlet side of the regulator.



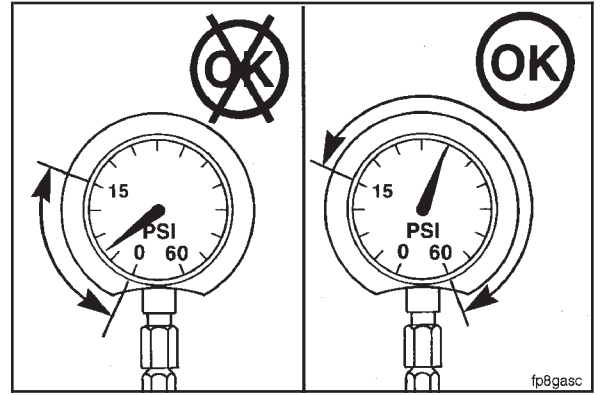
Adjust the air pressure regulator until the air pressure gauge shows 0 psi.



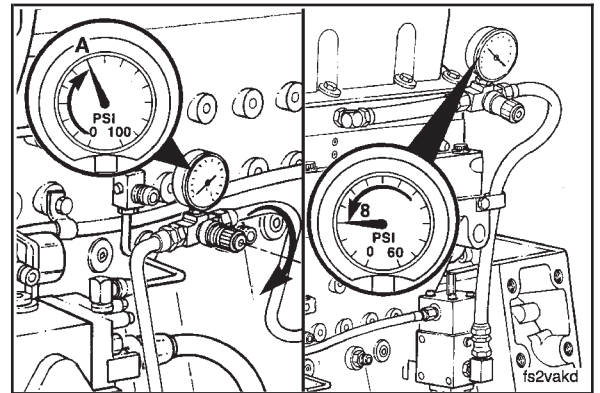
Operate the engine at idle. The oil pressure between the STC valve and the tappets **must** be at least 103 kPa [15 psi].

NOTE: Because the oil pressure can be less than 103 kPa [15 psi] when the coolant temperature is above 49°C [120°F], these tests **must** be performed at temperatures below this level.

NOTE: If the oil pressure will not reach 103 kPa [15 psi], the STC oil delivery system is not functioning properly. Perform the STC Oil Delivery System Diagnostics, Procedure 006-045.



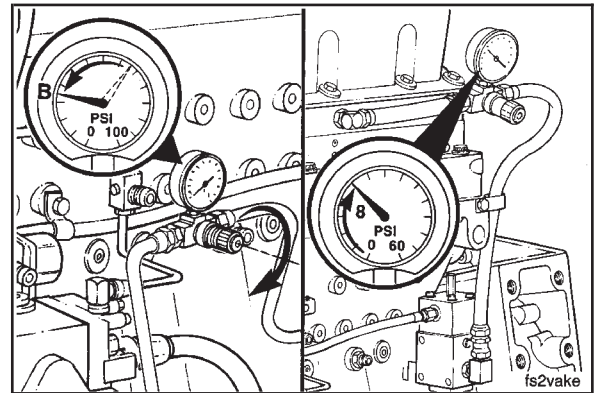
Slowly adjust the pressure regulator to increase the air pressure until the oil pressure drops below 55 kPa [8 psi]. Record the air pressure at this point. This is the upper shift-point (A).



NOTE: The sound of the overhead will become quieter when the 55 to 69 kPa [8 to 10 psi] point is reached. This is the shift from ADVANCED to NORMAL timing.



Raise the air pressure at least 103 kPa [15 psi] above the upper shift-point then slowly begin to lower it. Record the air pressure at which the oil pressure raises above 55 kPa [8 psi]. This is the lower shift-point (B).



NOTE: The lower shift-point is the shift from NORMAL to ADVANCED timing. The overhead will go from quiet to noisy. This pressure **must** be lower than the upper shift-point. If it is **not**, repair or replace the STC valve.



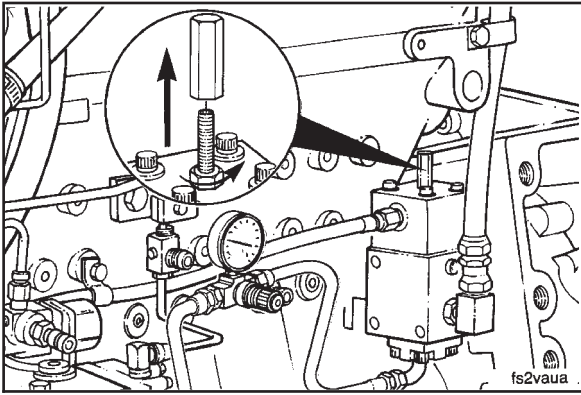
Compare the shift-point values to those specified for the valve. If the values are **not** within these specifications listed, recalibrate the STC valve.



NOTE: Some STC control valves do **not** have an adjusting screw. If the calibration is **not** within specifications, the valve **must** be removed and repaired or replaced.



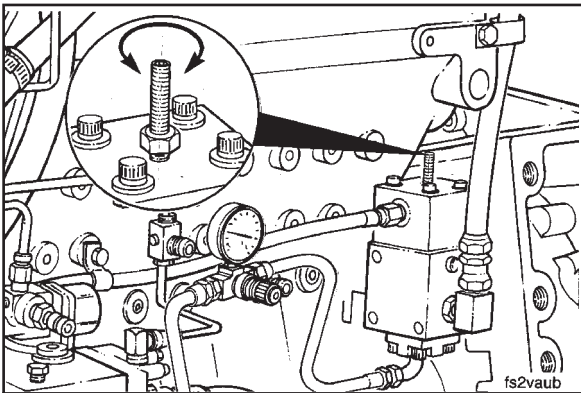
STC Control Valve Calibration Data			
	kPa		psi
Upper Shift Point	125	MIN	18
	193	MAX	28
Lower Shift Point	Not more than 34 kPa [5 psi] below the upper shift point.		



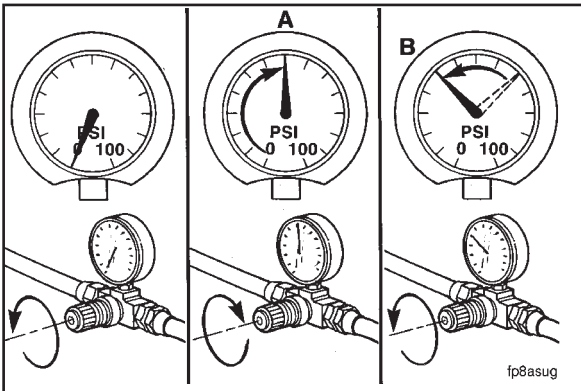
Remove the tamperproof wire from the acorn nut on the top of the STC valve.

Remove the acorn nut from the STC valve adjusting screw.

Loosen the locknut on the STC valve adjusting screw.



Use an Allen wrench to turn the STC valve adjusting screw. Turn the screw in a **clockwise** direction to raise the STC valve upper shift-point. Turn the screw in a **counterclockwise** direction to lower the upper shift-point.



NOTE: Always start with the air pressure at 0 psi before checking the upper shift-point (A). Always raise the air pressure to at least 103 kPa [15 psi] above the upper shift-point (A) before checking the lower shift-point (B).

After adjusting the screw, repeat the STC shift-point check procedure.



Repeat the calibration and check procedure until the shift-points are within the set values listed in the table. If the valve **cannot** be calibrated to these specifications, replace it.

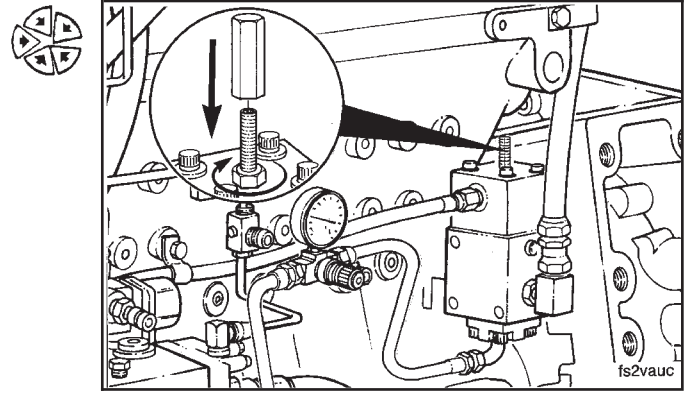


STC Control Valve Calibration Data

	kPa		psi
Upper Shift Point	125	MIN	18
	193	MAX	28
Lower Shift Point	Not more than 34 kPa [5 psi] below the upper shift point.		

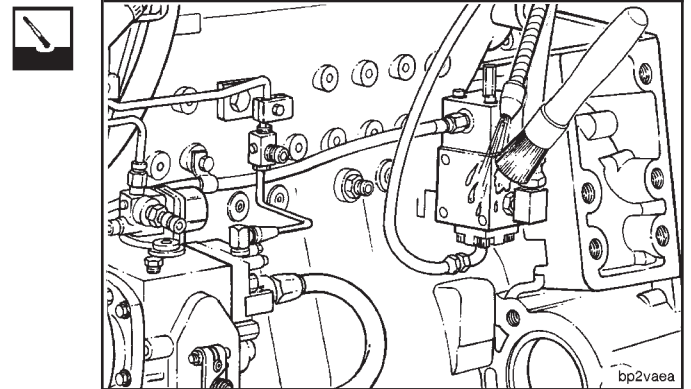


Tighten the STC adjusting screw locknut.
Install the acorn nut on the STC adjusting screw.
Install the tamperproof wire between the acorn nut and capscrew.



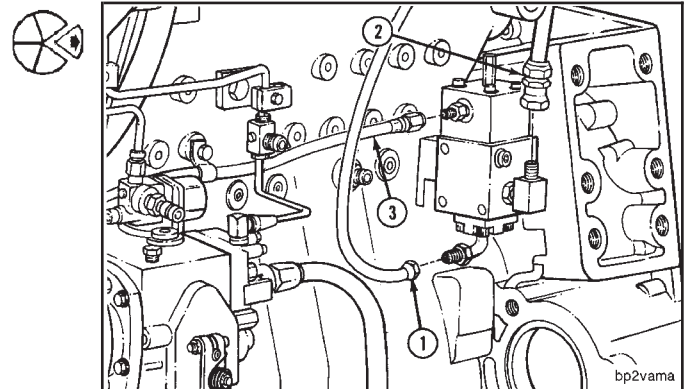
Remove (006-037-002)

Clean the STC oil control valve and the surrounding area before removing it from the engine.



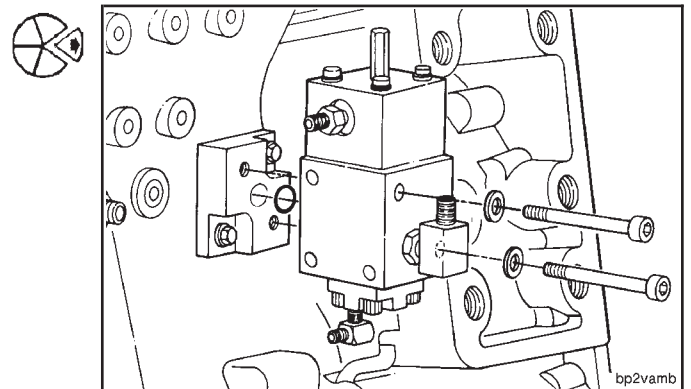
Remove the following lines from the STC oil control valve:

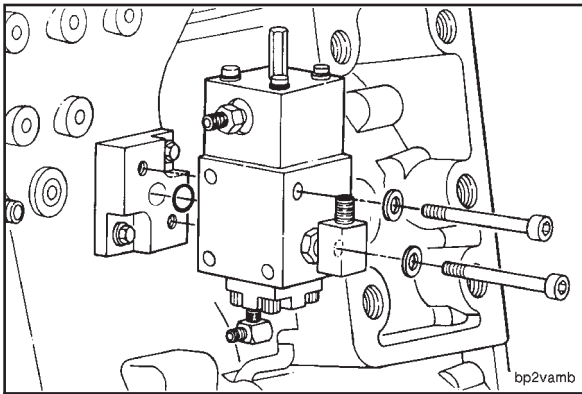
- Fuel pressure sensing line (1)
- Oil outlet line to tappets (2)
- Oil vent line (3)



Remove the two capscrews which hold the STC valve to the mounting plate.

Remove the STC control valve seal ring.





Install (006-037-026)

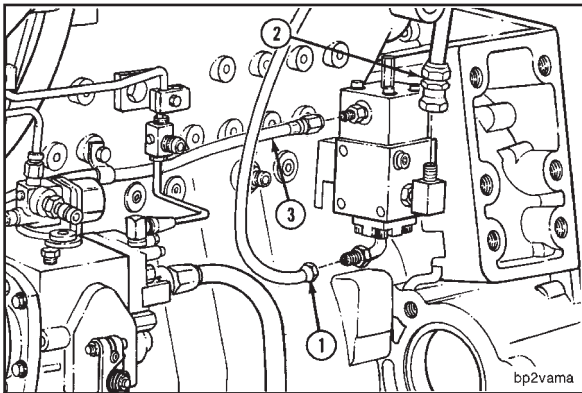
Install a new seal ring.



Install the STC oil control valve to the mounting plate with the two capscrews.

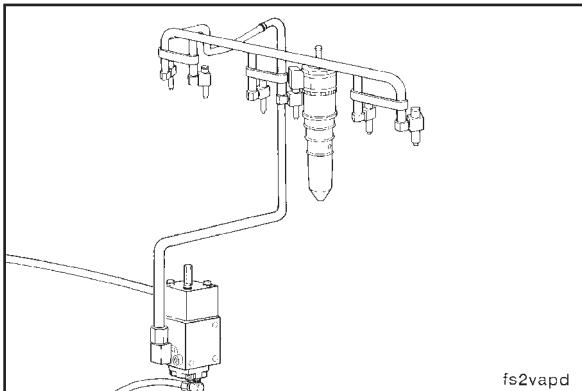
Tighten the capscrews.

Torque Value: 41 N•m [30 ft-lb]



Connect the following lines to the STC oil control valve:

- Fuel pressure sensing line (1)
- Oil outlet line to tappets (2)
- Oil vent line (3)

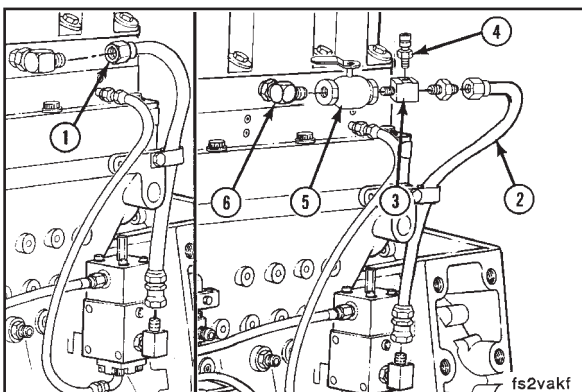


STC Oil Delivery System Diagnostics (006-045)

Test (006-045-012)

The following procedure outlines the proper method which **must** be used to test the STC oil delivery system.

NOTE: Because the oil pressure can be less than 103 kPa [15 psi] when the coolant temperature is above 49°C [120°F], these tests **must** be performed at temperatures below this level.



Remove the STC oil outlet line (1) from the engine.

Install a flexible hose (2) to the STC valve oil outlet fitting.



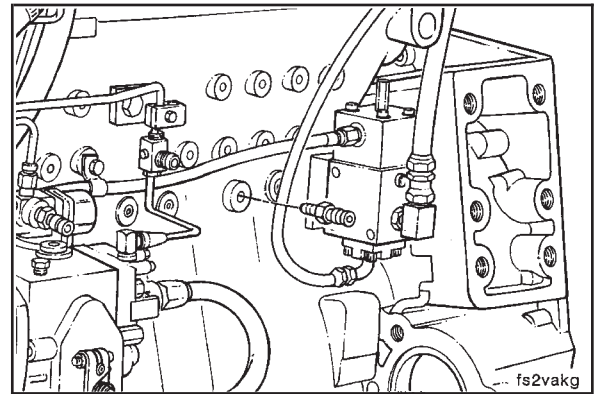
Use a tee fitting (3) to install a 1/8 inch male quick connect (4), Part No. 3377244, to the oil supply line (2).

Install a 3/8 inch shutoff valve (5) to the tee fitting. Connect the opposite end of the 3/8 inch shutoff valve to the rocker housing fitting (6).

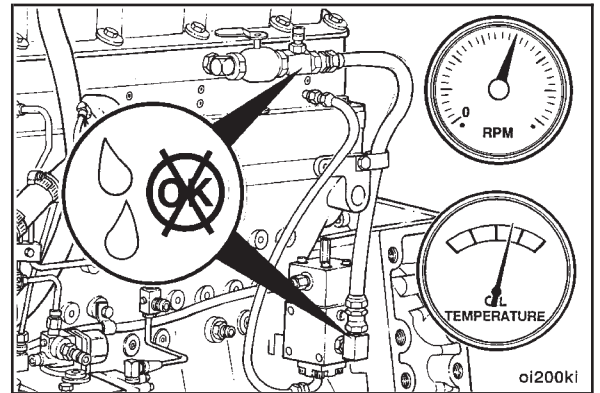
NOTE: The tee fitting and shutoff valve **must** be installed as shown to conduct the test correctly.

M11 Series
Section 6 - Injectors and Fuel Lines - Group 06

Install a 1/8 inch male quick connect, Part No. 3377244, to the main oil rifle.

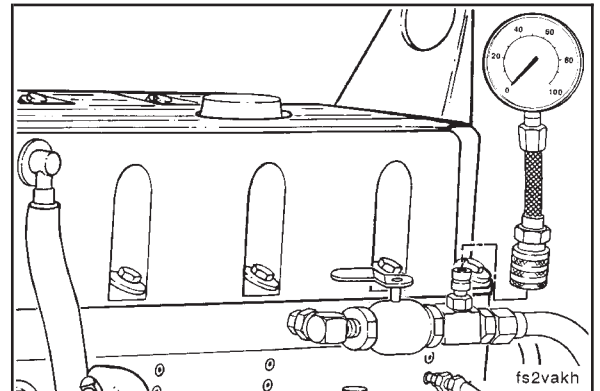


Operate the engine and check for leaks.



Install a 0–690 kPa [0–100 psi] pressure gauge, Part No. 3375388, to the quick connect fitting at the STC oil manifold connection.

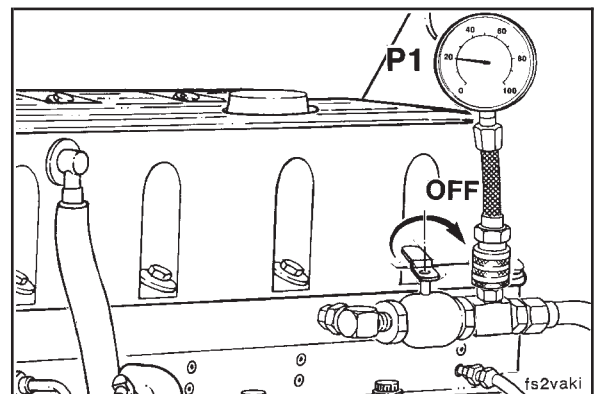
NOTE: Use one pressure gauge to make all of the pressure checks in this procedure. This will help to eliminate gauge to gauge error when measuring the pressure differential from the oil rifle to the STC oil manifold.

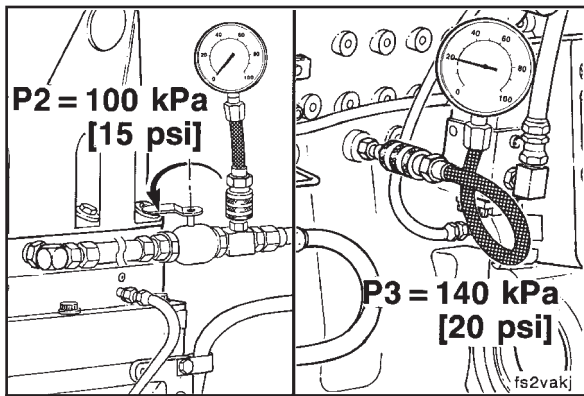


Idle the engine.

NOTE: All pressures taken **must** be taken at idle and while the coolant temperature is below 49°C [120°F].

Close the 3/8 inch shutoff valve at the STC oil manifold. Record the pressure (P1).





Open the 3/8 inch shutoff valve at the STC oil manifold. Record the pressure (P2).



Move the pressure gauge to the quick connect fitting at the main oil rifle and record the pressure (P3).



P3 **must** be at least 100 kPa [15 psi] when the engine coolant temperature is below 49°C [120°F]. If **not**, the main oil rifle pressure is inadequate. Refer to Troubleshooting Symptom: Lubricating Oil Pressure Low in Section TS.



If P1 is less than 100 kPa [15 psi], and P3 is at least 100 kPa [15 psi], a complete blockage exists between the oil rifle and the STC rocker housing connection. Check for blockage. Refer to Procedure 006-046-001.



If P1 is greater than or equal to 100 kPa [15 psi], and if P1 minus P2 is greater than 35 kPa [5 psi], partial blockage exists between the oil rifle and the STC rocker housing connector or leakage exists between the oil rifle and the STC rocker housing connection, or leakage exists between the STC rocker housing connection and injector(s).

Check for partial blockage or leakage in the system. Refer to Procedure 006-046.



If P1 is greater than or equal to 100 kPa [15 psi], and if P1 minus P2 is less than or equal to 35 kPa [5 psi], no problems exist between the oil rifle and the STC rocker housing connection. A possible leak or blockage exists between the STC rocker housing connection and injector(s).

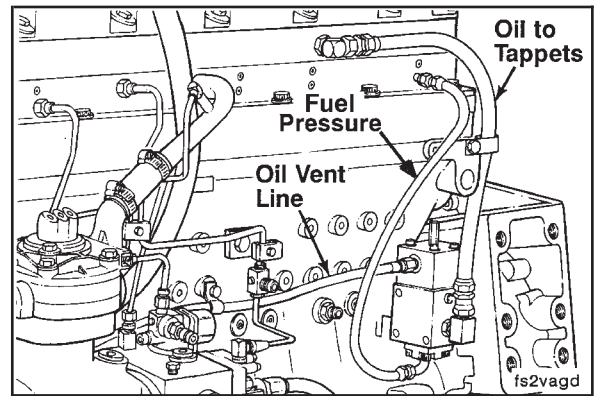
Check for blockage or leakage between the STC oil manifold and injector(s). Refer to the next step.

STC Oil Delivery System Blockage (006-046)

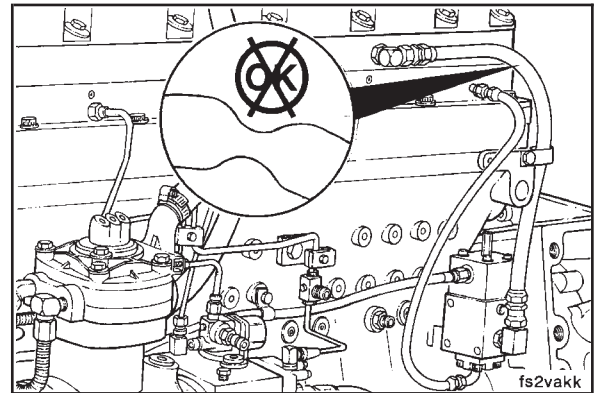
Initial Check (006-046-001)

Check the STC plumbing.

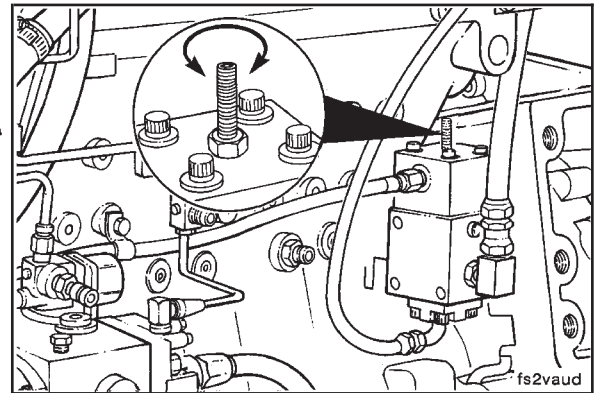
NOTE: Make sure the STC oil supply line is plumbed between the STC valve oil outlet fitting and the STC rocker housing connection.



Check for a collapsed or restricted oil supply line from the STC valve to the STC rocker housing connection.

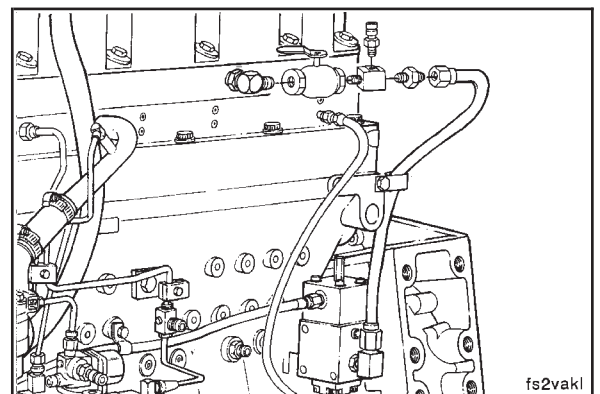


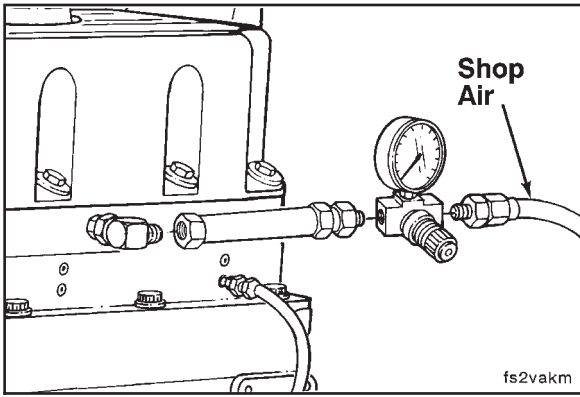
Check the STC valve calibration. Refer to Procedure 006-037-001.



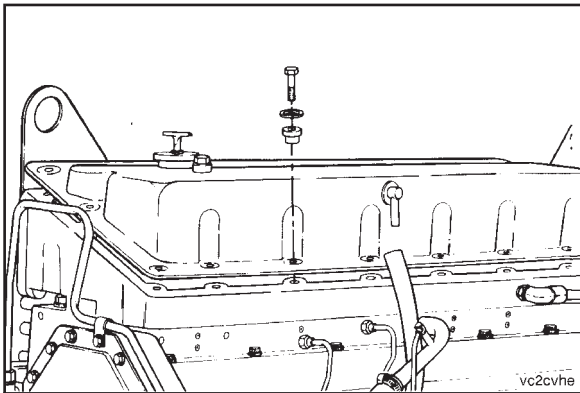
Leak Test (006-046-014)

Remove the shutoff valve from the STC rocker housing connecting.

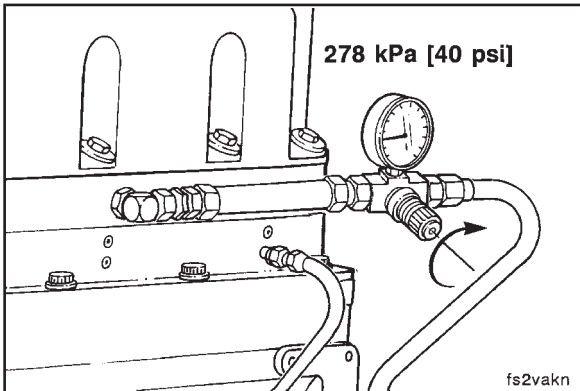




Install a shop air line regulator, Part No. ST-990-40, and a 0–1109 kPa [0–160 psi] pressure gauge, Part No. 3375275, to the STC rocker housing connection.

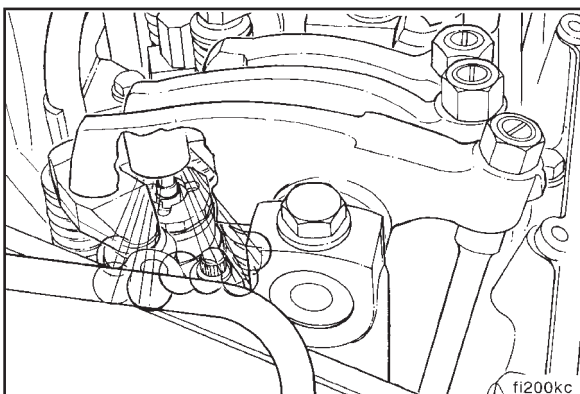


Remove the rocker lever cover assembly. Refer to Procedure 003-011-002.



Apply 278 kPa [40 psi] air pressure to the STC oil manifold to push oil out of the lines.

Lower the pressure to 69 kPa [10 psi].



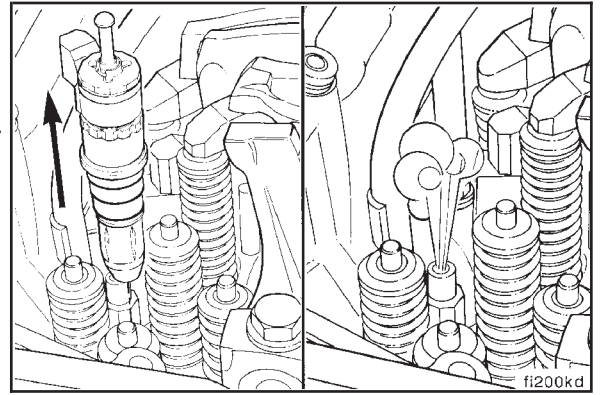
Air will leak around each injector link.

If the air leakage around a link is excessive, check the injector overhead adjustment. Refer to Procedure 003-004-010.

If air does **not** leak around each injector tappet link, remove the injector. Refer to Procedure 006-026-002.

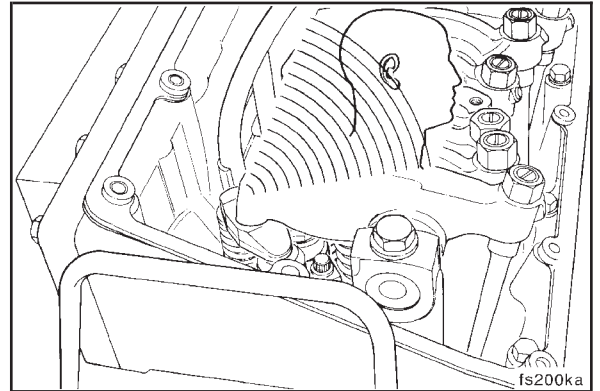
Once the injector is removed, air **must** leak at the STC oil supply tube.

If air does **not** leak at the oil supply tube, check the oil transfer tube and oil supply tube for restriction at the problem cylinder.



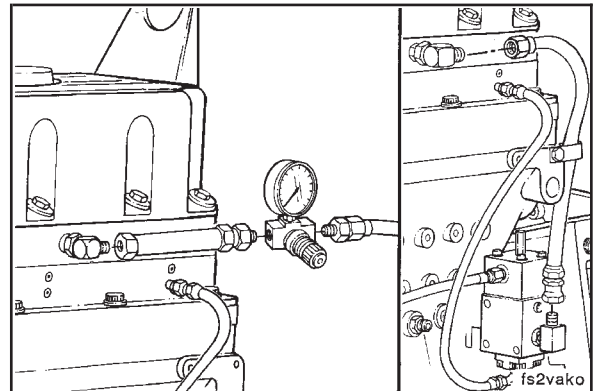
Listen for large air leaks at joints between the STC oil manifold and transfer tubes, or transfer tubes and injectors. This will indicate a missing or cut o-ring, or leaking oil plumbing.

Replace the defective part(s).



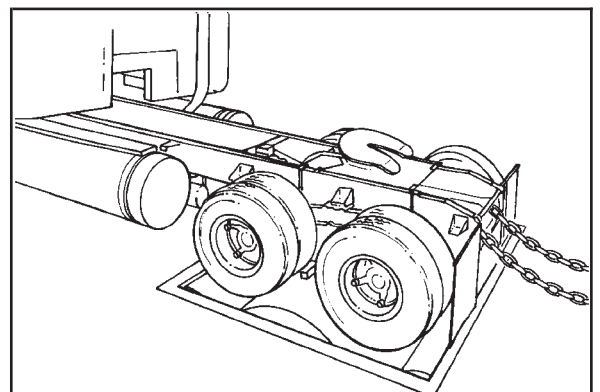
Remove the pressure gauge, tee fitting, and shutoff valve from the STC rocker housing connection.

Connect the oil supply line to the STC rocker housing connection.



AFC No Air Check (006-047) **Measure (006-047-010)**

NOTE: This procedure applies to STC engines only.
This no-air check **must** be made on a dynamometer.



1 Pump Code	X002-C
2 Date - Control Parts List	OCT82 0465
3 Test HP @ R.P.M.	285 - 295 @ 2200
4 Engine Fuel P.S.I.	160 - 178
37 AFC P.S.I. - Flow	71 - 262
38 AFC Spring	179826
39 AFC No Air Setting R.P.M.	1600
40 AFC No Air P.S.I. - Flow	58 - 230
41 Certified - Year - By	9999 CONS
42 Certified By	
43 Engine Model	10 LITRE
44 Notes	SEE NOTE (5)

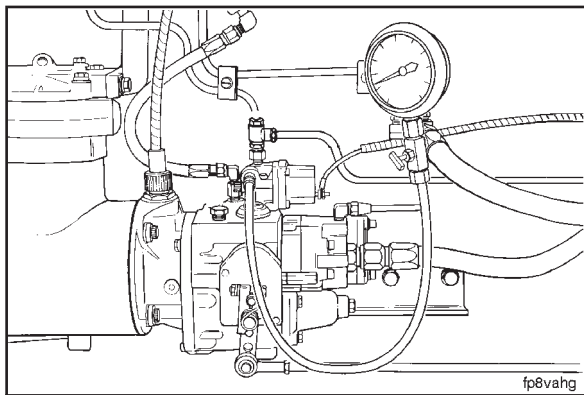
fc800ba



Check the fuel pump code AFC no-air fuel (rail) pressure at 1600 rpm.

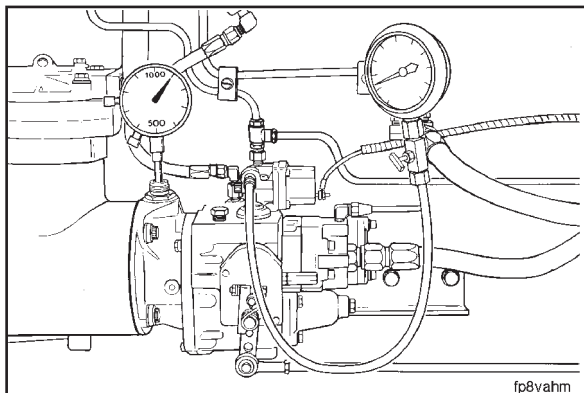


- The pressure on the engine must be within 48 kPa [7 psi] of the no-air pressure setting on the fuel pump test stand
- The fuel pump test stand no-air values are listed in the Fuel Pump Calibration Values Manual, Bulletin No. 3379352, under the fuel pump code number.

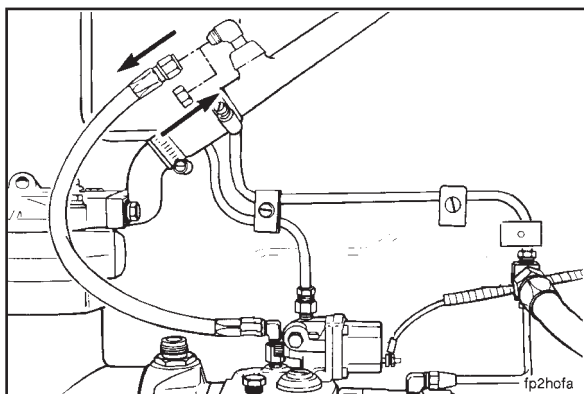


NOTE: Use line, Part No. ST-435-1, furnished with the gauge.

Install a rail pressure gauge, Part No. ST-435, to the shutoff valve.



Install a tachometer, Part No. 3375631 or 3377462.



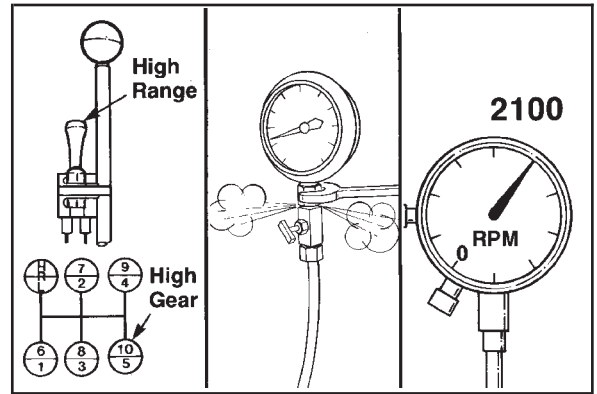
Remove the AFC air supply line from the air intake manifold or the compressor air tube.



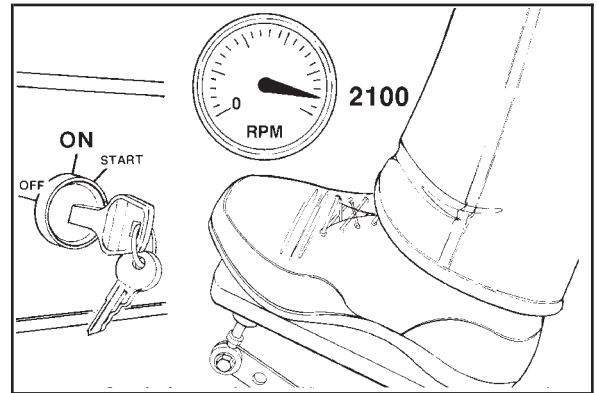
Install a plug or a cap in the intake manifold hole.

Operate the engine in the gear that will produce rated power and or speed.

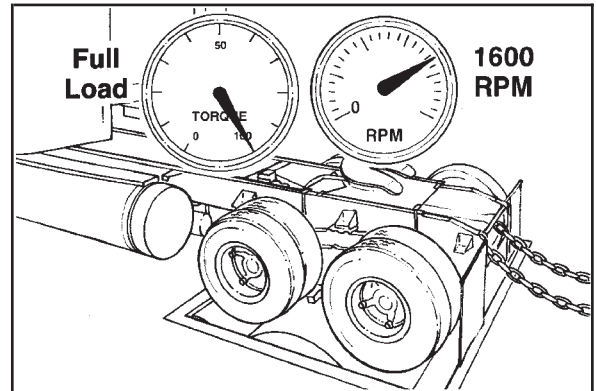
- Remove the air from the fuel and oil pressure gauge lines while the engine is warming to operating temperature



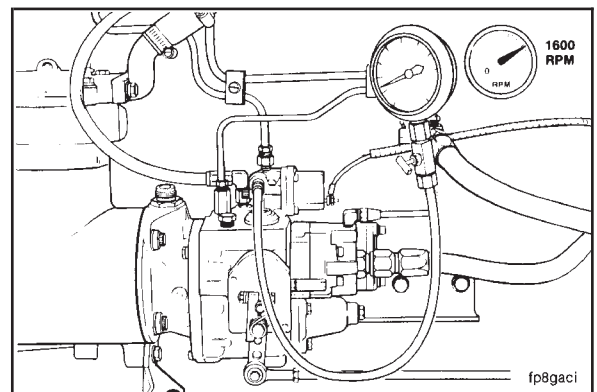
- Fully depress the accelerator or set the fuel pump throttle lever wide open

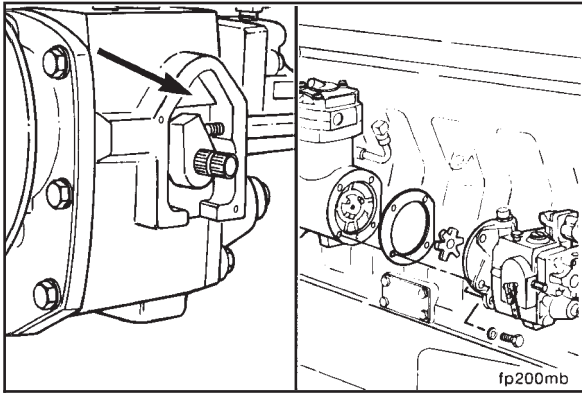


- Increase the load until the engine is at the specified rpm



Check the AFC no-air rail pressure.





If the no-air setting is **not** within the recheck specifications, remove the fuel pump and set the no-air value on a fuel pump calibration stand.

1 Pump Code	X002-C
2 Date - Control Parts List	OCT82 0465
3 Test HP. @ R.P.M.	285 - 295 @ 2200
4 Engine Fuel P.S.I.	160 - 178
37 A.F.C. P.S.I. - Flow	71 - 262
38 A.F.C. Spring	179826
39 A.F.C. No Air Setting R.P.M.	1600
40 A.F.C. No Air P.S.I. - Flow	58 - 230
41 Certified - Year - By	9999 CONS
42 Certified By	
43 Engine Model	10 LITRE
44 Notes	SEE NOTE (5)

fc800ba

⚠ CAUTION ⚠

It is illegal to adjust the fuel pump greater than the given specifications in the Fuel Pump Calibration Manual, Bulletin No. 3379352.

Section 7 - Lubricating Oil System - Group 07

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Lubricating Oil System - General Information

The use of quality engine lubricating oils combined with appropriate oil drain and filter change intervals is a critical factor in maintaining engine performance and durability.

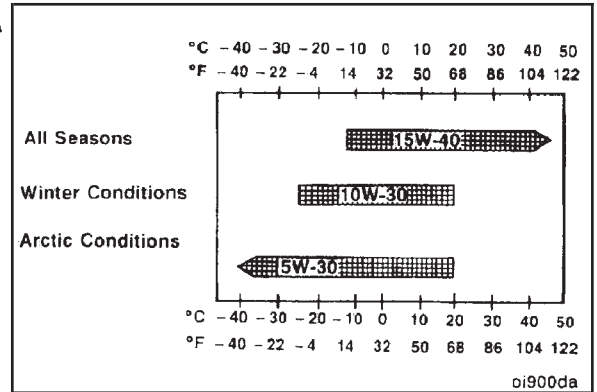
Cummins Engine Company, Inc. recommends the use of a high quality SAE 15W-40 heavy duty engine oil, such as Cummins Premium Blue, which meets the American Petroleum Institute (API) performance classification CG-4 or CF-4.

NOTE: In areas where CG-4 or CF-4 engine oils are **not** yet available, contact your Cummins Distributor for other oil recommendations.

A sulfated ash limit of 1.0 mass percent is suggested for optimum valve and piston deposit, and oil consumption control. The sulfated ash **must not** exceed 1.85 mass percent.

For further details and discussion of engine lubricating oils for Cummins engines, refer to Cummins Engine Oil Recommendations, Bulletin No. 3810340.

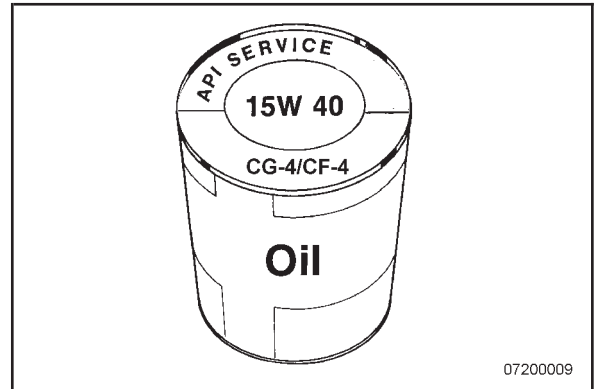
The use of low viscosity oils, such as 10W or 10W-30 can be used to aid in starting the engine and in providing sufficient oil flow at ambient temperatures below -5°C [23°F]. However, continuous use of low viscosity oils can decrease engine life due to wear. Refer to the accompanying chart.



The API service symbols are shown in the accompanying illustration. The upper half of the symbol displays the appropriate oil categories.

The lower half can contain words to describe oil energy conserving features.

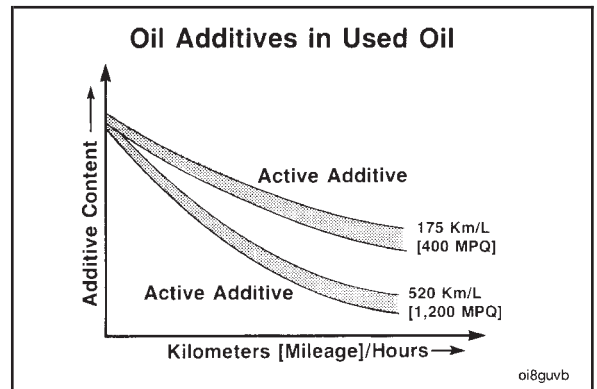
The center section identifies the SAE oil viscosity grade.



As the engine oil becomes contaminated, essential oil additives are depleted. Lubricating oils protect the engine as long as these additives are functioning properly. Progressive contamination of the oil between oil and filter change intervals is normal. The amount of contamination will vary depending on the operation of the engine, kilometers or miles on the oil, fuel consumed, and new oil added.

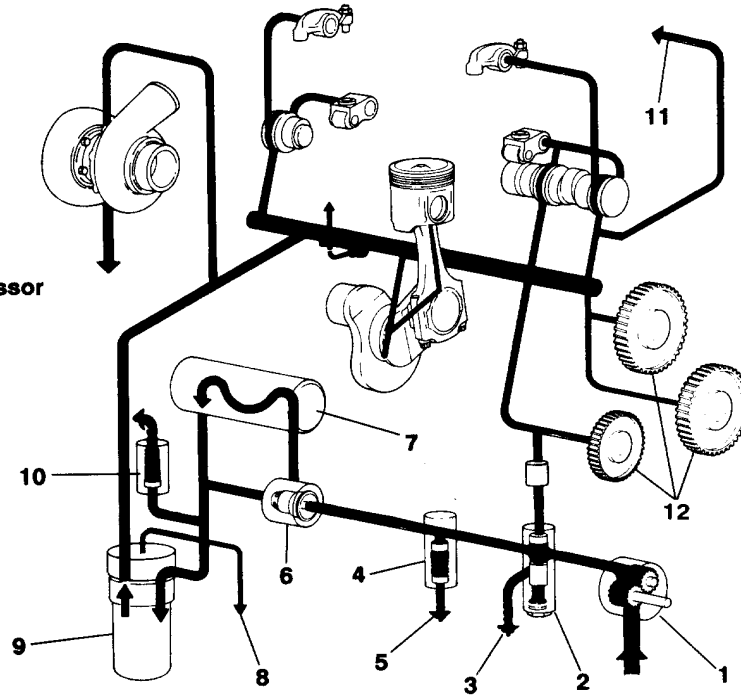
Extending oil and filter change intervals beyond the recommendations will decrease engine life due to factors such as: corrosion, deposits, and wear.

Refer to the oil drain chart in this section to determine which oil drain interval to use for your application.

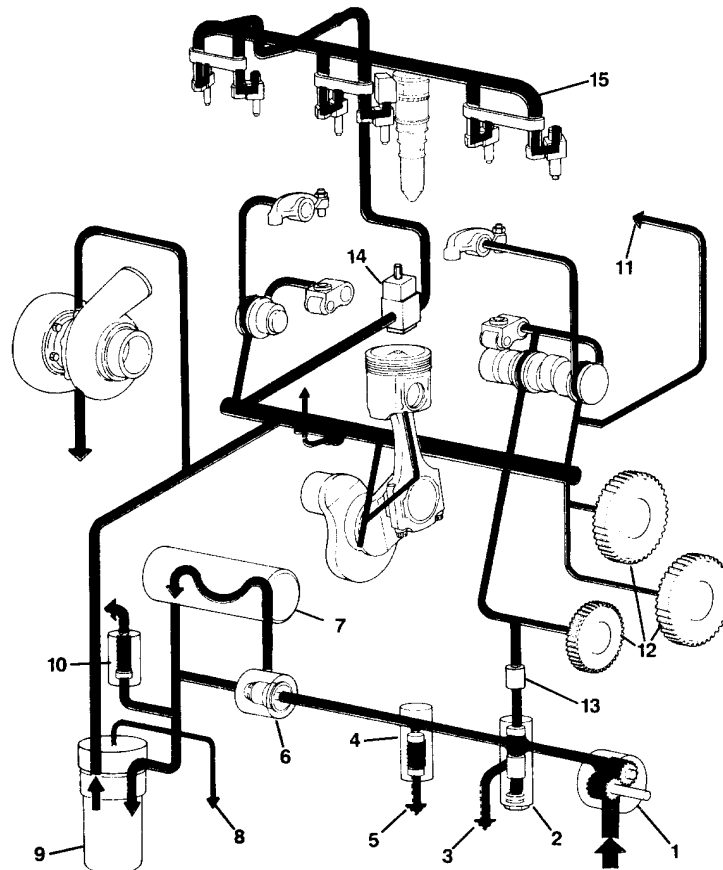


Flow Diagram, Lubricating Oil System

1. Oil Pump
2. Pressure Regulator Valve
3. Oil Return to Pan
4. High Pressure Relief Valve
5. Oil Return to Pan
6. Oil Thermostat
7. Oil Cooler
8. Bypass Filtered Oil Return
9. Combination Oil Filter
10. Filter Bypass Valve
11. Accessory Drive/Air Compressor
12. Idler Gears
13. Viscosity Sensor



1. Oil Pump
2. Pressure Regulator Valve
3. Oil Return to Pan
4. High Pressure Relief Valve
5. Oil Return to Pan
6. Oil Thermostat
7. Oil Cooler
8. By-pass Filtered Oil Return
9. Combination Oil Filter
10. Filter By-pass Valve
11. Accessory Drive/Air Compressor
12. Idler Gears
13. Viscosity Sensor
14. STC Control Valve
15. STC Oil Manifold



Specifications

Lubricating Oil System

Oil Pressure:

Low Idle (Minimum Allowable) 55 kPa [8 psi]
At 1200 rpm or Torque Peak (Minimum Allowable) 172 kPa [25 psi]

Oil Capacity of Standard Engine:

Combination Filter 2.6 liters [0.7 U.S. gal.]
Oil Pan (High-Low) 34 - 26.5 liters [9 - 7 U.S. gal.]

Cummins/Fleetguard® Filter Specifications

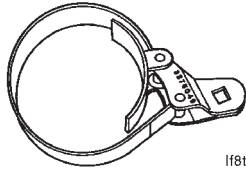
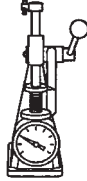
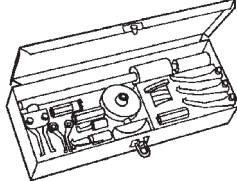
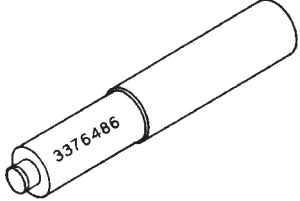
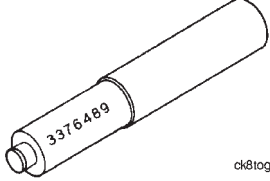
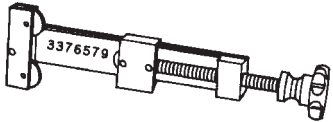
Lubricating Oil Filters

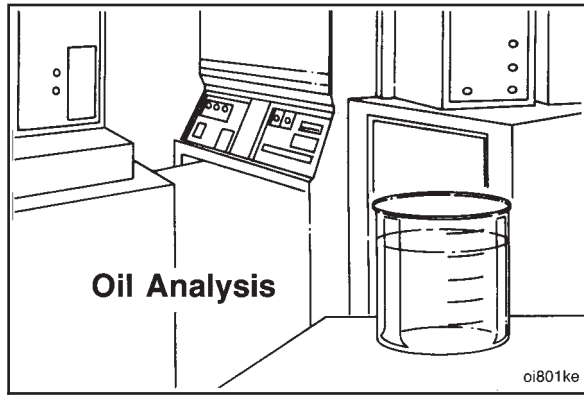
Cummins Engine Company, Inc. requires a lubricating oil filter(s) be used that meets the specifications given in the table below.

Lubricating Oil Filter Specifications			
Per Cummins Source Approval Method (SAM)	Combo (LF3000) 10,634	Full Flow (LF670) 10,509	Bypass (LF777) 10,547
Flow vs. Restriction Pressure differential at 40 GPM maximum	21 kPa [3 psi]	21 kPa [3 psi]	N/A
Element Collapse Pressure differential	1034 kPa [150 psi]	1034 kPa [150 psi]	1034 kPa [150 psi]
Partical Retention Absolute retention, percent of 40 micrometre and above, minimum	N/A	100%	N/A
Percent retention of 20 to 30 micrometre	N/A	95 %	N/A
Hydrostatic Pressure Pressure, mimumum	1724 kPa [250 psi]	1724 kPa [250 psi]	1724 kPa [250 psi]

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
3375049	Oil Filter Wrench Used to remove and install the lubricating oil filters.	 lf8togb
3375182	Spring Compression Tester Measures spring force at a given spring height.	 kn8togs
3375784	Light Duty Puller Kit Used to remove the high oil pressure regulator retainer plug.	 ck8togi
3376486	Regulator Valve Seat Driver Used to install the high oil pressure seat in the cylinder block.	 3376486
3376489	Retainer Plug Driver Used to install the high oil pressure regulator retainer plug in the cylinder block.	 3376489
3376579	Tube Cutter Used to open the oil filter for filter element inspection.	 3376579



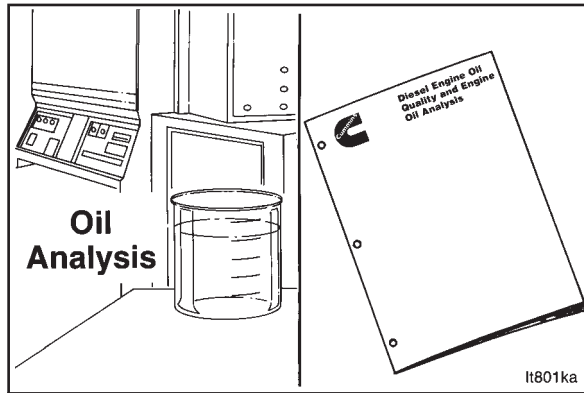
Lubricating Oil and Filters (007-002)

Inspect (007-002-062)

Analysis

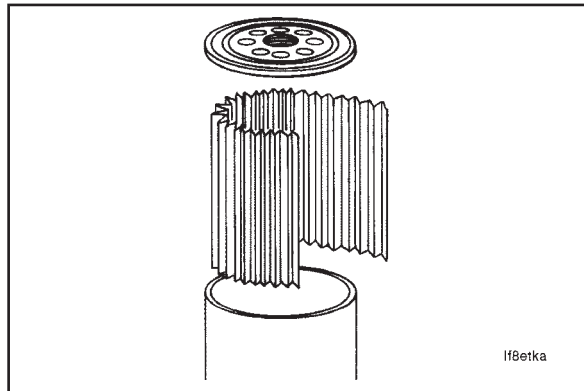
A used oil analysis can help diagnose internal damage and determine the cause such as:

- Intake air filter malfunction
- Coolant leaks
- Oil diluted with fuel
- Metal particles causing wear



For additional oil analysis information, refer to Diesel Engine Oil Quality and Engine Oil Analysis, Bulletin No. 3810232.

NOTE: Do **not** disassemble an engine for repair based only on the results of an oil analysis. Inspect the oil filters also. If the oil filter shows evidence of internal damage, find the source of the problem and repair the damage. Refer to the appropriate section(s) based on the following oil filter inspection.

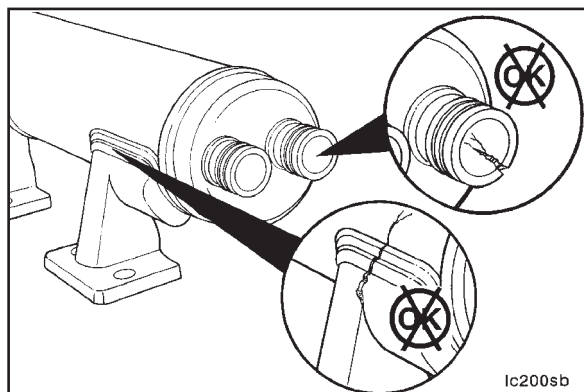


Oil Filter

Use tube cutter, Part No. 3376579, to open the combination oil filter.

Inspect the filter element for evidence of moisture or metal particles.

Metal	Possible Source
Copper	Bearings and Bushings
Chromium	Piston Rings
Iron	Cylinder Liners, Overhead Components
Lead	Bearing Overlay Material
Aluminum	Piston Wear or Scuffing



Lubricating Oil Cooler (007-003)

Remove (007-003-002)

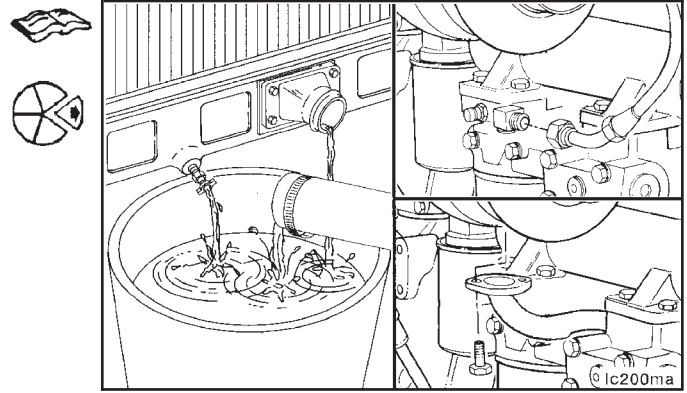
Do **not** attempt to repair a defective oil cooler. A defective oil cooler **must** be replaced.

Some applications can require turbocharger removal. Refer to Procedure 010-033-002.

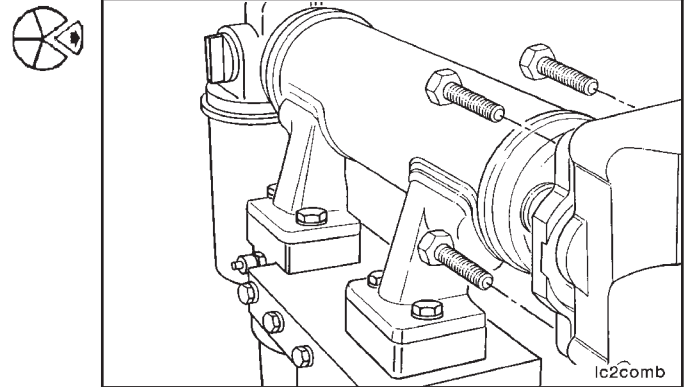
Drain the cooling system. Refer to Procedure 008-018-005.

Remove the turbocharger oil supply line from the lubricating oil filter head.

Remove the turbocharger drain line from the turbocharger. Remove the support bracket capscrew.

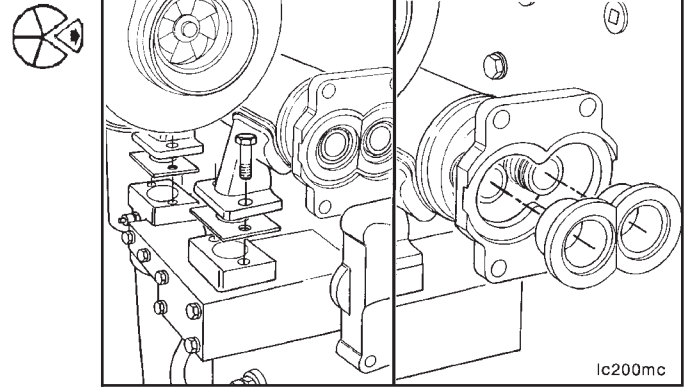


Remove the four oil cooler thermostat housing flange capscrews.



Remove the four oil cooler mounting capscrews, the oil cooler and gaskets.

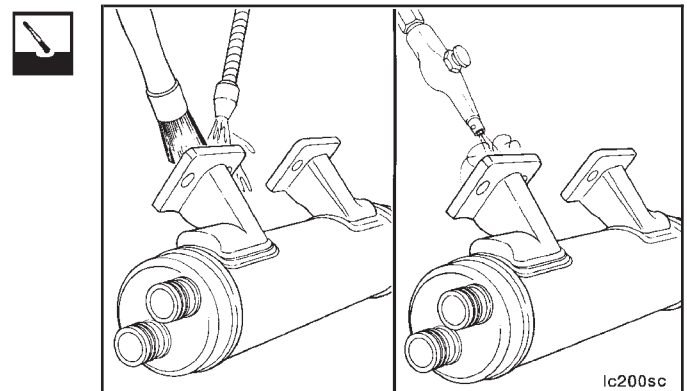
Remove the oil cooler water inlet and outlet tubes and the mounting flange.

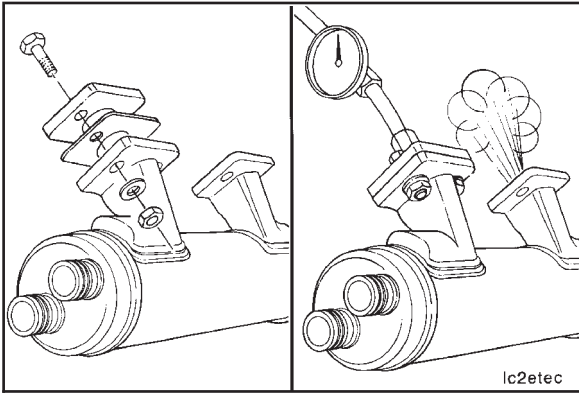


Clean (007-003-006)

Do not allow dirt to enter the oil passages when cleaning the oil cooler.

Use solvent to clean the oil cooler. Dry with compressed air.



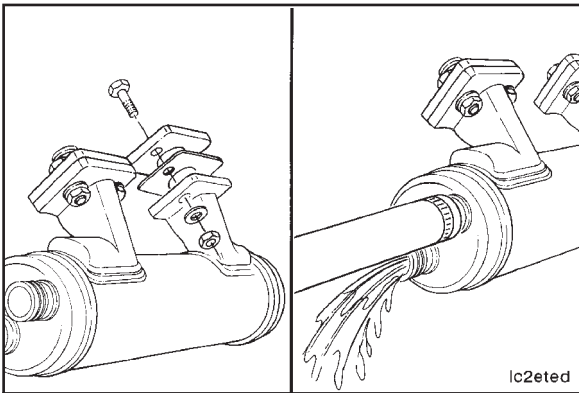


Use lubricating oil cooler pressure test kit, Part No. 3376861, to seal the oil passages.



Install pressure test plate, Part No. 3376889, on one of the two oil passage openings.

Attach an air pressure line to the test plate and blow the oil from inside the oil passages.

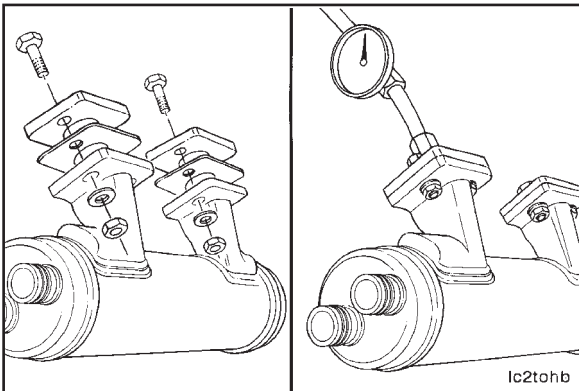


Install the other pressure test plate to seal the oil passage openings.



NOTE: Both oil passage openings **must** be sealed before cleaning the water core of the oil cooler.

Use a water system cleaner, attached to the water outlet side of the housing, to clean the water core.



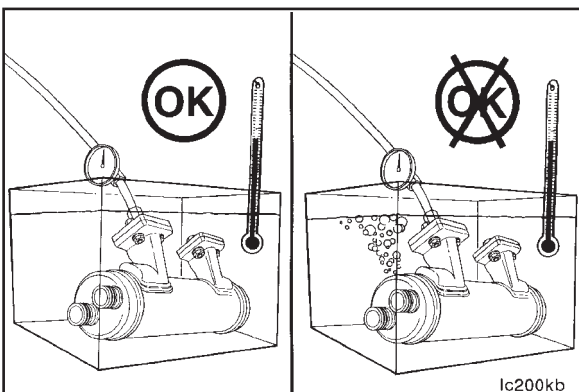
Pressure Test (007-003-013)

Install the two test plates and gaskets from lubricating oil cooler pressure test kit, Part No. 3376861, to the oil passage openings of the oil cooler housing.



Install a regulated air pressure line to test plate, Part No. 3376889, and apply air pressure.

Air Pressure 414 kPa [60 psi]



Install the oil cooler in a tank of heated water and inspect for leaks.

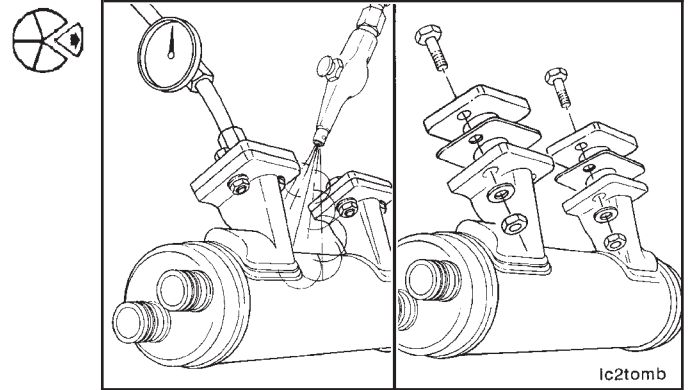


Temperature 82 °C [180 °F]

If leaks are found, the oil cooler **must** be replaced.



Remove the oil cooler from the water tank.
Dry the oil cooler with compressed air.
Remove the pressure test equipment.

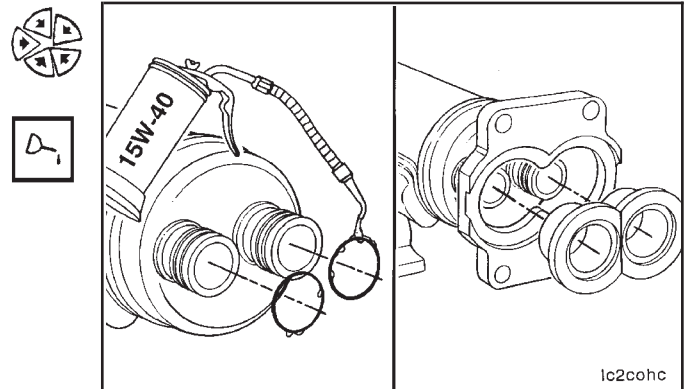


Install (007-003-026)

Install two new o-rings on the oil cooler water inlet and outlet transfer tubes.

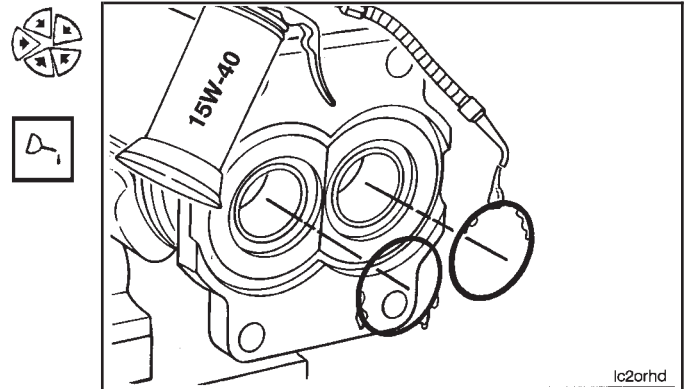
Lubricate the o-rings with clean 15W-40 engine oil.

While holding the mounting flange in place, install both transfer tubes into the oil cooler as far as possible. The straight sides of the transfer tube flanges **must** face each other when installed.



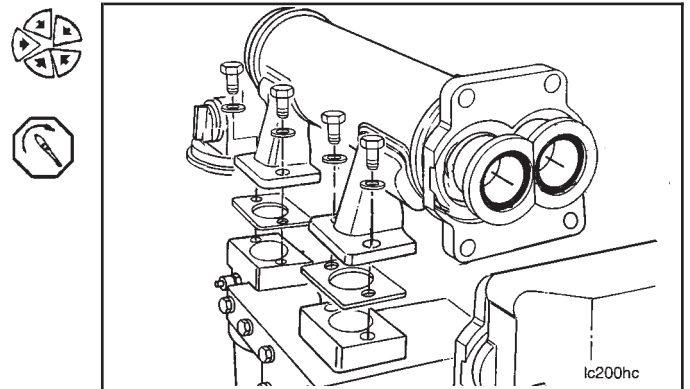
Install two new o-rings on the ends of the oil cooler water transfer tubes.

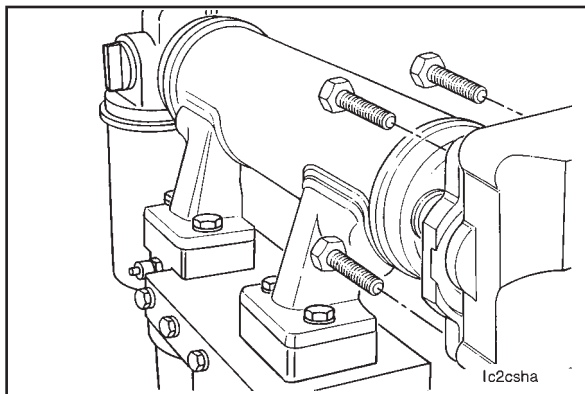
Lubricate the o-rings with clean 15W-40 engine oil.



Install two new gaskets on the lubricating oil filter head.
Install the oil cooler on the engine and tighten the mounting capscrews.

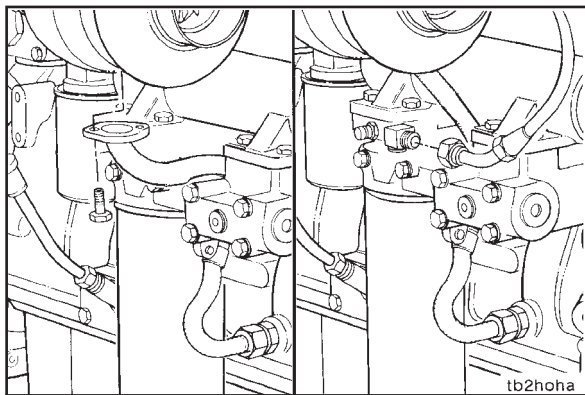
Torque Value: 47 N•m [35 ft-lb]





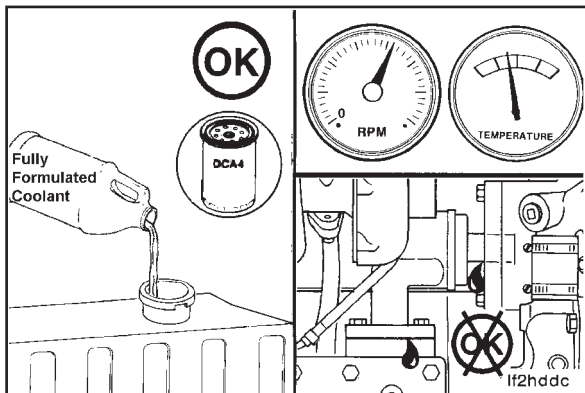
Install the four oil cooler thermostat mounting flange capscrews. Tighten the capscrews alternately and evenly.

Torque Value: 47 N•m [35 ft-lb]



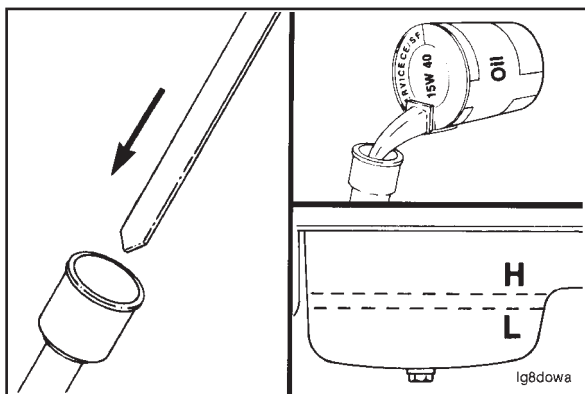
Install the turbocharger drain line and support bracket.

Install the turbocharger oil supply line to the lubricating oil filter head.



Fill the cooling system. Refer to Procedure 008-018-028.

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



Lubricating Oil Dipstick (007-009) Calibrate (007-009-030)



NOTE: This procedure **must** begin with the oil pan drained.

Install the dipstick in the dipstick tube housing.

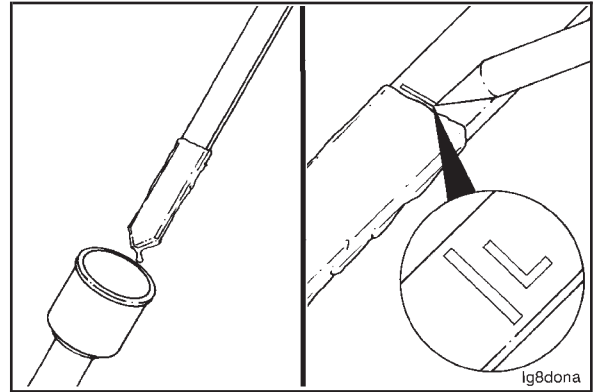
Use the correct volume of clean 15W-40 oil to fill the oil pan to the specified "low" oil level. Refer to Lubricating Oil System - Specifications in this section for the correct engine oil capacity for your application.

▲ CAUTION ▲

Use care when marking the dipstick, or the dipstick will break if the scribe mark is too deep.

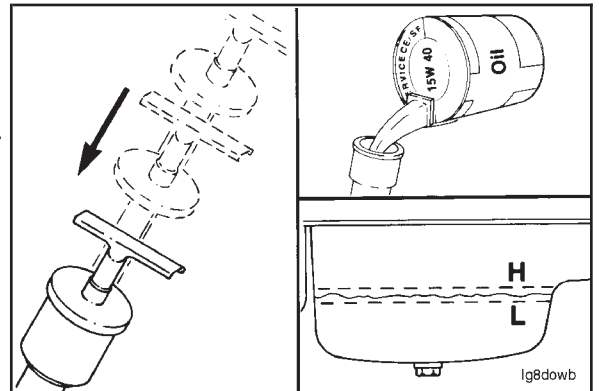
Remove the dipstick and scribe a mark across the stick at the oil level. Label the mark with an "L" to indicate the "low" oil level.

If a new blank dipstick is being used, cut the dipstick off approximately 38 mm [1.5 inch] below the "low" oil level mark.

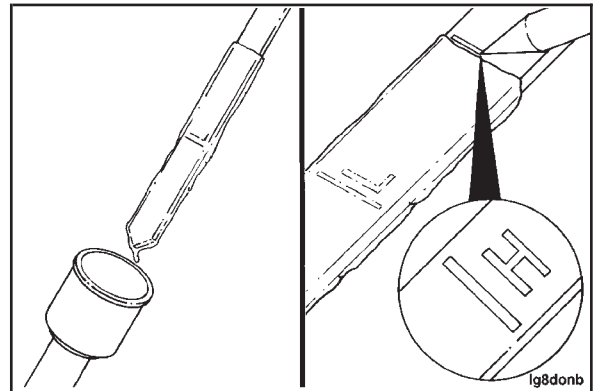


Wipe off the dipstick and install it in the dipstick tube housing.

Use the correct volume of oil to fill the oil pan to the specified "high" oil level. Refer to Lubricating Oil System Specifications in this section for engine oil capacity.



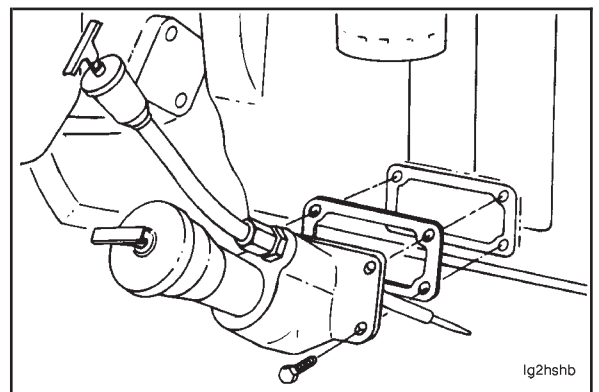
Remove the dipstick and scribe a mark across the stick at the oil level. Label the mark with a "H" to indicate the "high" oil level.

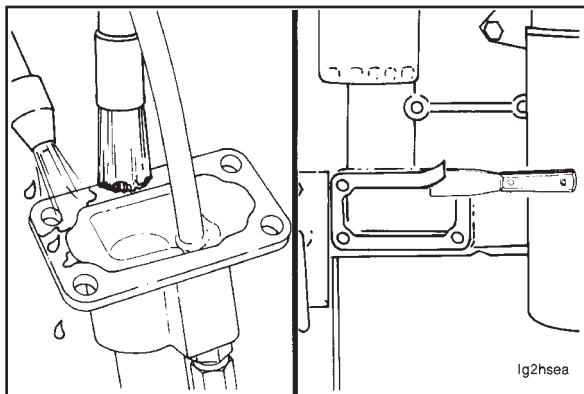


Lubricating Oil Dipstick Housing (007-010)

Remove (007-010-002)

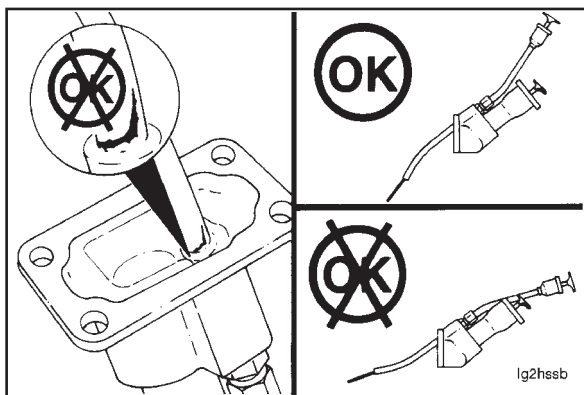
Remove the four capscrews and the housing.





Clean (007-010-006)

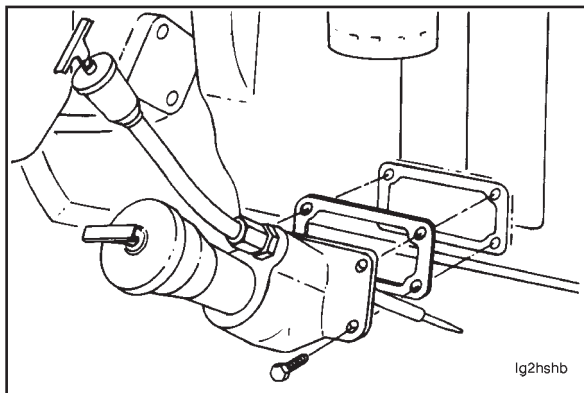
Clean the housing gasket surface.
Clean the cylinder block gasket surface.



Inspect for Reuse (007-010-007)

Inspect the dipstick guide tube.

If the guide tube is cracked, missing or **not** angled downward into the oil pan, replace the dipstick tube housing.



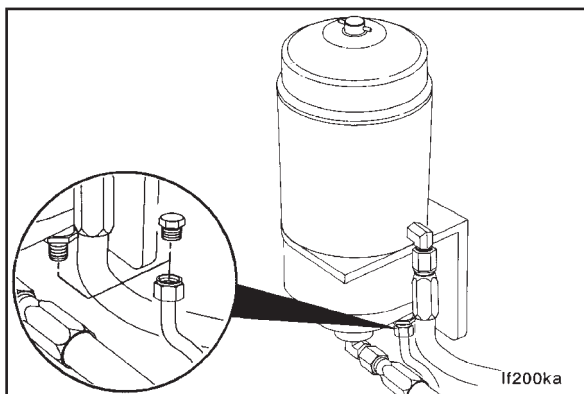
Install (007-010-026)

Install a new gasket and the dipstick tube housing.

Install the four capscrews.

Torque Value: 47 N•m [35 ft-lb]

Check the dipstick calibration. Refer to Procedure 007-009.



Lubricating Oil Filter (Canister-Type) (007-012)



Leak Test (007-012-014)

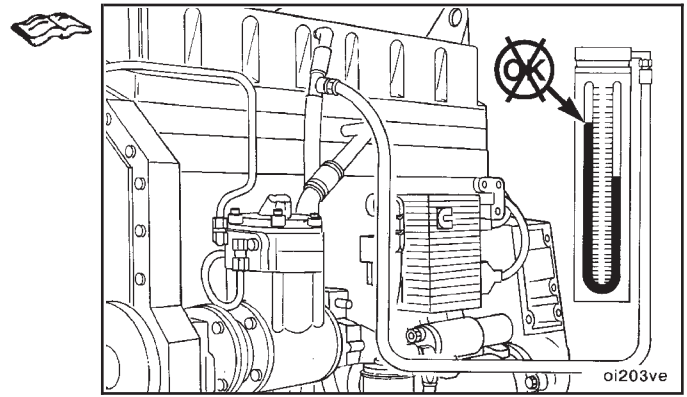
This procedure outlines the steps to isolate a centrifugal bypass filter when checking possible causes of high engine crankcase blowby.



Disconnect the air supply line from the centrifugal bypass filter assembly. Cap the end of the air supply line to prevent system air loss during test.

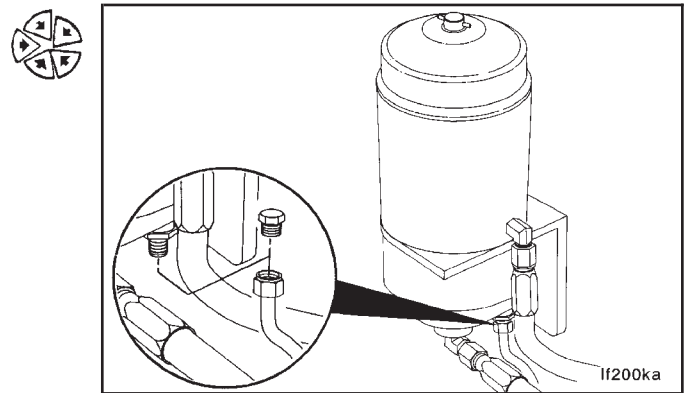
Operate the engine and check the engine blowby. Refer to Section 14.

If the blowby falls within the correct specifications, repair the centrifugal filter. Refer to the manufacturer's guidelines for the correct procedure.



Remove the cap from the air supply line.

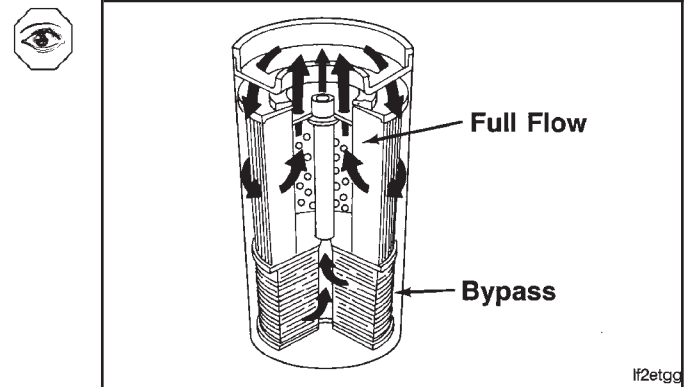
Connect the air supply line (1) to the centrifugal bypass filter assembly.



Lubricating Oil Filter (Spin-On) (007-013)

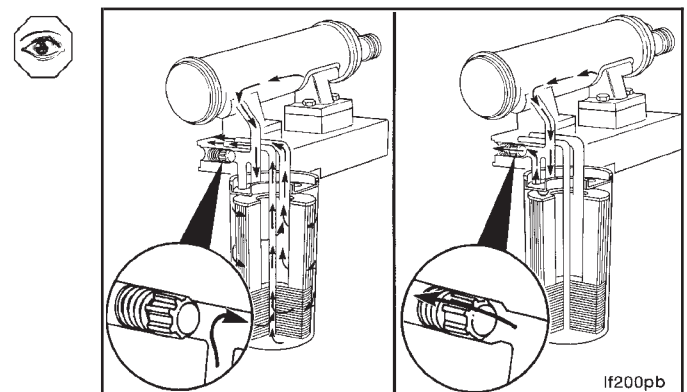
General Information

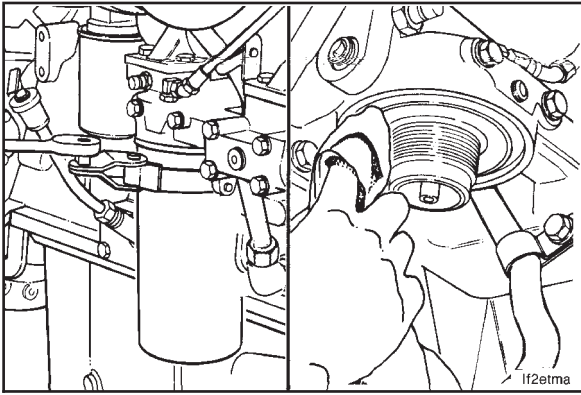
A combination oil filter is used on the M11 engine. The upper section of the filter contains the full flow filter element while the lower section contains the bypass element.



During normal engine operation, oil circulates through the full flow section of the combination filter and into the main oil rifle. If the full flow section becomes plugged to the point that a 655 kPa [95 psi] pressure difference exists across the filter, the bypass valve opens in the oil filter head and routes unfiltered oil to the main oil rifle.

NOTE: Engine oil pressure will **not** decrease as restriction in the full flow oil filter increases.



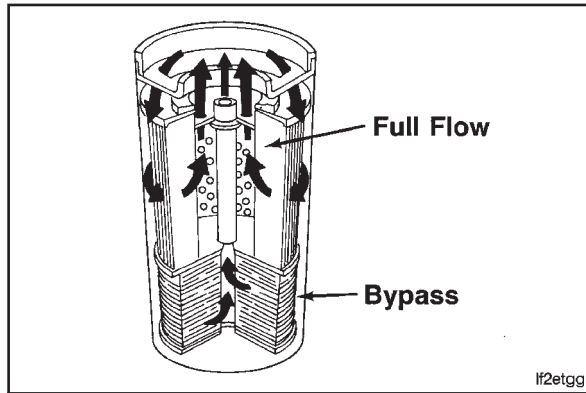


Remove (007-013-002)

Clean the area around the lubricating oil filter head.

Use oil filter wrench, Part No. 3375049, to remove the filter

Clean the gasket surface of the filter head. The o-ring can stick on the filter head. Make sure it is removed.



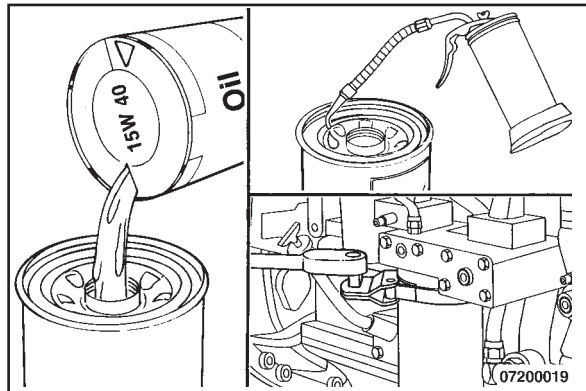
Install (007-013-026)

Use the correct oil filter for your engine. Cummins Engine Company, Inc. requires a lubricating oil filter(s) be used that meets the specifications given in the table following this text block per Cummins SAM 10,509/10,547/10,634.

Combination Lube Filter

Cummins Part No. 3318853

Fleetguard® Part No. LF-3000



⚠ CAUTION ⚠

The lack of lubrication during the delay until the filter is pumped full of oil at startup is harmful to the engine.

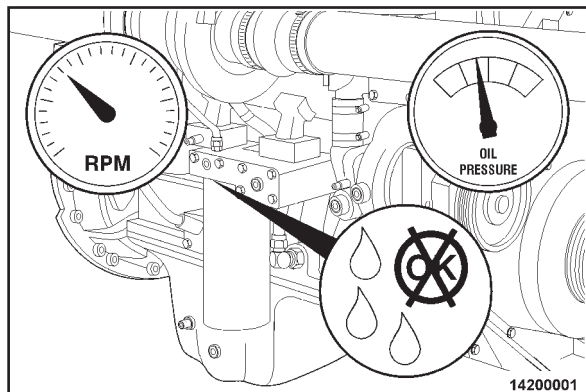
Fill the filter with clean 15W-40 oil. Apply a light film of oil to the gasket sealing surface before installing the new filter.

⚠ CAUTION ⚠

Mechanical overtightening of the filter can distort the threads or damage the filter element seal.

Install the filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

Use oil filter wrench, Part No. 3375049, to tighten the filter to the specifications supplied with the filter.



Operate the engine at idle speed for 3 minutes to inspect for leaks at the filter(s).

NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

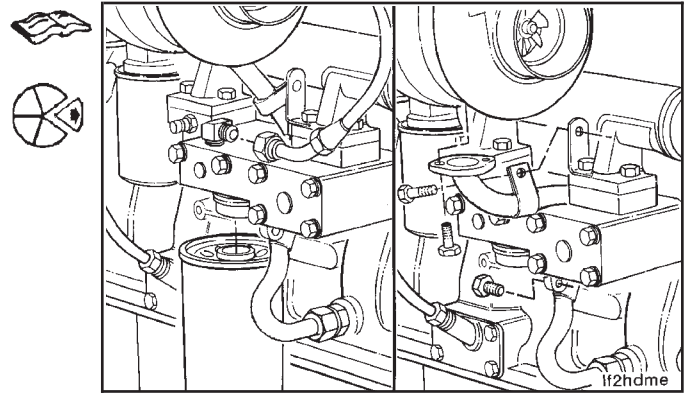
Lubricating Oil Filter Head (007-015)

Remove (007-015-002)

Remove the oil filter. Refer to Procedure 007-013-002.

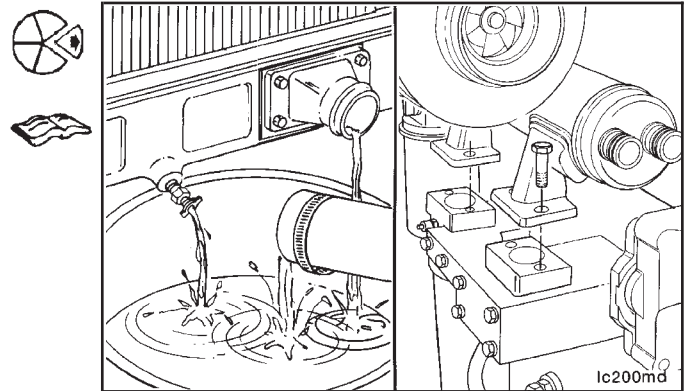
Remove the turbocharger oil supply line from the oil filter head.

Remove the turbocharger oil drain line from the turbocharger. Remove the two support brackets from the filter head.

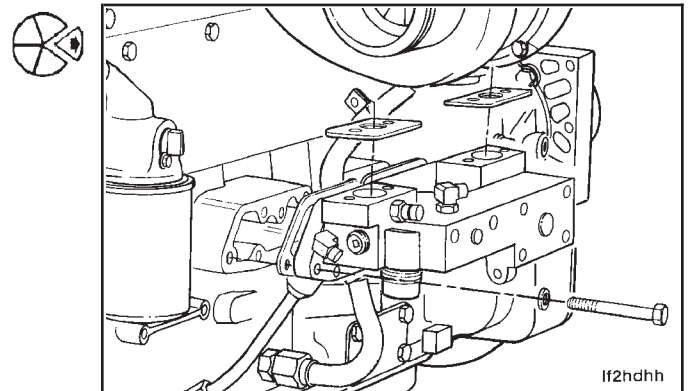


Drain the cooling system. Refer to Procedure 008-018-005.

Remove the lubricating oil cooler. Refer to Procedure 007-003-002.



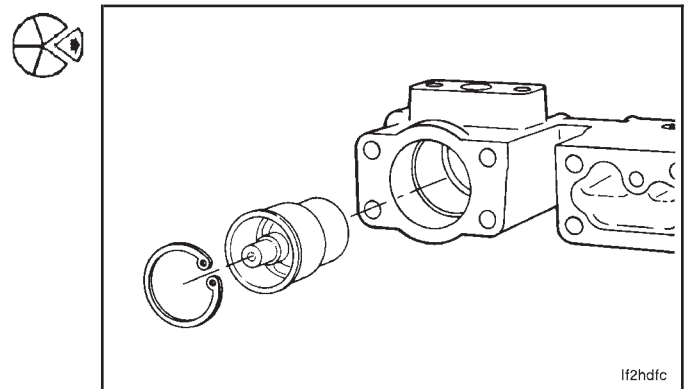
Remove the nine filter head capscrews and the filter head.
Remove the gaskets.

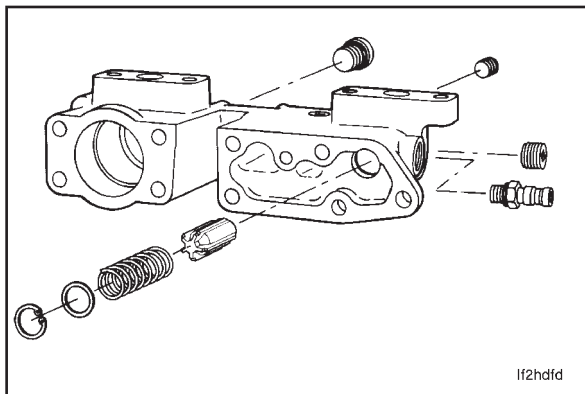


Disassemble (007-015-003)

Use snap ring pliers to remove the snap ring in the thermostat bore.

Remove the lubricating oil thermostat.





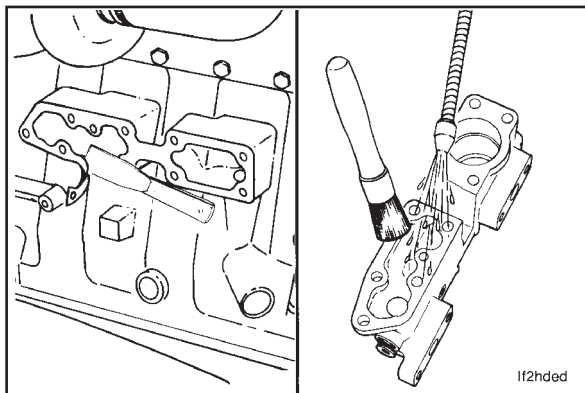
CAUTION

To avoid personal injury, use care while removing the bypass valve. The valve spring is under compression. Wear face and eye protection.

Remove the snap ring from the bypass valve bore.

Remove the washer, spring, and bypass valve.

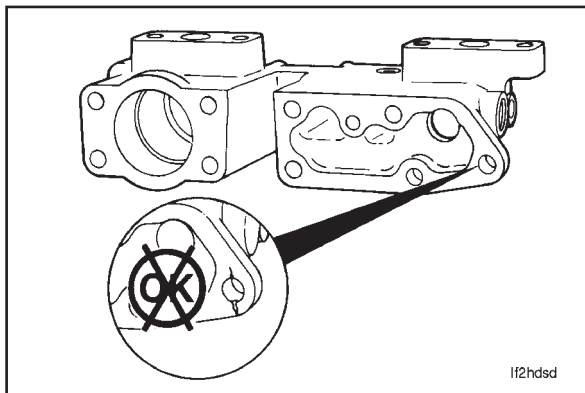
Remove the remaining plugs and fittings from the filter head.



Clean (007-015-006)

Clean the filter head and cylinder block gasket surfaces.

Use solvent to clean the filter head. Dry with compressed air.

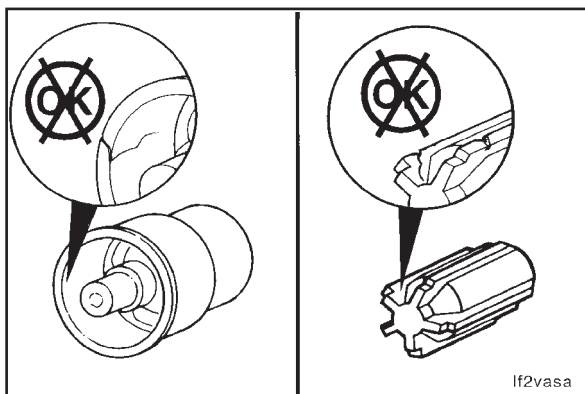


Inspect for Reuse (007-015-007)

Visually inspect for cracks or other damage.



Inspect the lubricating oil thermostat. Refer to Procedure 007-039.



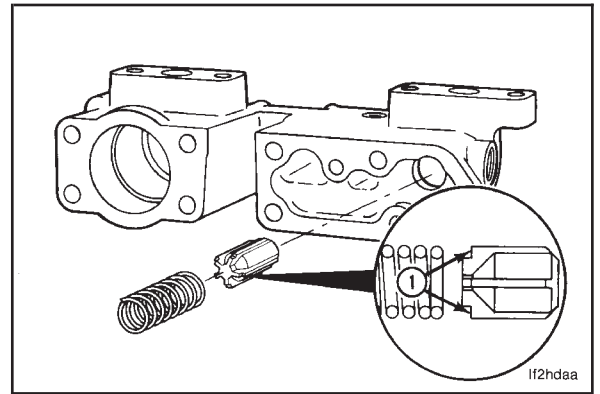
Visually inspect the thermostat and bypass valve for checks or other damage.

If the bypass valve is damaged, it **must** be replaced.

Assemble (007-015-025)

Install the bypass valve into the filter head. The notched end of the valve (1) **must** face the engine side of the filter head.

Insert the spring into the bore. Check to be sure the spring is properly located over the notched end of the valve (1).

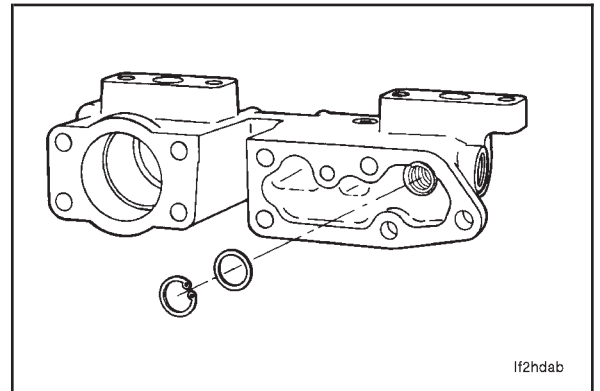


⚠ CAUTION ⚠

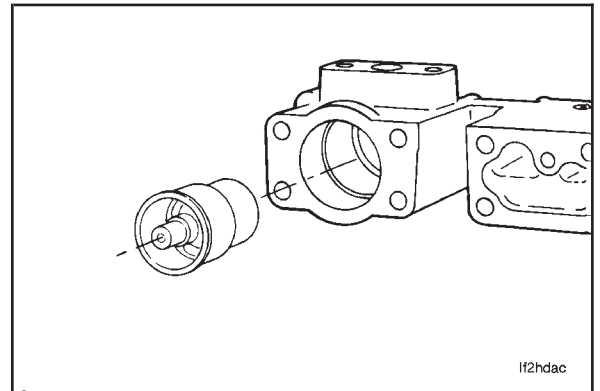
The valve spring must be compressed to install the snap ring. To avoid personal injury, wear face and eye protection

Place the washer on top of the spring.

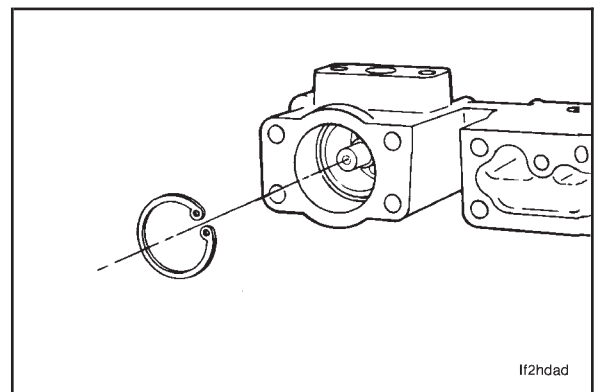
Using snap ring pliers, install the snap ring into the groove inside the bore.

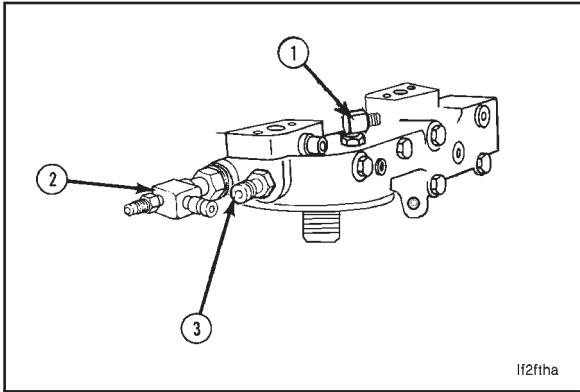


Insert the oil thermostat into the filter head. The beveled end of the thermostat goes in first.



Install the snap ring into the groove using snap ring pliers.





Install the following fittings into the filter head:

- Turbocharger oil supply fitting (1)

Torque Value: 12 N•m [105 in-lb]



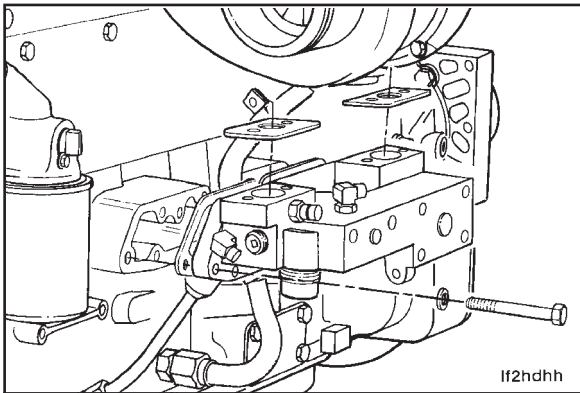
- Engine brake supply fitting (2)

Torque Value: 12 N•m [105 in-lb]

- Compuchek fitting (3)

- Remaining plugs

Torque Value: 25 N•m [20 ft-lb]



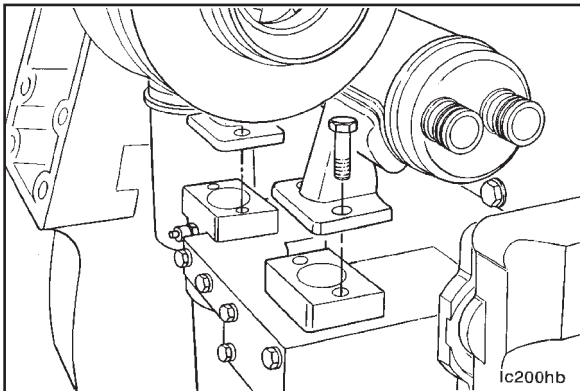
Install (007-015-026)

Use a new gasket and install the filter head to the cylinder block.

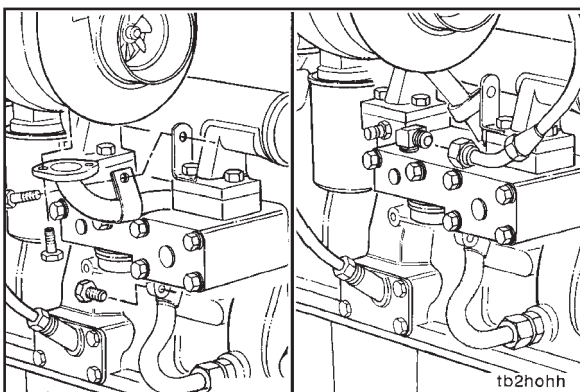


Install the nine cap screws and tighten.

Torque Value: 47 N•m [35 ft-lb]

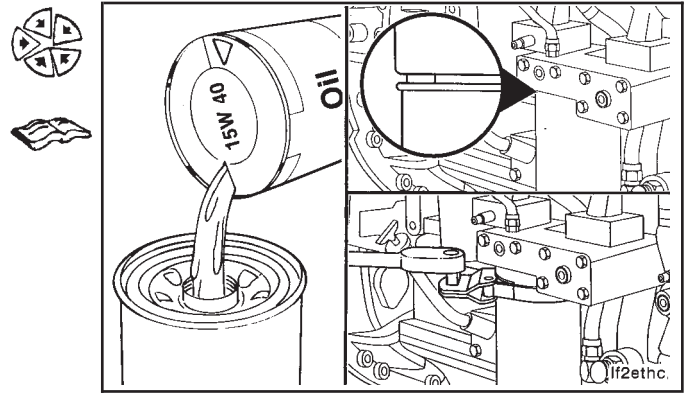


Install the lubricating oil cooler. Refer to Procedure 007-003-026.



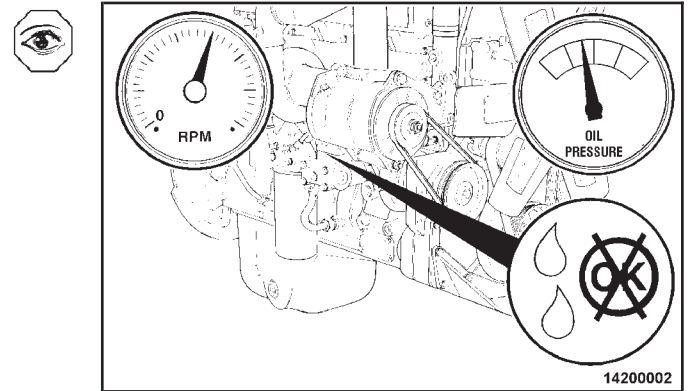
Install the turbocharger oil supply and drain lines and support brackets.

Install the lubricating oil filter. Refer to Procedure 007-013-026.



Operate the engine at idle speed for 3 minutes to inspect for leaks at the filter head.

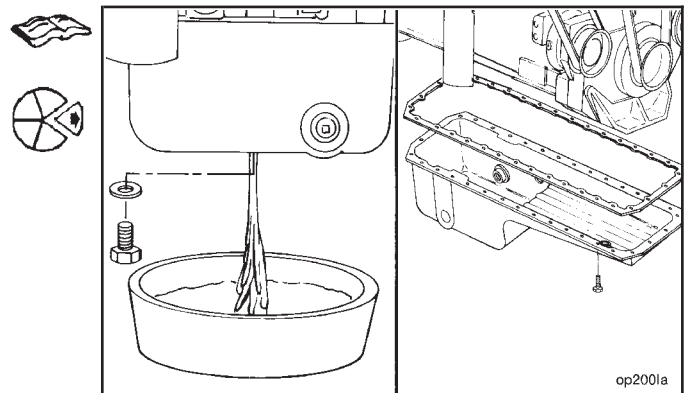
NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.



Lubricating Oil High Pressure Relief Valve (007-021)

Initial Check (007-021-001)

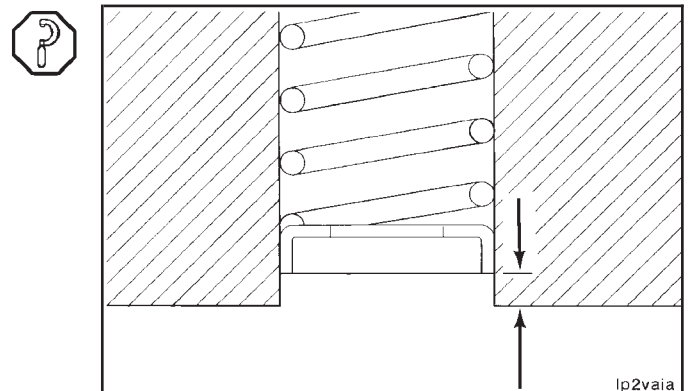
Drain the lubricating oil. Refer to Procedure 007-025-005.
Remove the oil pan. Refer to Procedure 007-025-002.

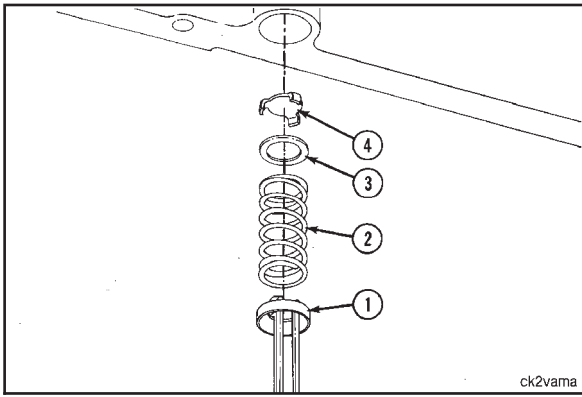


Measure the installed depth of the relief valve retainer cup plug.

Relief Valve Retainer Installed Depth		
mm		in
8.03	MIN	0.316
8.53	MAX	0.336

NOTE: If the plug depth is **not** within the specifications given, remove the high pressure regulator assembly and inspect the parts.





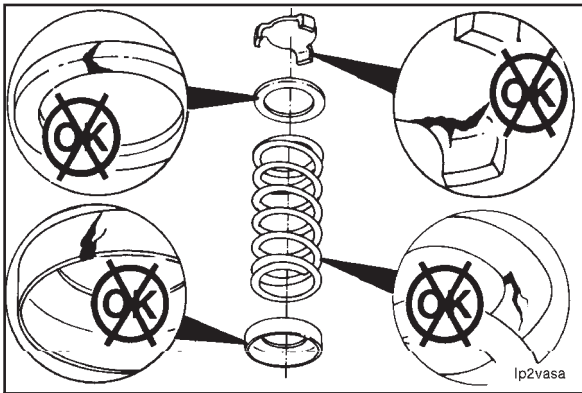
Remove (007-021-002)

WARNING

Use caution while removing the retainer plug (1). The pressure relief valve spring (2) is under compression. Personal injury can result. Wear face and eye protection.

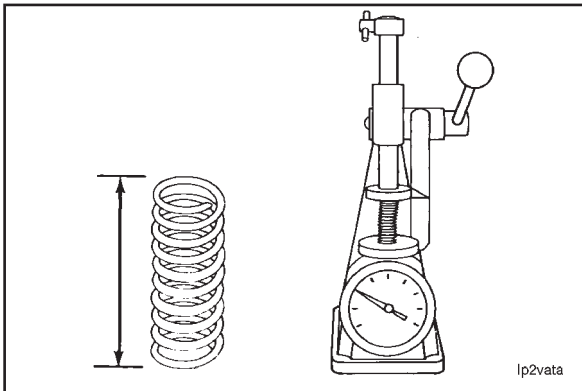
Use light duty puller kit, Part No. 3375784, or equivalent to remove the retainer plug (1).

Remove the pressure relief valve spring (2), washer (3), and valve disc (4).



Inspect for Reuse (007-021-007)

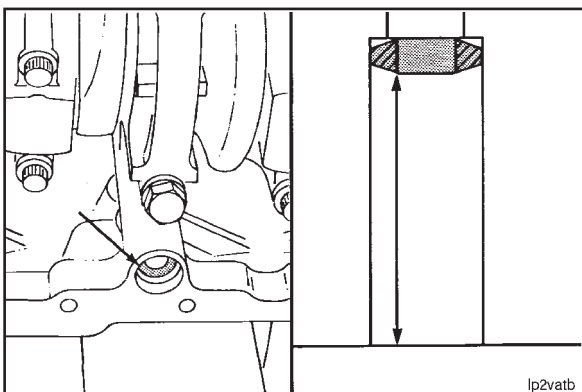
Visually inspect the parts for damage.



Use a spring compression tester, Part No. 3375182, to measure the relief valve spring tension.

Compress the spring to 29.1 mm [1.15 in] height. The force required to compress the spring **must** be:

Force Required to Compress Spring to 29.1 mm [1.15 in]		
N		lbf
263	MIN	59
322	MAX	72



Measure the relief valve seat depth in the cylinder block.



Relief Valve Seat Depth		
mm		in
62.62	MIN	2.465
63.62	MAX	2.505

If the relief valve seat is **not** at the specified depth, or is loose or **not** level in the cylinder block, the seat **must** be removed and inspected. Use puller kit, Part No. 3375784, to remove the seat.

If the seating surfaces are free of indentations, the seat can be reused. If the surfaces have indentations, the seat **must** be replaced. Use relief valve seat driver, Part No. 3376486, to install the seat.

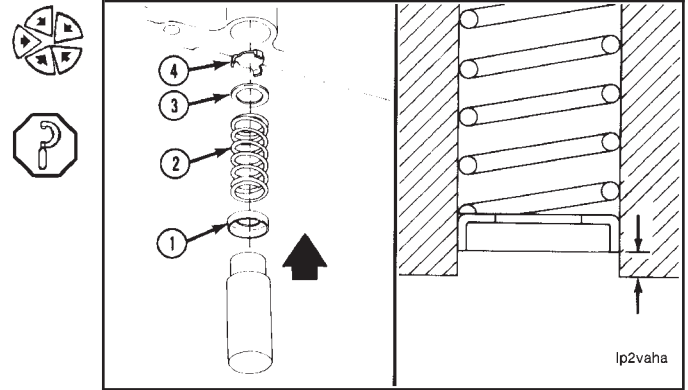
Install (007-021-026)

Install the valve disc (4), washer (3) and spring (2).

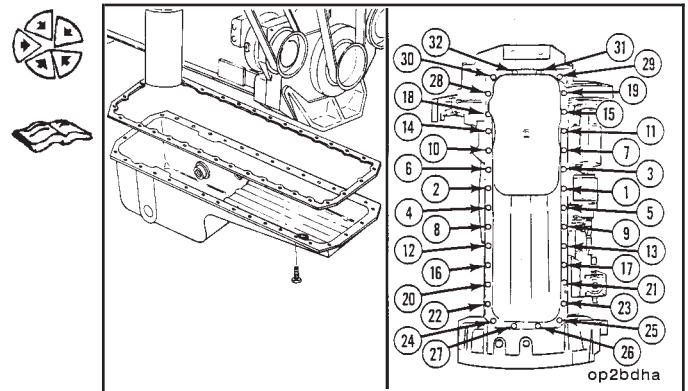
Use flat washers equal to 5 mm [0.197 in] with plug driver, Part No. 3376489, to install the new retainer cup plug (1).

Measure the retainer plug depth in the cylinder block.

Relief Valve Retainer Installed Depth		
mm		in
8.03	MIN	0.316
8.53	MAX	0.336



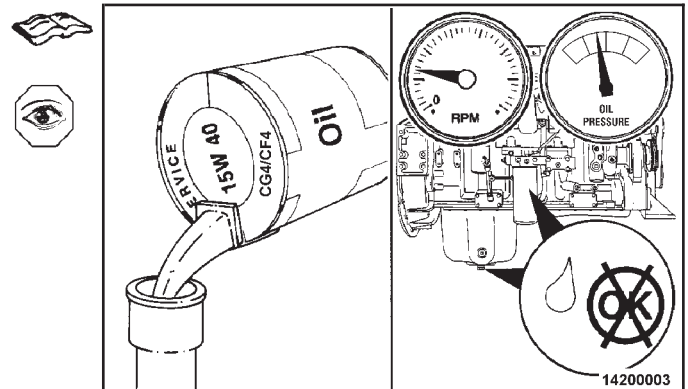
Install the oil pan. Refer to Procedure 007-025-026.



Fill the engine with clean 15W-40 oil. Refer to Procedure 007-025-028.

Operate the engine at idle speed for 3 minutes to inspect for leaks.

NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.



Lubricating Oil Leaks (007-024)

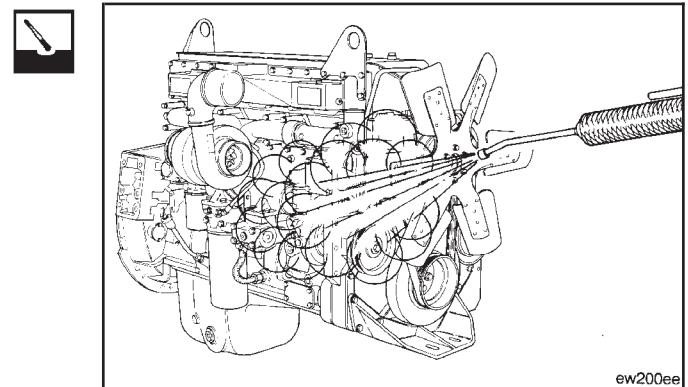
Maintenance Check (007-024-008)

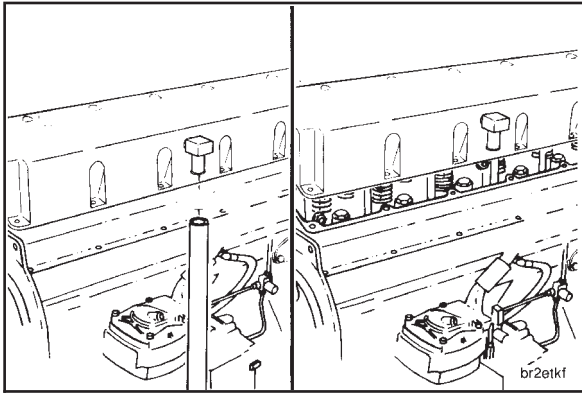
External



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

Use a steam cleaner or high pressure washer to clean the engine. Dry with compressed air.

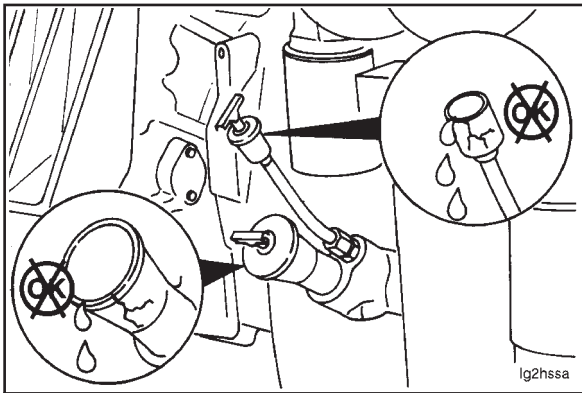




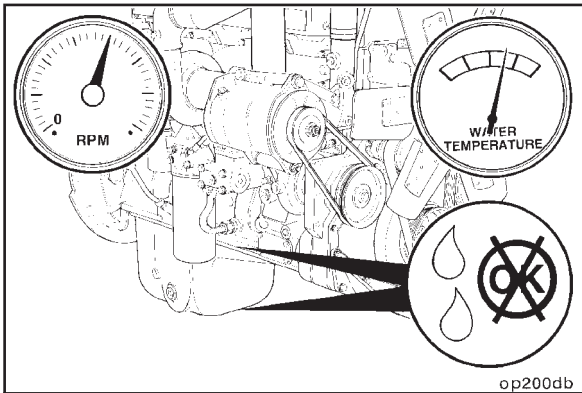
Visually inspect the internal crankcase breather, hose, and tube for restriction. Refer to Procedure 003-002-007.



NOTE: The rocker lever housing cover **must** be removed to inspect the internal engine crankcase breather.



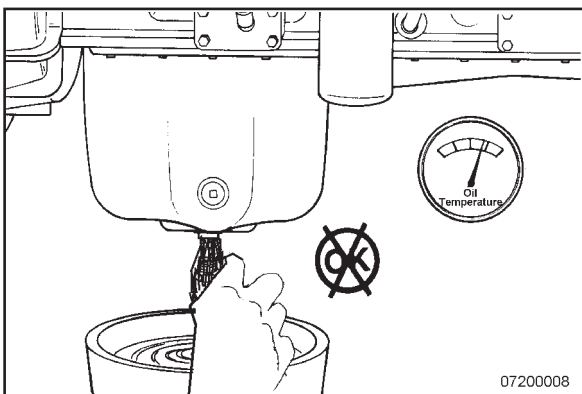
Check for a loose, damaged or missing oil dipstick tube, dipstick or oil filler cap.



Operate the engine to normal operating temperature, and inspect the exterior of the engine for leaking gaskets, seals, o-rings, pipe plugs or fittings.



NOTE: Before replacing any gaskets, check the capscrews to be sure they are tightened to the correct torque values. Refer to Section V for the specific component capscrew torque specifications.



Lubricating Oil Pan (007-025)

Drain (007-025-005)



WARNING

Some state and federal agencies in the United States of America have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.



WARNING

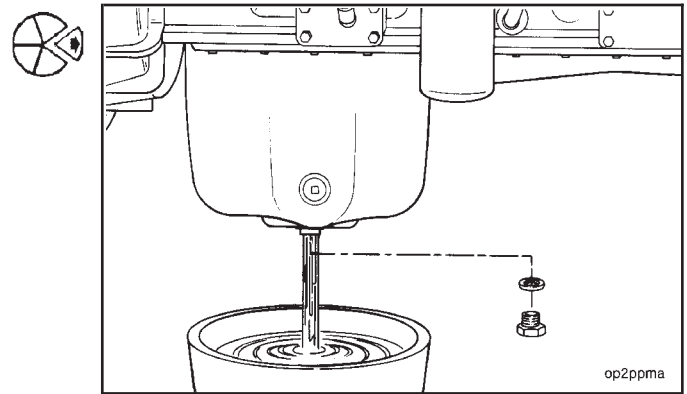
Avoid direct contact of hot oil with your skin. Hot oil can cause personal injury.

Operate the engine until the water temperature reaches 60°C [140°F]. Shut off the engine. Remove the oil drain plug from the bottom of the lubricating oil pan. Do **not** remove the plugs on either side of the oil pan to drain the oil. They will **not** allow the oil to drain completely.

NOTE: Fittings used in the bottom drain opening of the oil pan other than Cummins specified parts **must not** exceed the following size and weight limits:

Oil Drain Fitting Specs		
Length	63.50 mm	[2.500 in]
Diameter	41.28 mm	[1.625 in]
Weight	0.363 mm	[0.80 lbf]

Do **not** use fittings other than the Cummins supplied fitting in the side drain location.

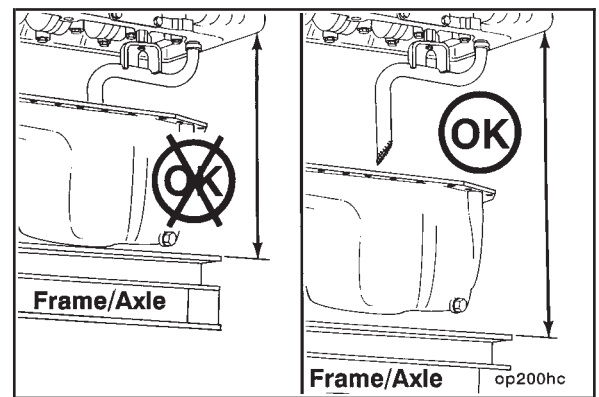


Remove (007-025-002)

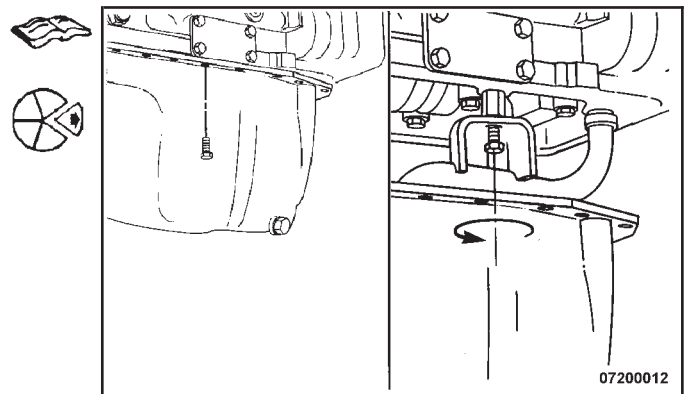
Front Sump Pan

Front sump oil pans have a block mounted suction tube which requires approximately 610 mm [24 in] clearance between the vehicle frame or axle and the cylinder block oil pan mounting flange to remove the oil pan.

If an application will **not** allow the oil pan to be lowered that much, the suction tube **must** be removed from the cylinder block before the oil pan can be removed from the chassis.

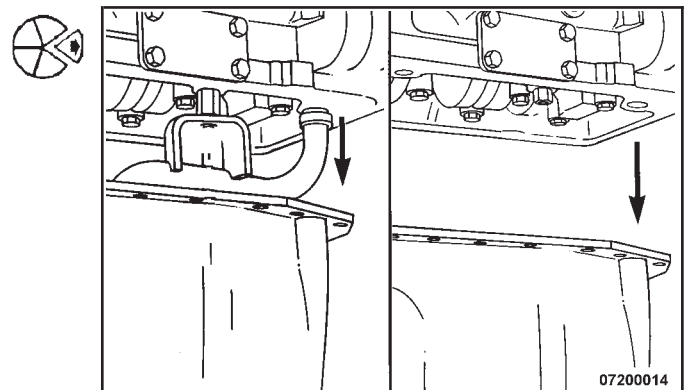


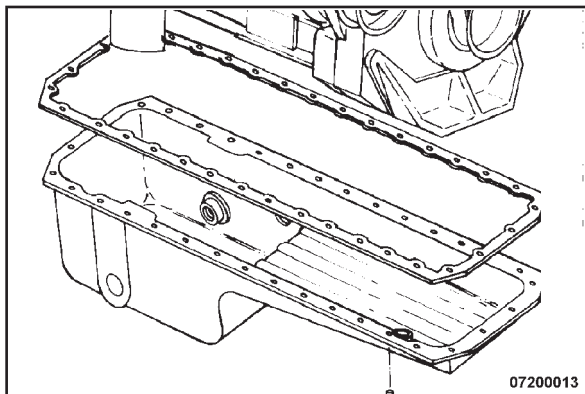
Remove the oil pan mounting capscrews. Lower the oil pan far enough to allow one hand to reach inside the engine and remove the suction tube mounting capscrew.



Remove the suction tube from the cylinder block and let it drop into the oil pan.

Remove the oil pan from the chassis.

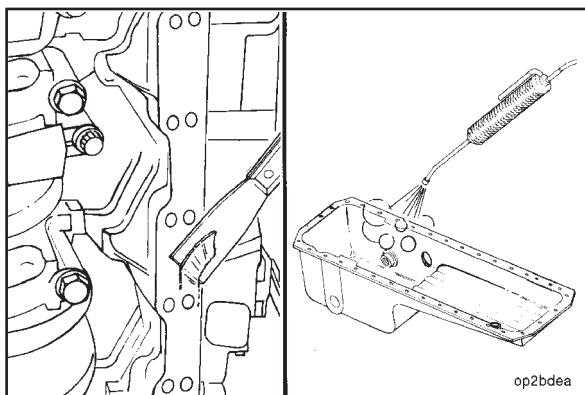




Rear Sump Pan

Remove the capscrews and the oil pan.

07200013

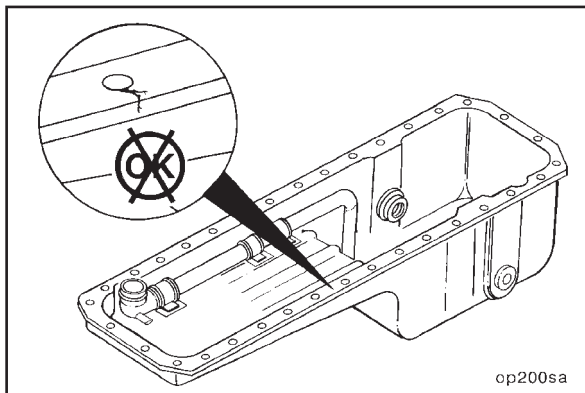


Clean (007-025-006)

Remove all gasket material from the cylinder block and oil pan surfaces.

Steam clean the oil pan and dry with compressed air.

op2bdea



Inspect for Reuse (007-025-007)

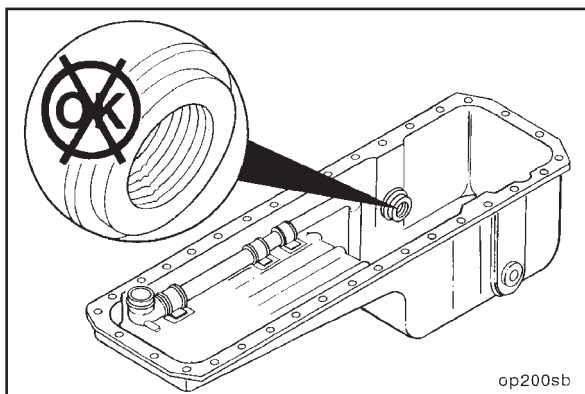
Inspect the oil pan, suction tube, and tube braces for cracks or damage.



NOTE: If cracks are found, replace the damaged part. Do not attempt to repair the oil pan by welding.

Inspect the oil transfer tube. Refer to Procedure 007-040.

op200sa



Visually inspect the threaded holes for damage. Damaged threads can be chased with the following taps.

Oil Pan Threaded Holes	
Thread Location	Tap Size
Temperature Gauge	3/8 in. NPTF
Oil Sump Heater	1-18 NS-3B
Oil Drain	1 in. NPTF

NOTE: If the threaded holes **cannot** be repaired with the taps listed above, the oil pan **must** be replaced.

op200sb

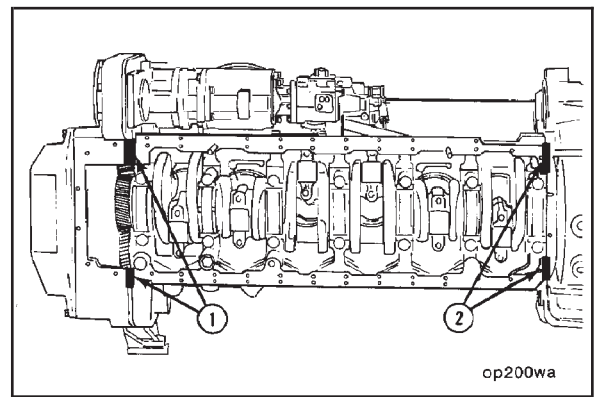
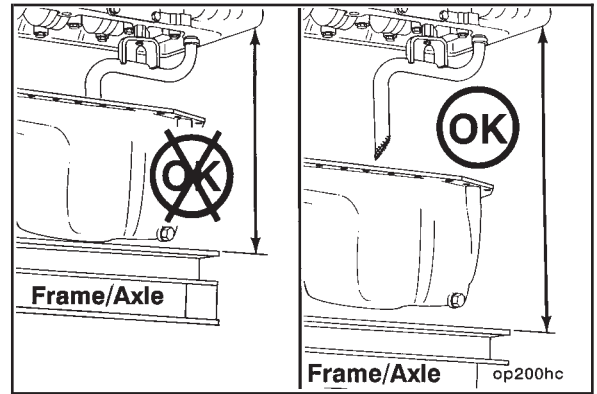
Install (007-025-026)

Front Sump Pan

On front sump oil pans, if the application does **not** allow approximately 610 mm [24 in] clearance between vehicle frame or axle and the cylinder block oil pan mounting surface during installation, the suction tube and oil pan will need to be installed together as an assembly. Installation requires approximately this much clearance to maneuver the oil pan over the frame or axle and under the block mounted suction tube when installing the pieces separately. Follow all the steps as outlined on the following pages.

If the application does allow approximately 610 mm [24 in] clearance, install the suction tube first by itself then the oil pan.

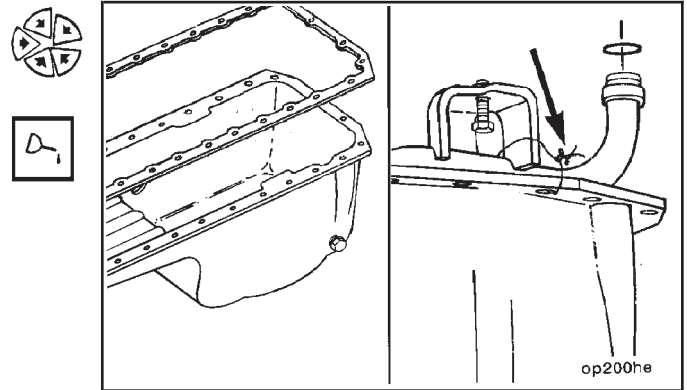
Apply a 2mm [1/16 inch] bead of sealant, Part No. 3823494, to the oil pan mounting surfaces at the cylinder block to gear housing joint (1) and flywheel housing to cylinder block joint (2).



Install a new o-ring to the oil suction tube. Use clean 15W-40 engine oil to lubricate the o-ring.

Place a new gasket on the oil pan mounting flange.

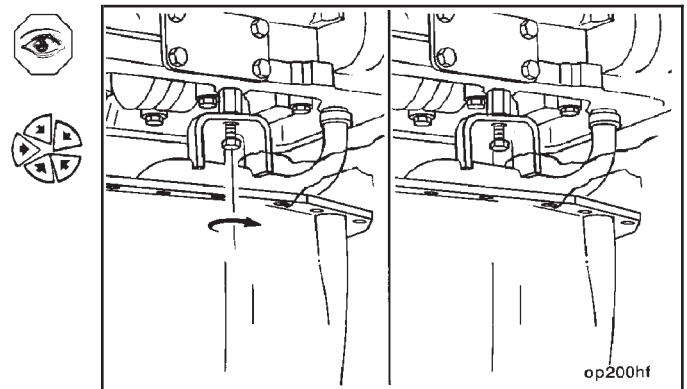
Attach the suction tube to the oil pan mounting flange with a piece of wire. This will hold the suction tube and oil pan together as one assembly until the tube is fastened to the cylinder block.

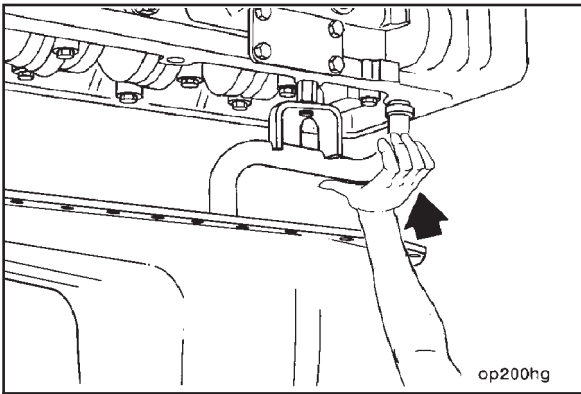


Maneuver the assembly into place under the engine in the chassis.

Align the suction tube with the cylinder block suction tube hole. Reach inside the engine and start the capscrew into the mounting hole to hold the suction tube in place.

After the capscrew is started in the mounting hole by several threads, the wire holding the suction tube to the oil pan can be removed and the oil pan can be lowered to allow more hand clearance to complete the suction tube installation.





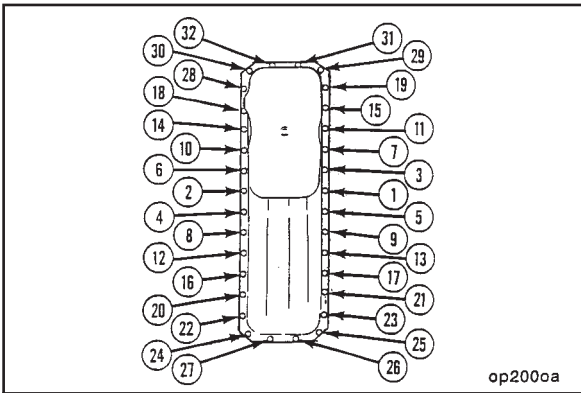
CAUTION

Do not use the capscrew to pull the suction tube into place during installation. To do so will cause misalignment of the suction tube which can cause damage to the engine.

Reach inside the engine and push the suction tube completely up into place in the cylinder block suction tube mounting hole by hand.

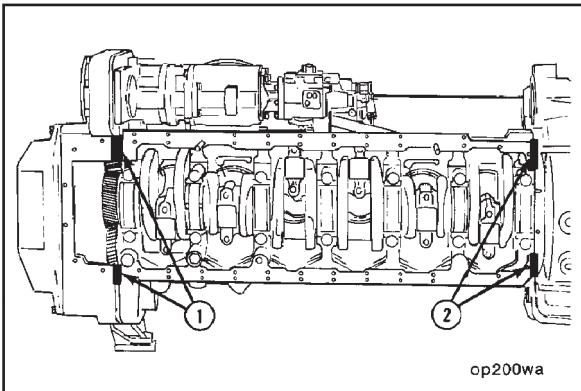
Complete the suction tube retaining capscrew installation.

Torque Value: 61 N•m [45 ft-lb]



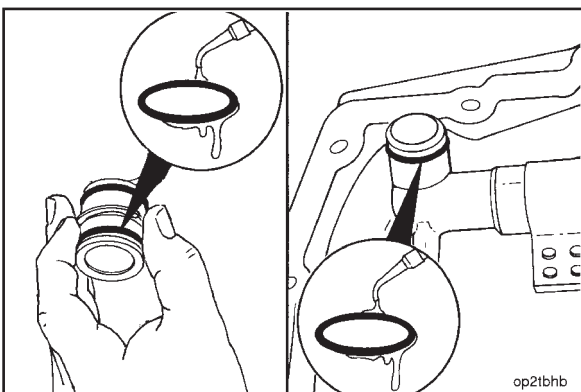
Install the oil pan. Tighten the capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]



Rear Sump Pan

Apply a 2mm [1/16 inch] bead of sealant, Part No. 3823494, to the oil pan mounting surfaces at the cylinder block to gear housing joint (1) and flywheel housing to cylinder block joint (2).



Install new o-rings on the oil transfer tube.

Use clean 15W-40 oil to lubricate the o-rings.

Install the transfer tube in the oil pan.

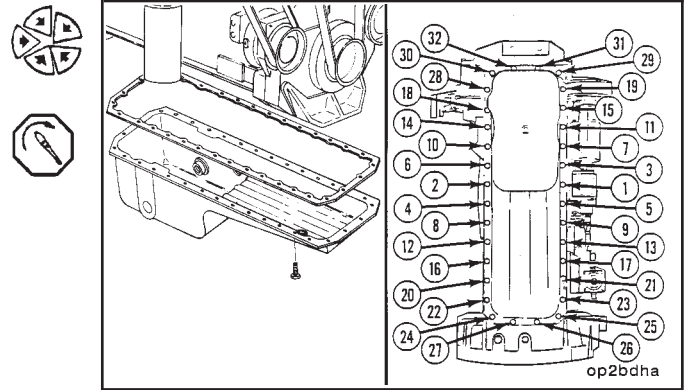


Be sure the transfer tube is aligned with the cylinder block suction tube hole when installing the oil pan.

Use a new gasket and install the oil pan.

Install and tighten the capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]



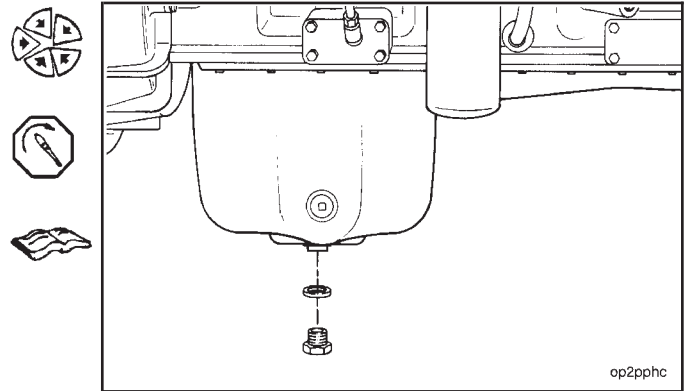
Fill (007-025-028)

Clean and check the oil drain plug threads and the seal surface.

Install the oil drain plug in the lubricating oil pan.

Torque Value: 88 N•m [65 ft-lb]

NOTE: Check the torque of the side and bottom drain plug to be sure **both** are tight.

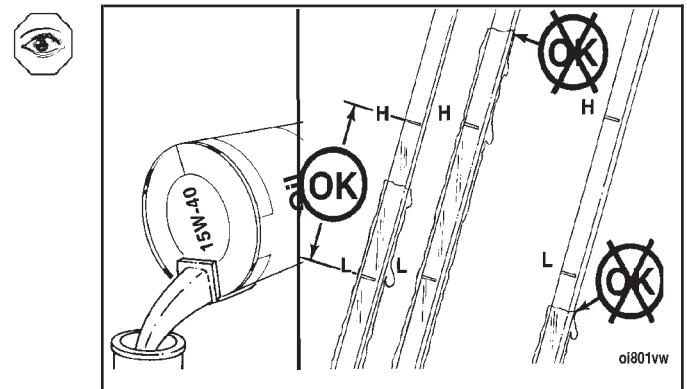


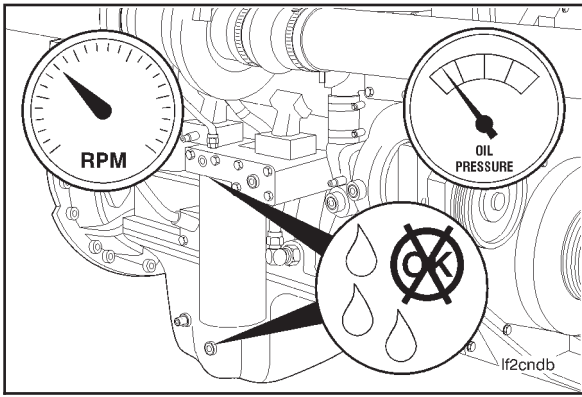
Use a high quality API CG-4 or CF-4 15W-40 multi-viscosity oil such as Cummins Premium Blue, or its equivalent, in Cummins engines. Choose the correct oil for your operating climate as outlined in Section V.



Fill the engine with clean oil to the “H” (high) mark on the dipstick.

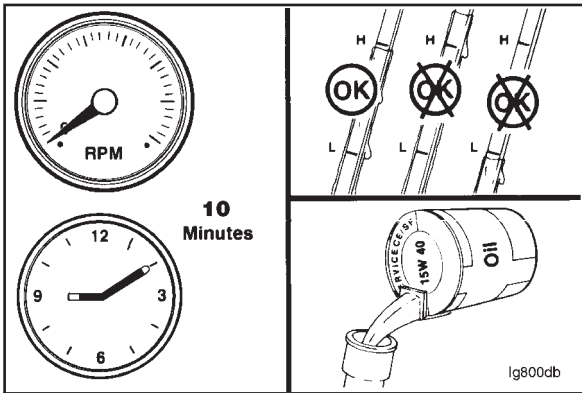
NOTE: The oil pan capacity is 34 liters [9 U.S. gal]. The filter capacity is 2.6 liters [0.7 U.S. gal].





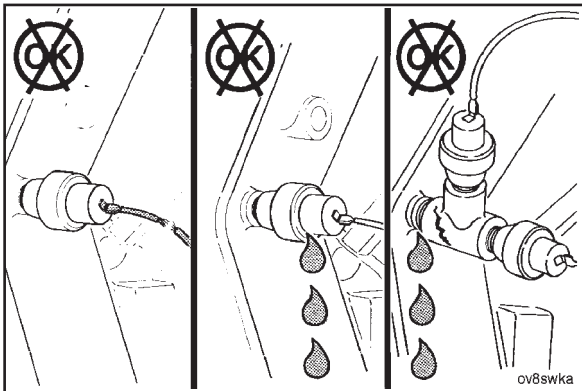
Operate the engine at idle speed to inspect for leaks at the filter(s) and the drain plug.

NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.



Shut off the engine. Wait approximately 10 minutes for the oil to drain back from the upper parts of the engine to the oil pan.

Check the oil level again. Add oil as necessary to bring the level up to the "H" (high) mark on the dipstick.



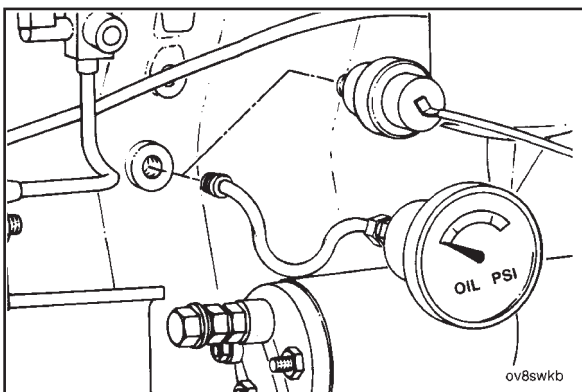
Lubricating Oil Pressure Gauge (007-028)



Test (007-028-012)

Check the following for defects:

- Electrical wiring broken
- Sending unit malfunction
- Plumbing loose or broken



To check for a sending unit malfunction:



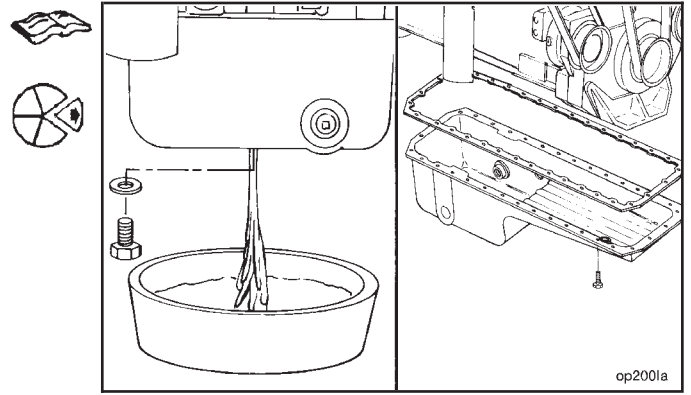
- Use a Compulink™ to verify the readings of the suspect gauge.
- If readings from the engine sensors are suspected, use a master gauge of known accuracy to verify.
- Connect the line from the master gauge to the main oil rifle on the fuel pump side of the engine.
- Replace the sending unit or sensor if it is defective.

Lubricating Oil Pressure Regulator (Main Rifle) (007-029)

Remove (007-029-002)

Drain the lubricating oil. Refer to Procedure 007-025-005.

Remove the oil pan. Refer to Procedure 007-025-002.

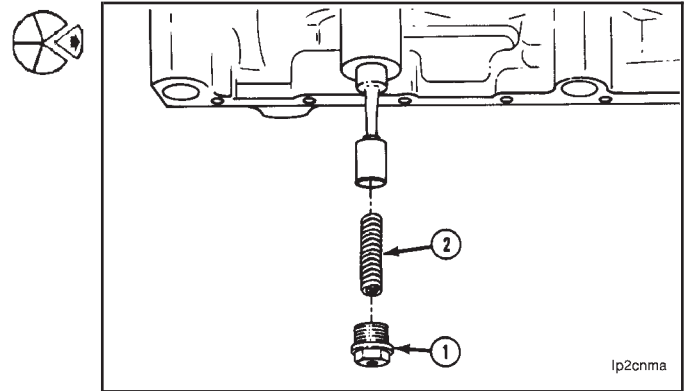


⚠ WARNING ⚠

Carefully remove the retainer plug (1). The pressure regulator spring (2) is under compression. Personal injury can result. Wear face and eye protection.

Remove the retainer plug, regulator spring and regulator plunger.

Remove the orifice from the plunger.



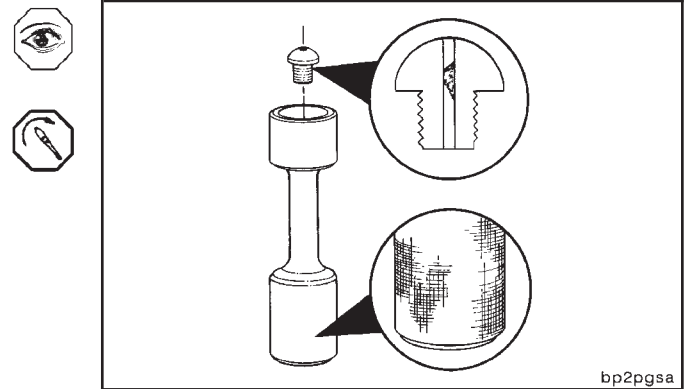
Inspect for Reuse (007-029-007)

Visually inspect the regulator plunger for scratches or scoring. If scratches are deep enough to be felt with a fingernail, the plunger **must** be replaced.

Check the orifice in the plunger to make sure it is **not** plugged. If the orifice is plugged, clean it before replacing.

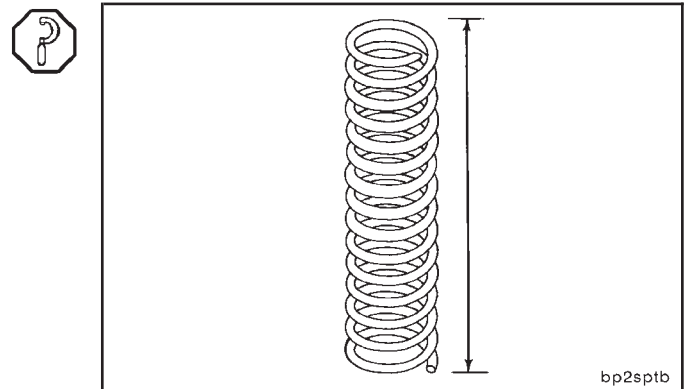
NOTE: The orifice is threaded into the plunger.

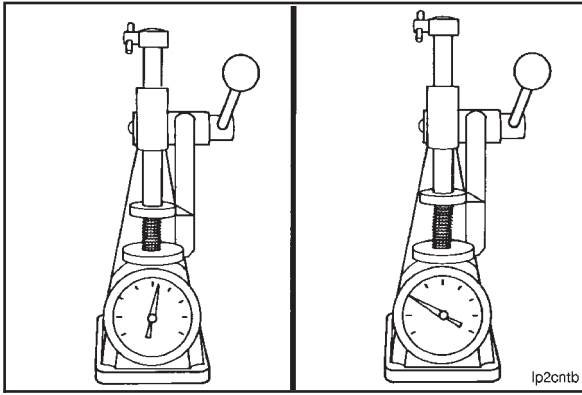
Torque Value: 1 N•m [6 in-lb]



Measure the free length of the regulator spring.

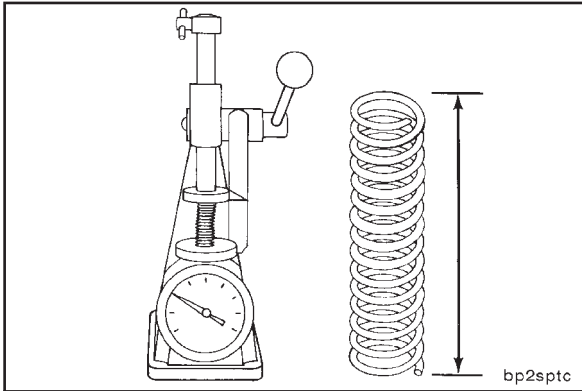
Regulator Spring Free Length		
mm	NOMINAL	in
84.1		3.31





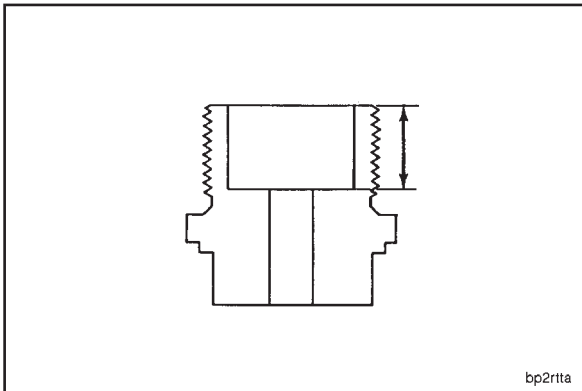
Use a spring compression tester to determine if the spring is defective.

Replace the spring with a new spring if it is defective.



**Main Oil Pressure Regulator Spring Load
at 48.3 mm [1.90in.]**

N		lbf
91.1	MIN	20.50
94.7	MAX	21.30



Measure the retainer plug to determine if it is defective. If it does **not** meet the specification, replace it with a new one.

Main Oil Pressure Regulator Retainer Plug

mm		in
11.1	MIN	0.44
13.4	MAX	0.53

Install (007-029-026)



WARNING

The regulator spring must be compressed to install the retainer plug (1). Personal injury can result. Wear face and eye protection.

NOTE: A counterbore plunger and orifice is unique to engines with a viscosity sensor. Low oil pressure will result if a solid plunger is used with a viscosity sensor.

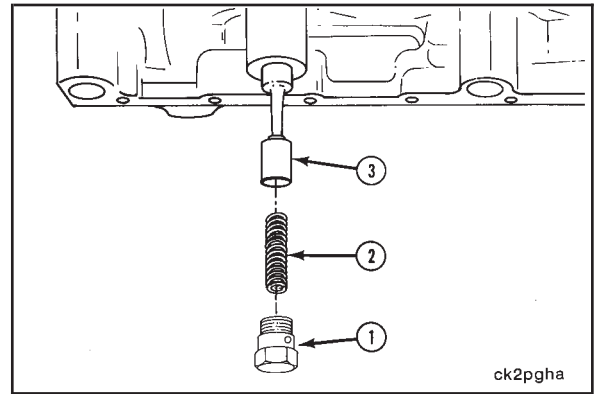
Install the plunger (3) and spring (2).

Install and tighten the retainer plug (1).

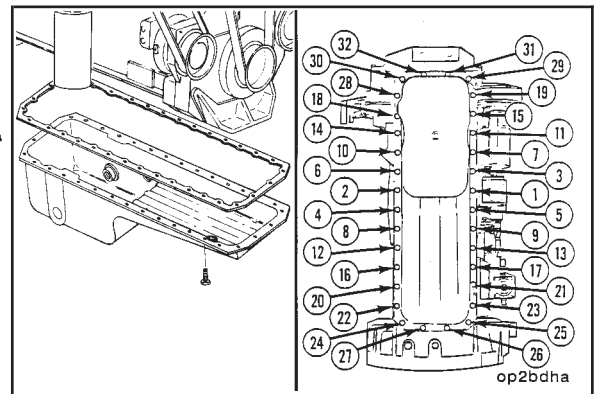
Torque Value:

Rear Sump Oil Pan	75 N•m	[55 ft-lb]
Front Sump Oil Pan	122 N•m	[90 ft-lb]

Install the oil pan. Refer to Procedure 007-025-026.



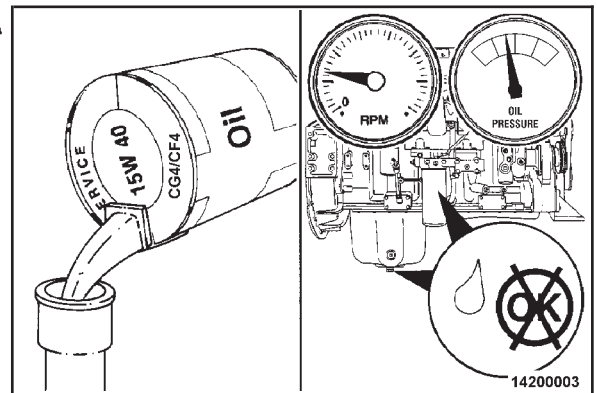
ck2pgha



op2bdha

Operate the engine at idle speed for 3 minutes to inspect for leaks.

NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

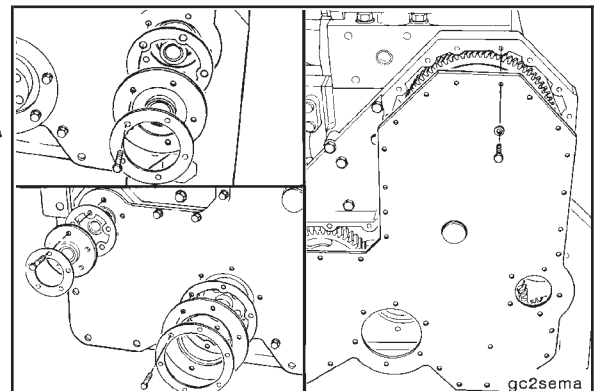


1420003

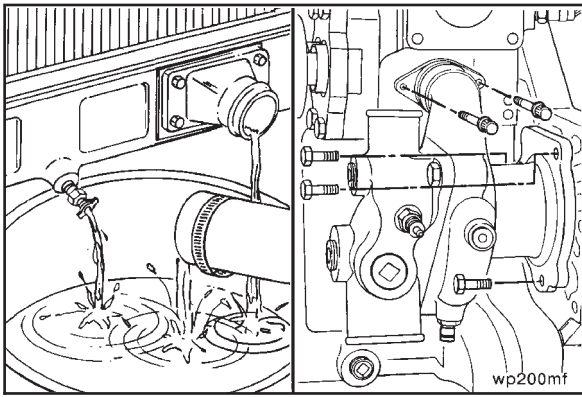
Lubricating Oil Pump (007-031)

Remove (007-031-002)

Remove the gear cover. Refer to Procedure 001-031-002.

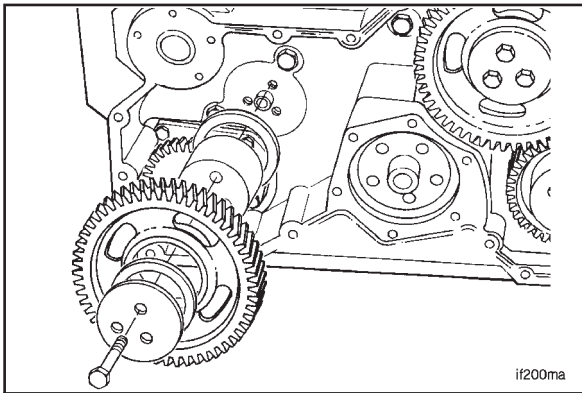


gc2sema

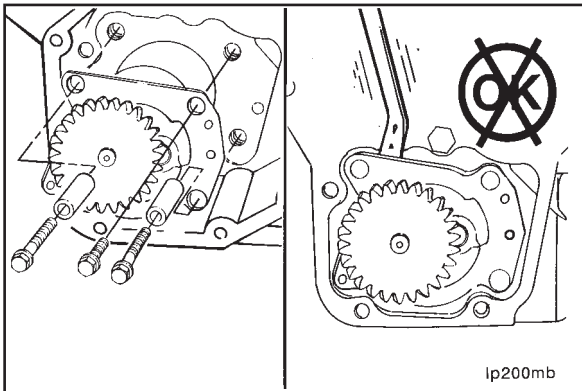


The water pump **must** be removed to remove the water pump idler gear.

Drain the cooling system and remove the water pump. Refer to Procedure 008-018-005 and 008-062-002 respectively.



Remove the water pump idler gear. Refer to Procedure 001-040-002.

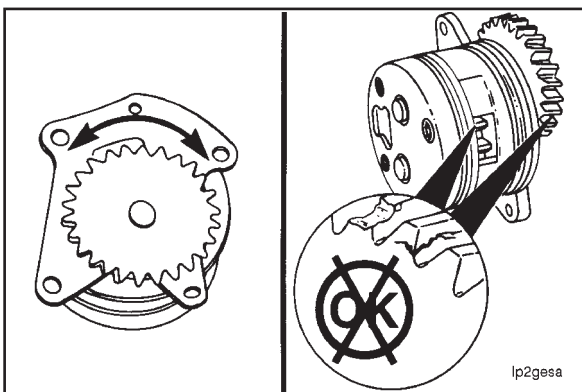


CAUTION

Do not pry on the gear or pump flange. This can result in damage to the pump.

Remove the three mounting capscrews and spacers.

Use both hands to pull, or insert two capscrews (M8X1.25) into the puller holes to push the pump from the engine.

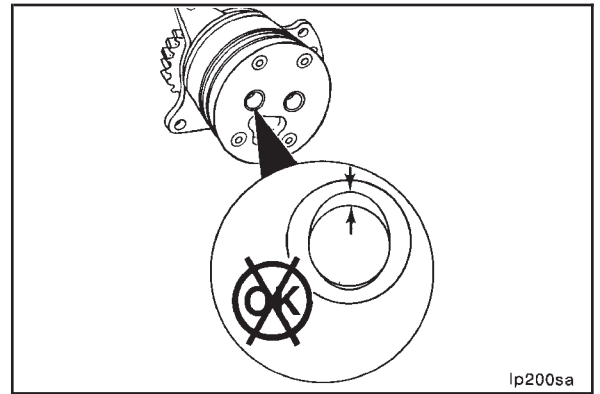


Inspect for Reuse (007-031-007)

Turn the main drive gear by hand to check the gears for freedom of rotation.

Visually inspect the gears for cracked, worn or broken teeth.

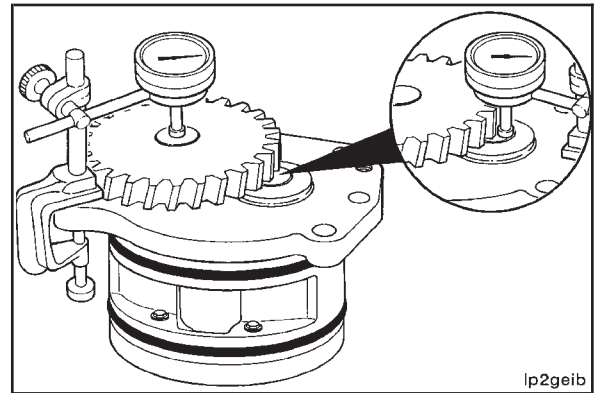
Visually inspect the rear cover plate shaft bores for excessive wear or discoloration due to overheating or shaft seizure.



lp200sa

Measure the drive shaft and driven shaft end clearance.

Drive Shaft End Clearance		
mm		in
0.064	MIN	0.0025
0.269	MAX	0.0106



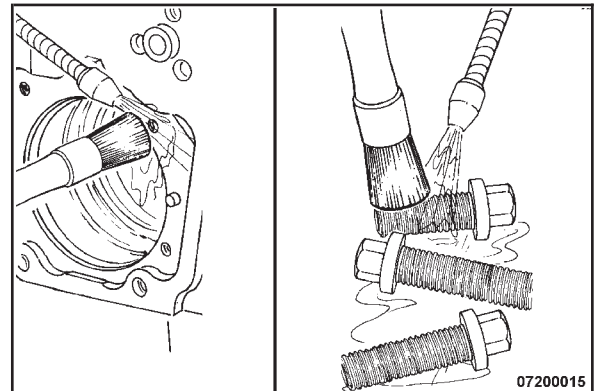
lp2geib

If the gears are damaged, the shaft does **not** turn freely by hand or the end clearance is **not** within the specifications given, the oil pump **must** be replaced.

Install (007-031-026)

Clean the threaded lube pump mounting holes in the cylinder block with solvent. Dry with compressed air.

Clean the capscrew threads with solvent. Dry with compressed air.

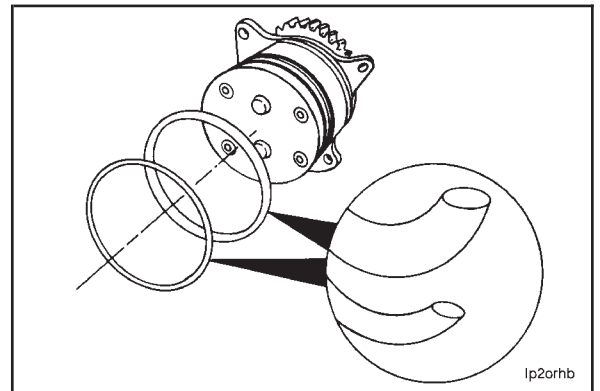


07200015

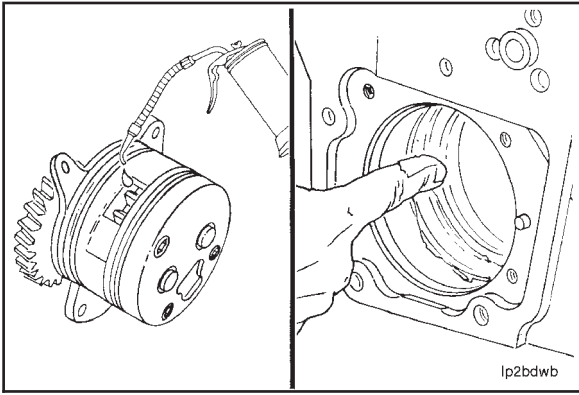
Install two new o-rings on the oil pump body.

Install the thickest o-ring into the groove nearest to the oil pump drive gear.

NOTE: Do **not** lubricate the two oil pump body o-rings. The o-rings will swell, and the pump **cannot** be installed.

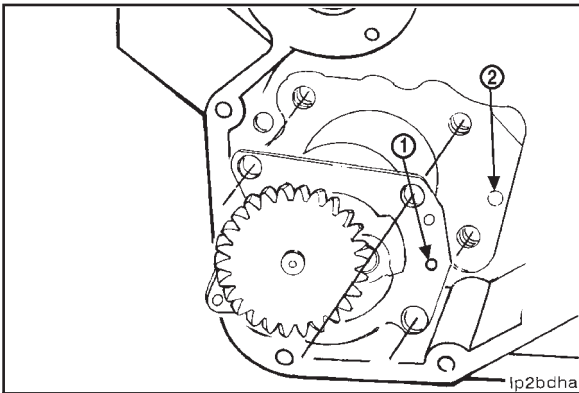


lp2orhb



Use clean 15W-40 oil to lubricate the oil pump gears.

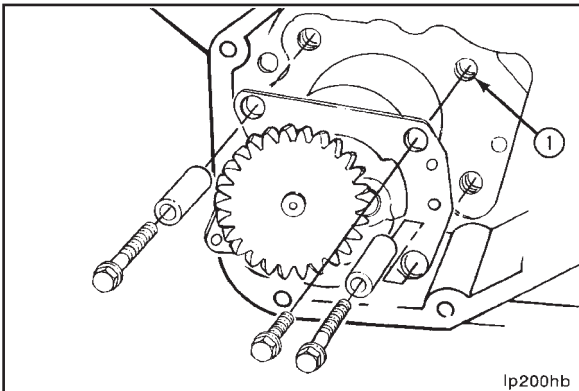
Apply a film of grease to the oil pump bore in the cylinder block.



CAUTION

The dowel pin bore in the oil pump flange (1) must be aligned with the dowel pin in the cylinder block (2) to prevent damage to the oil pump flange during installation. Do not use the mounting capscrews to pull the oil pump into the bore. This can damage the mounting flange of the oil pump.

Install the oil pump by hand.



Sealant, Part No. 3824038 or equivalent, **must** be used to coat the threads of the three mounting capscrews to prevent air from being drawn past the capscrews during engine operation.

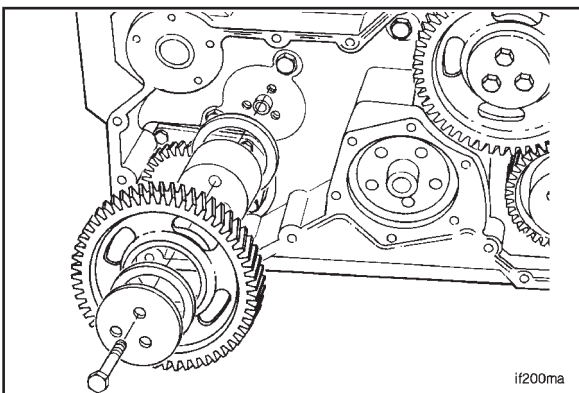


CAUTION

The shorter flange head capscrew must be used in the upper right hand mounting hole (1) to prevent the idler gear from contacting the head of the capscrew and causing damage to the lubricating oil pump.

Install the three capscrews and spacers. Use the short flange head capscrew in the upper right hand mounting hole (1). Use the longer flange head capscrews and spacers in the other two holes.

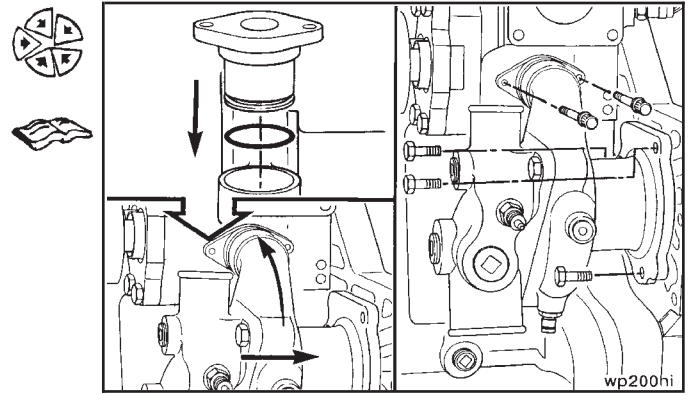
Torque Value: 41 N•m [30 ft-lb]



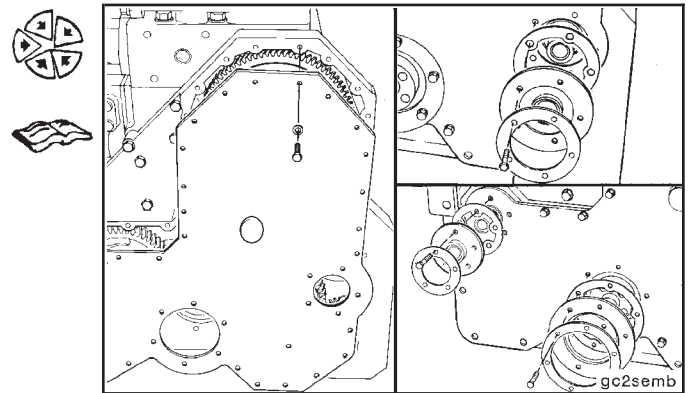
Install the water pump idler gear. Refer to Procedure 001-040-026.



Install the water pump. Refer to Procedure 008-062-026.



Install the gear cover. Refer to Procedure 001-031-026.
Operate the engine and check for leaks.



Lubricating Oil System (007-037) Prime (007-037-050)



The lubricating oil system must be primed before operating the engine after a rebuild or extended shutdown to avoid internal component damage. If an external pressure pump is used, do not prime the system after the filter. The filter will be damaged.

Remove the plug at the “filter in” fitting of the lubricating oil filter head. This will allow oil to flow in the correct direction through the filter.

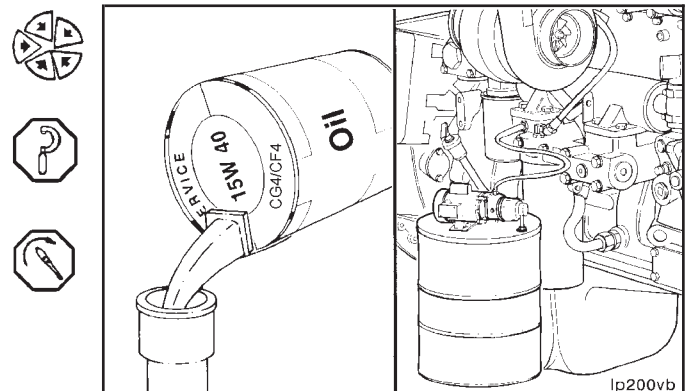
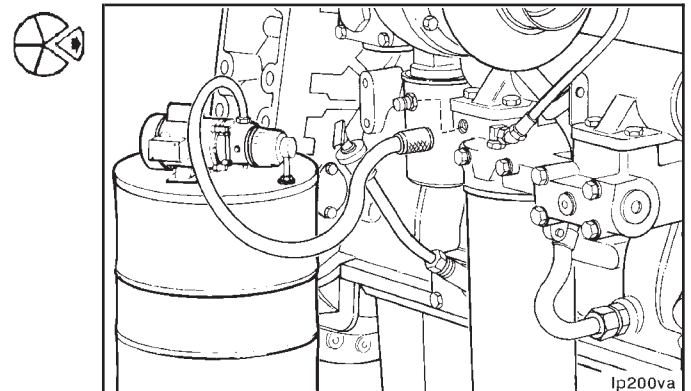
Install an oil supply line connected to a source of clean 15W-40 lubricating oil in the Compuchek® fitting drilling of the filter head.

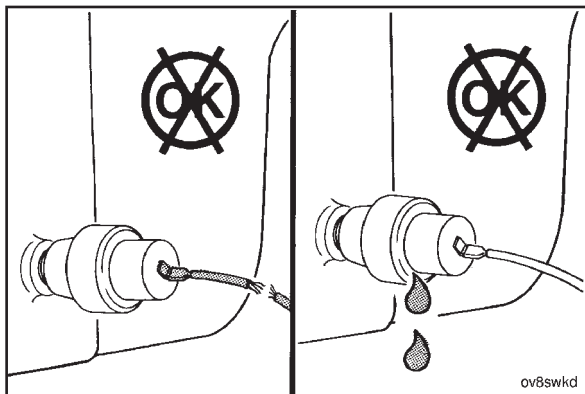
Prime the lubricating system until the oil pressure gauge indicates a positive pressure.

NOTE: The oil pressure **must not** exceed the maximum of 276 kPa [40 psi].

Remove the oil supply and install the Compuchek® fitting.

Torque Value: 54 N•m [40 ft-lb]



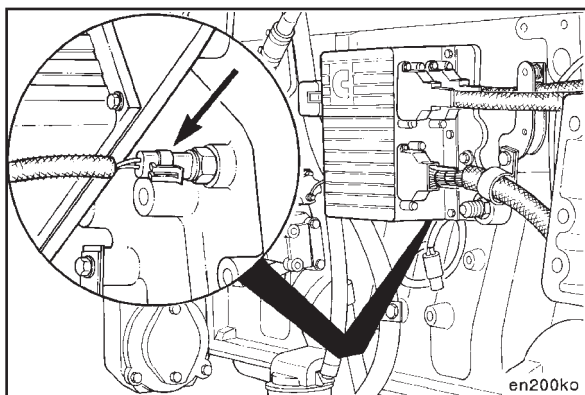


Lubricating Oil Temperature Gauge (007-038)

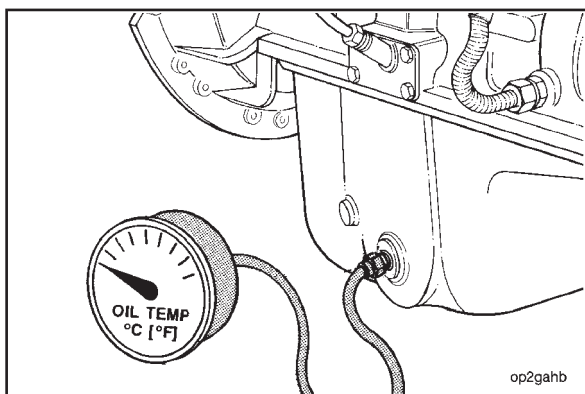
Test (007-038-012)

Check the following for defects.

- Electrical wiring broken
- Sending unit malfunction

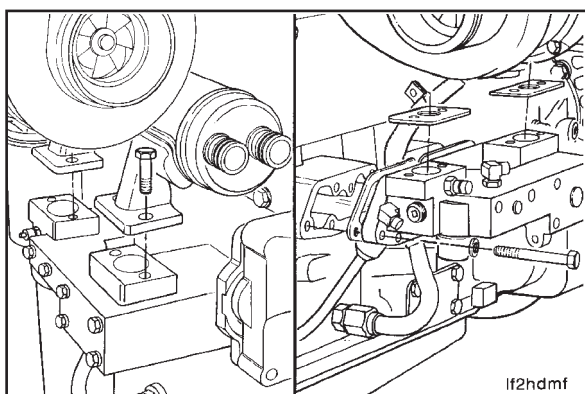


NOTE: The M11 CELECT™ and CELECT™ Plus engine oil temperature sensor is located on the engine block behind the ECM in the main oil rifle galley.



To check for a sending unit malfunction:

- Use a master gauge of known accuracy to verify the reading of the suspect gauge
- Drain the oil pan
- Remove the pipe plug on the side of the oil pan, and install the master oil temperature gauge sending unit
- Fill the oil pan with 15W-40 oil
- Replace the sending unit if it is defective



Lubricating Oil Thermostat (007-039)

Remove (007-039-002)



Remove the lubricating oil filter head. Refer to Procedure 007-015-002.

Inspect for Reuse (007-039-007)



WARNING

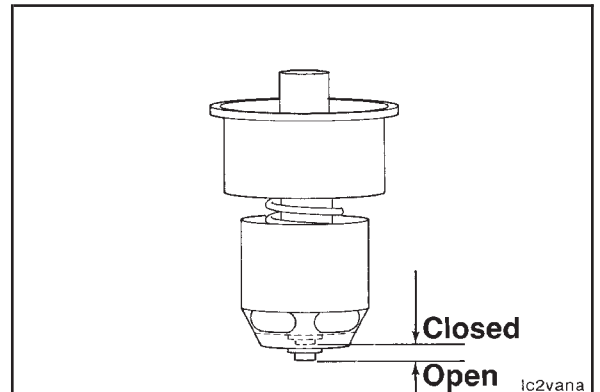
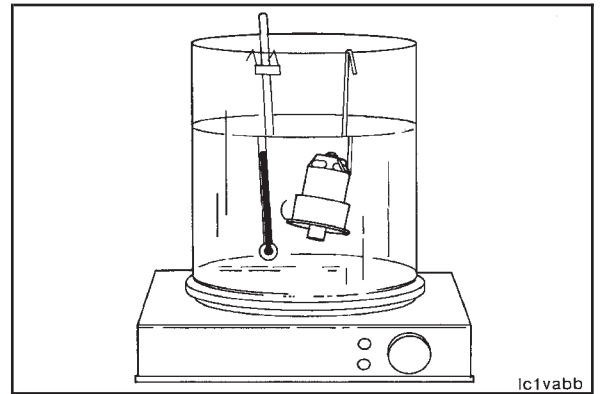
The flash point of new lubricating oil is approximately 221°C [430°F]. Do not allow the oil temperature in the container to exceed 149°C [300°F]. Do not allow water droplets to enter the container of hot oil. Water droplets will cause a violent reaction which can cause personal injury.

Suspend the thermostat and a 116°C [240°F] thermometer in a container of new lubricating oil. Do **not** allow the thermostat or the thermometer to touch the sides of the container.

Heat the lubricating oil.

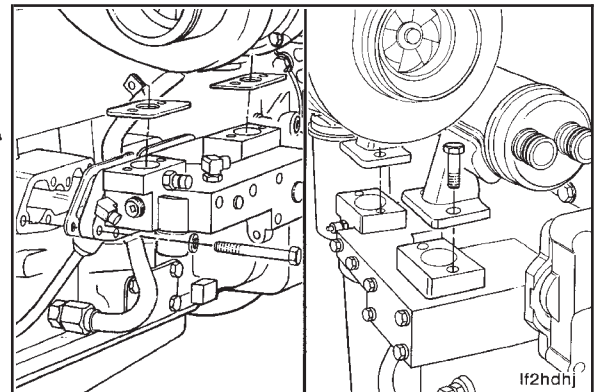
Write down the temperature at which the valve is fully extended. The valve **must** be fully extended to at least 6 mm [0.250 inch] from the closed position when the temperature reaches 116°C [240°F].

Replace the thermostat if it does **not** operate as described.



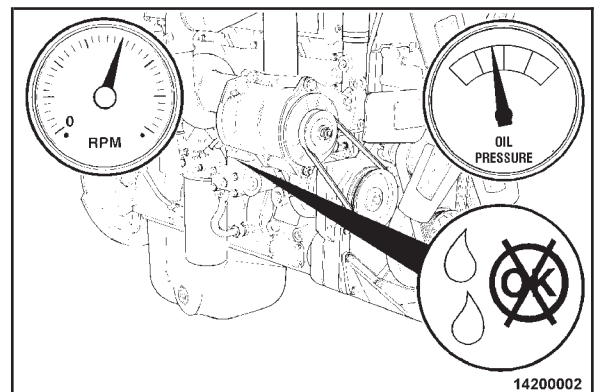
Install (007-039-026)

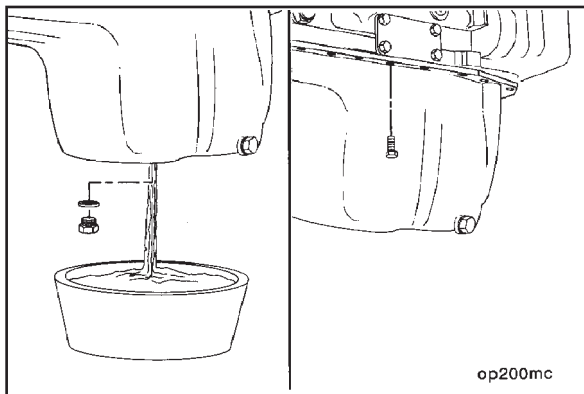
Install the filter head onto the engine. Refer to Procedure 007-015-026.



Operate the engine at idle speed for 3 minutes to inspect for leaks at the filter head.

NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.





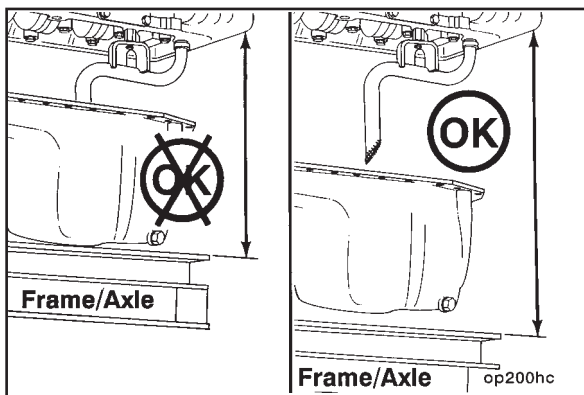
Lubricating Oil Transfer Tube (007-040)



Remove (007-040-002)

Drain the lubricating oil. Refer to Procedure 007-025-005.

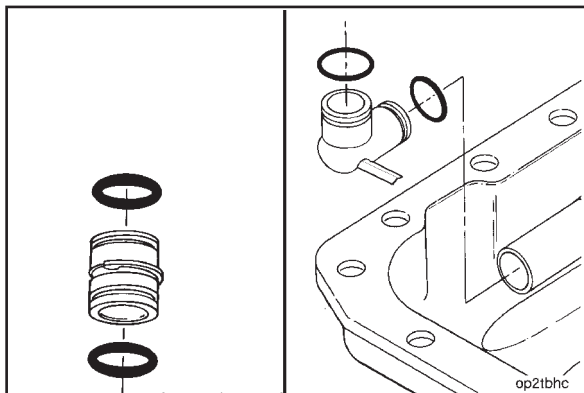
Remove the oil pan mounting capscrews. Refer to Procedure 007-025-002.



Most front sump oil pans have a block mounted suction tube which requires approximately 610 mm [24 in] clearance between the vehicle frame or axle and the cylinder block oil pan mounting flange to remove the oil pan.

If the application will not allow this much clearance, lower the oil pan as much as possible, and reach inside the pan and remove the suction tube retaining capscrew from the cylinder block.

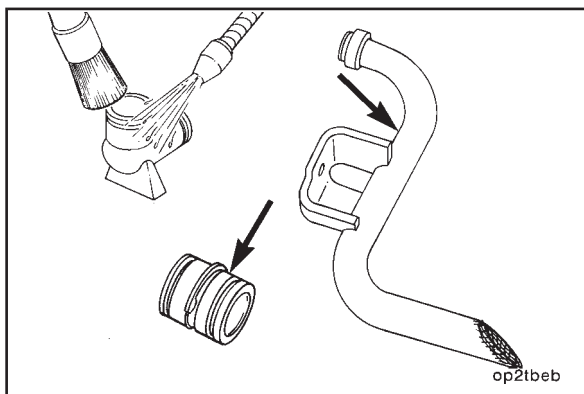
Let the suction tube lay inside the oil pan while the pan is removed from the chassis.



On rear sump pans, remove the oil transfer tube.

Remove and discard the o-ring(s) on the transfer tube or the suction tube.

NOTE: The straight transfer tube is used on some aluminum front sump oil pan applications.

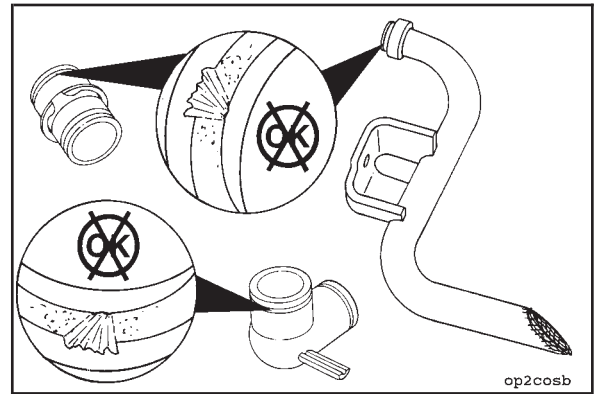


Clean (007-040-006)

Use solvent to clean the oil transfer tube and locating snap ring. Dry with compressed air.

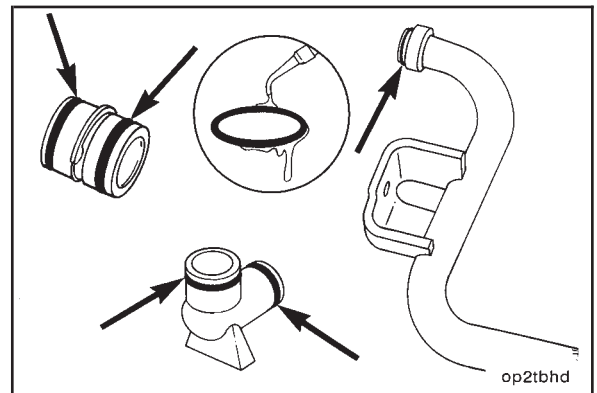
Inspect for Reuse (007-040-007)

Visually inspect the oil transfer tube for cracks or damage.
Visually inspect the o-ring grooves for cavitation or damage.
If cracks, damage, or cavitation is found, the oil transfer tube **must** be replaced.



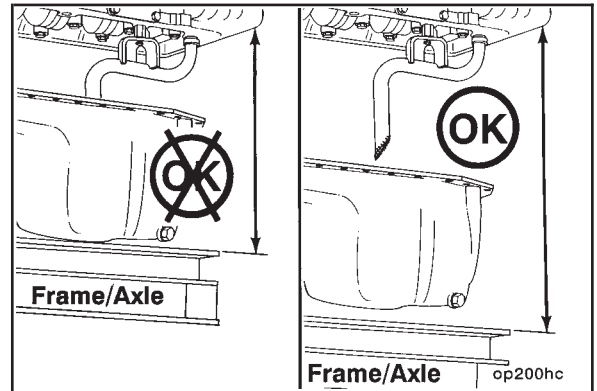
Install (007-040-026)

Install new o-ring(s) on the transfer tube or suction tube.
Use clean 15W-40 oil to lubricate the o-ring(s).
On rear sump oil pans, install the transfer tube in the oil pan.



On front sump oil pans, if the application does **not** allow approximately 610 mm [24 in] clearance between vehicle frame or axle and the cylinder block oil pan mounting surface during installation, the suction tube and oil pan will need to be installed together as an assembly. Installation requires approximately this much clearance to maneuver the oil pan over the frame or axle and under the suction tube when installing separately. Follow all the steps as outlined on the following pages.

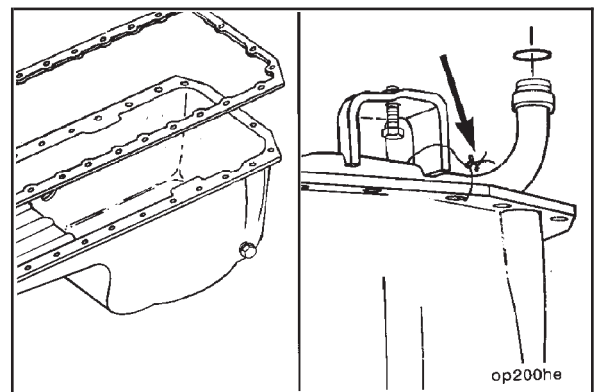
If the application does allow approximately 610 mm [24 in] clearance, install the suction tube first by itself then the oil pan.

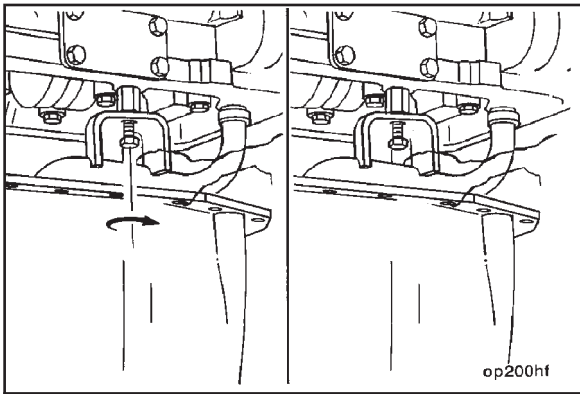


Install a new o-ring to the oil suction tube. Use clean 15W-40 engine oil to lubricate the o-ring.

Place a new gasket on the oil pan mounting flange.

Attach the suction tube to the oil pan mounting flange with a piece of wire. This will hold the suction tube and oil pan together as one assembly until the tube is fastened to the cylinder block.



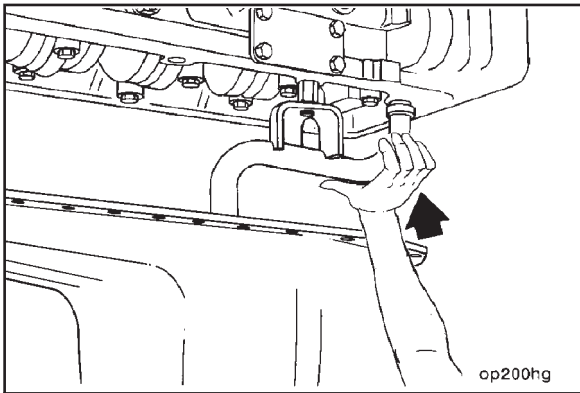


Maneuver the assembly into place under the engine in the chassis.



Align the suction tube with the cylinder block suction tube hole. Reach inside the engine and start the capscrew into the mounting hole to hold the suction tube in place.

After the capscrew is started in the mounting hole by several threads, the wire holding the suction tube to the oil pan can be removed and the oil pan can be lowered to allow more hand clearance to complete the suction tube installation.



CAUTION

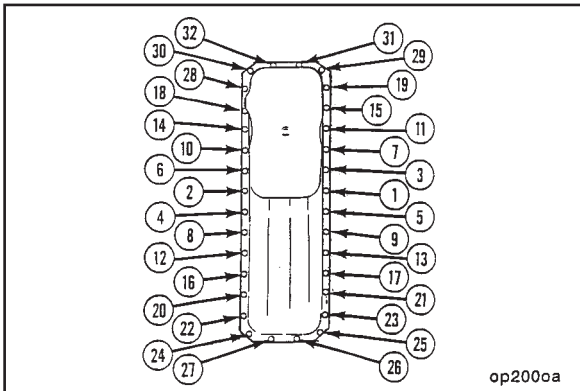
Do not use the capscrew to pull the suction tube into place during installation. To do so will cause misalignment of the suction tube which can cause damage to the engine.



Reach inside the engine and push the suction tube completely up into place in the cylinder block suction tube mounting hole by hand.

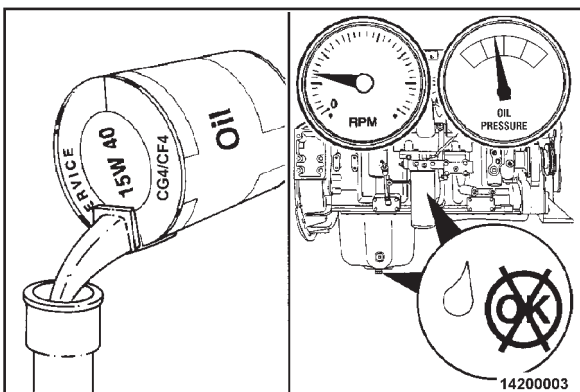
Complete the capscrew installation.

Torque Value: 61 N•m [45 ft-lb]



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

Torque Value: 47 N•m [35 ft-lb]



Fill the engine with clean 15W-40 oil. Refer to Procedure 007-025-028.



Operate the engine at idle speed for 3 minutes to inspect for leaks.

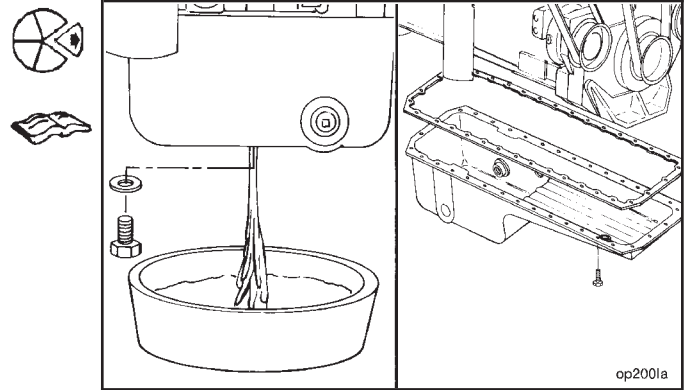
NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

Lubricating Oil Viscosity Sensor (007-041)

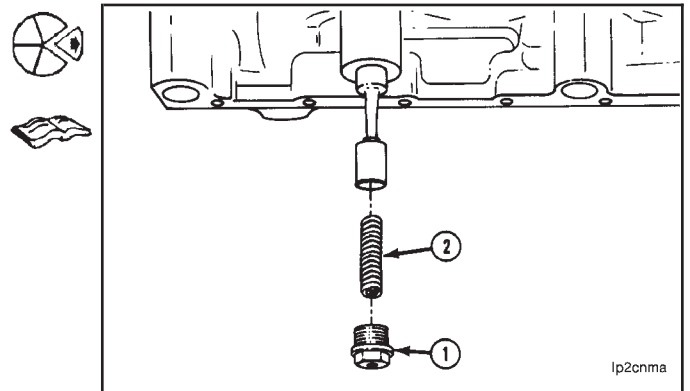
Remove (007-041-002)

Drain the lubricating oil. Refer to Procedure 007-025-005.

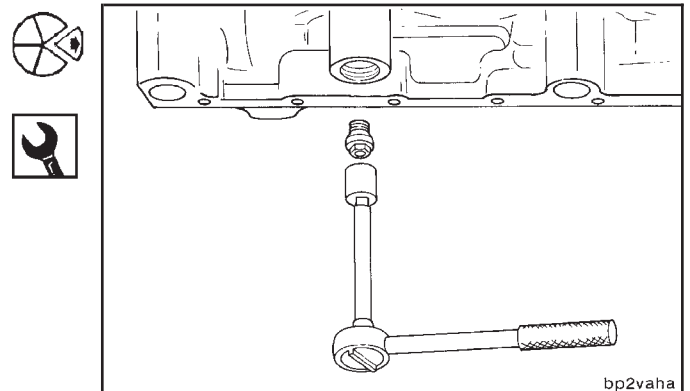
Remove the oil pan. Refer to Procedure 007-025-002.



Remove the main oil pressure regulator. Refer to Procedure 007-029-002.



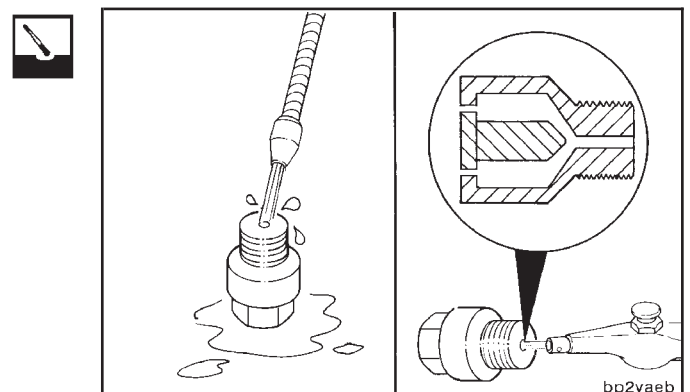
Remove the viscosity sensor with a 7/16 inch socket, an extension and ratchet.

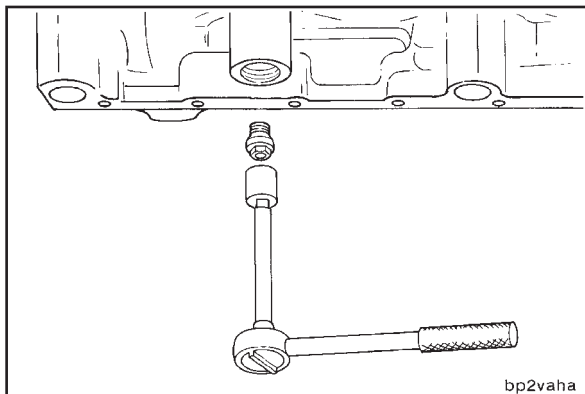


Inspect for Reuse (007-041-007)

If the viscosity sensor is plugged, or contains debris, it **must** be cleaned.

Use solvent and compressed air to remove the debris. If the viscosity sensor **cannot** be cleaned of all debris, it **must** be replaced.

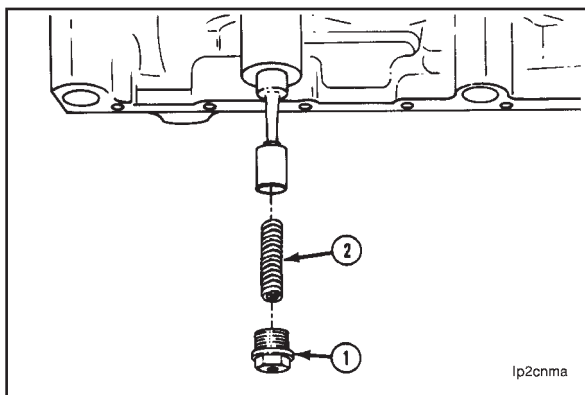




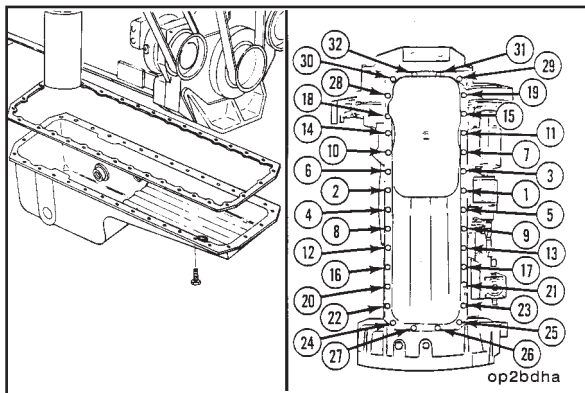
Install (007-041-026)

Install the viscosity sensor in the cylinder block.

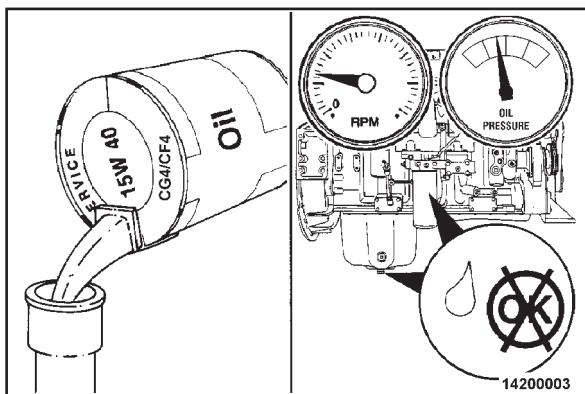
Torque Value: 24 N•m [18 ft-lb]



Install the main oil pressure regulator. Refer to Procedure 007-029-026.



Install the oil pan. Refer to Procedure 007-025-026.



Fill the engine with clean 15W-40 oil. Refer to Procedure 007-025-028.



Operate the engine at idle speed for 3 minutes to inspect for leaks.

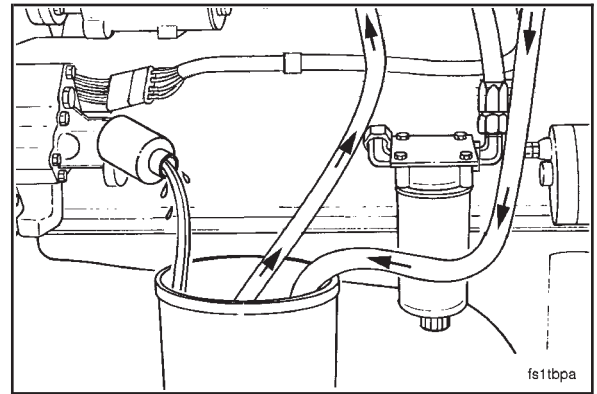
NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

Lubricating Oil Contamination (007-044)

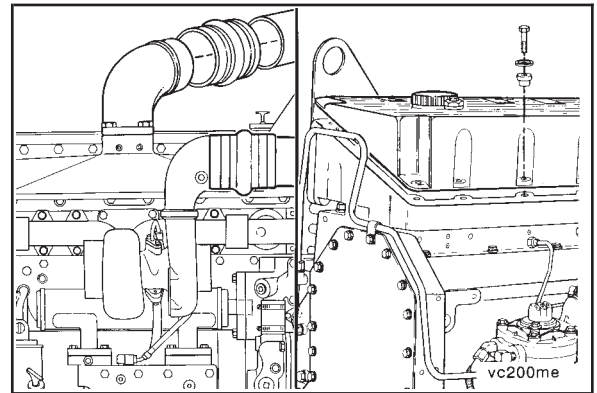
Fluorescent Dye Tracer (007-044-054)

NOTE: This test is **not** effective on a cold engine, less than 21°C [70°F] coolant temperature, or with a loose overhead setting.

Install an isolated fuel supply tank to the inlet and drain lines. Add fluorescent tracer, Part No. 3376891, to the fuel supply tank.

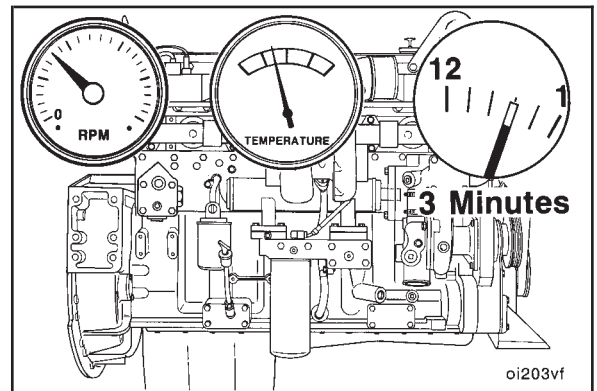


Remove the valve cover mounting hardware but do **not** remove the valve cover.

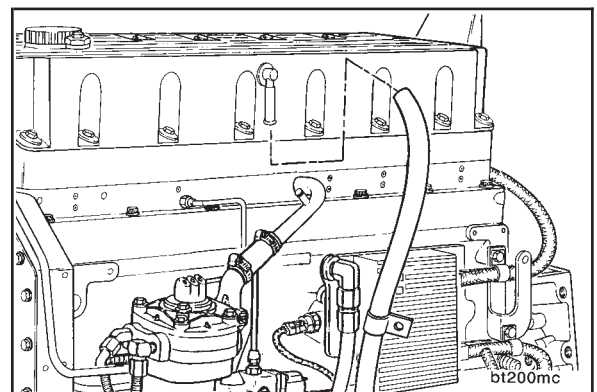


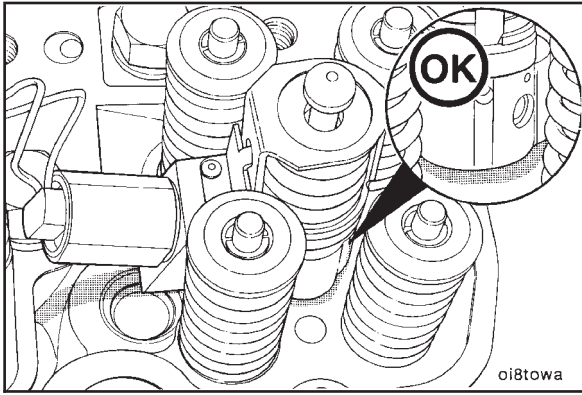
Start the engine and operate it at high idle for 30 seconds. Let the engine go to low idle.

Complete the next step within 5 minutes.



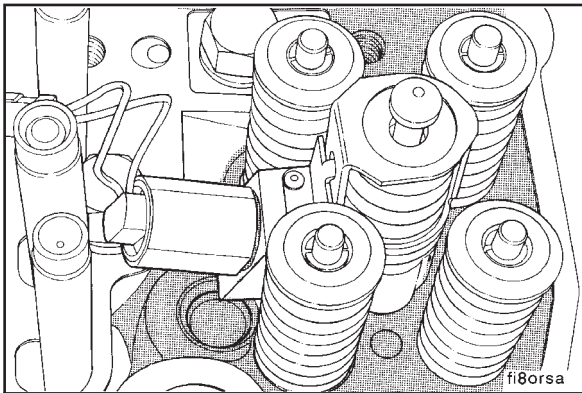
While the engine is operating at low idle, remove the valve cover. Refer to Procedure 003-011-002.





Use black light, Part No. 3377253 or 3377394, to find fuel leaks from inside or around the injector. Refer to the black light operating instructions.

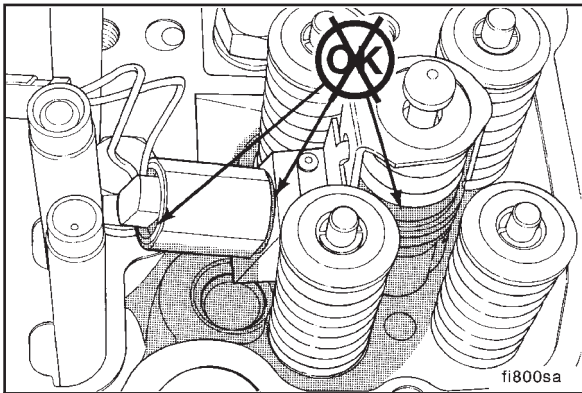
NOTE: Injectors normally have a small amount of fuel leakage.



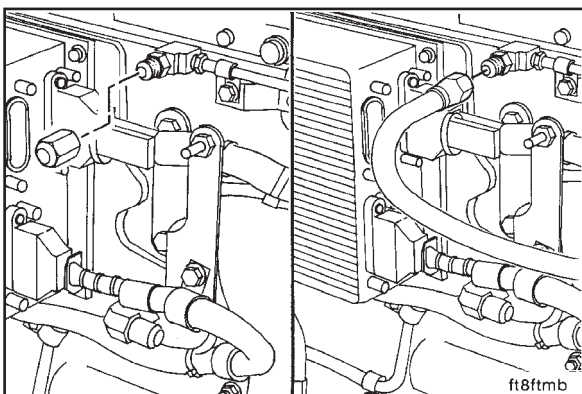
If there is excess leakage around the outside of the injector, check the top o-ring for damage.



Remove the injector and replace all three o-rings. Refer to Procedure 006-026.



If there is excess leakage from inside the injector, replace the injector. Refer to Procedure 006-026.

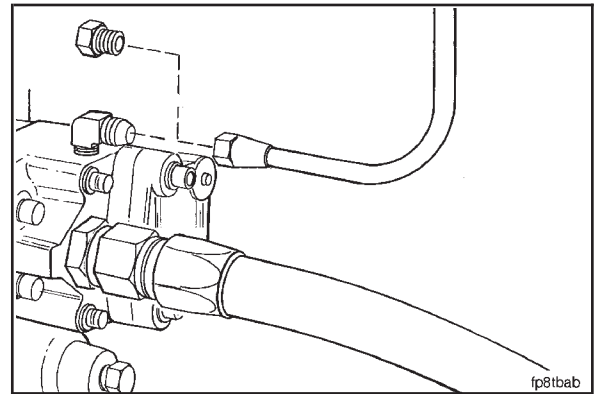


Fuel Pressure Test (007-044-061)



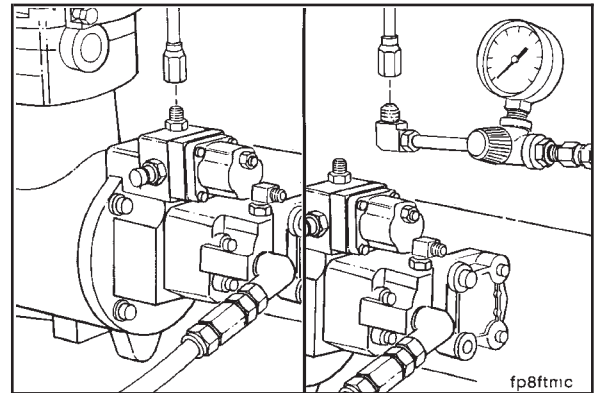
Remove the fuel drain line from the fuel drain tee fitting. Install a cap on the tee fitting.

Remove the fuel drain line from the gear pump check valve.
Install a plug in the fuel line.

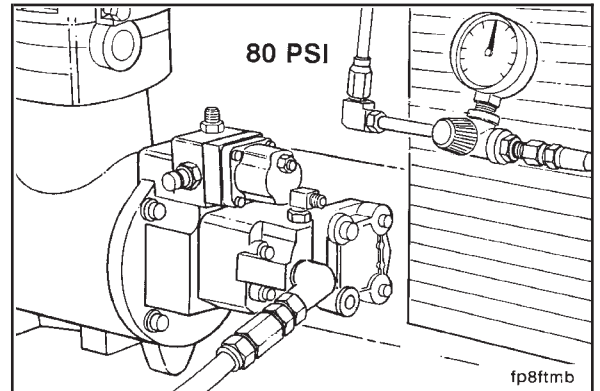


Remove the fuel supply line from the fuel supply pump shutoff valve.

Install a regulated air supply to the fuel supply line.

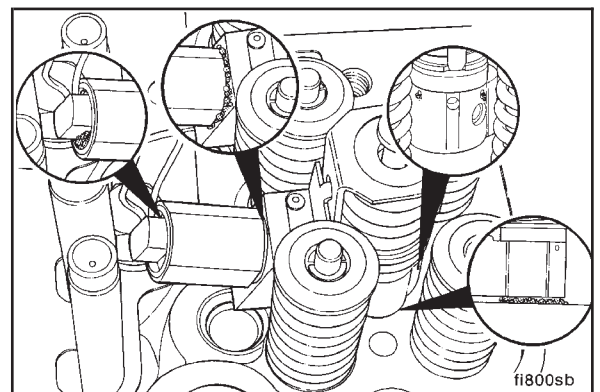


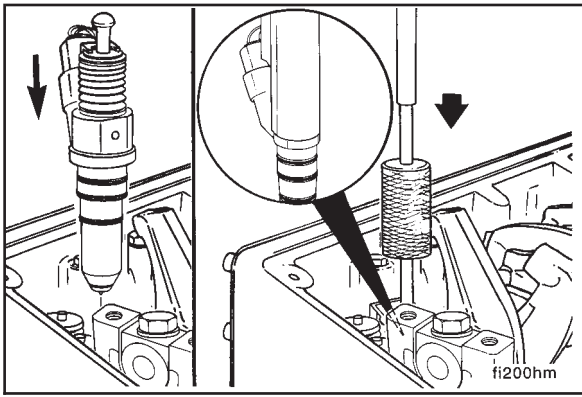
Apply air pressure to the cylinder head. The maximum air pressure is 552 kPa [80 psi].



Check for fuel leaks at each injector.

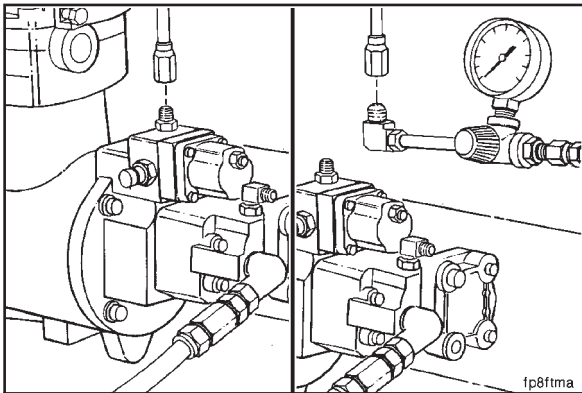
NOTE: A little engine oil is helpful to expose fuel leaks. Some leaks can be heard.



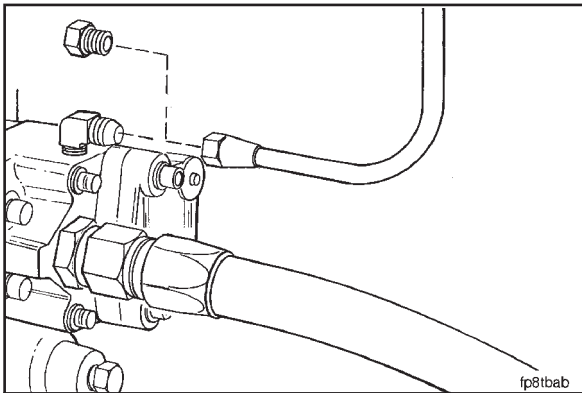


Replace the leaking injector or replace all three outer o-rings. Refer to Procedure 006-026.

Check the injector for normal leakage.

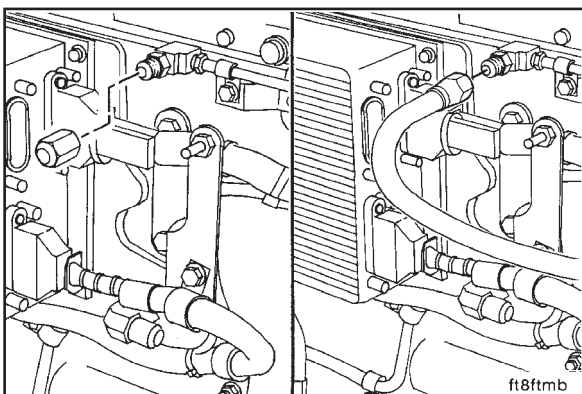


Remove the air line and install the fuel supply line.



Remove the plug from the gear pump drain line.

Install the drain line on the gear pump check valve.



Remove the cap from the fuel drain line fitting.

Install the fuel drain line.



Section 8 - Cooling System - Group 08

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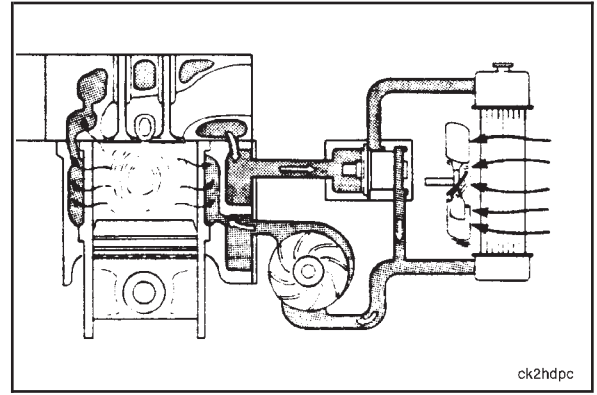
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Cooling System - General Information

The primary function of the cooling system is to remove the heat created by the engine and its support components. The excess heat energy that is **not** removed by the cooling system is carried away by exhaust gases and radiation into the atmosphere.

The coolant **must** be made up of proper proportions of water, antifreeze and supplemental coolant additives (SCA) to properly perform these functions.

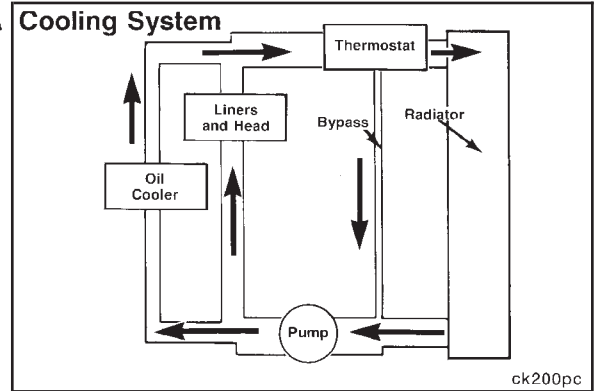


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The accompanying chart illustrates the coolant flow through the engine. For more detail, refer to the coolant flow diagrams.

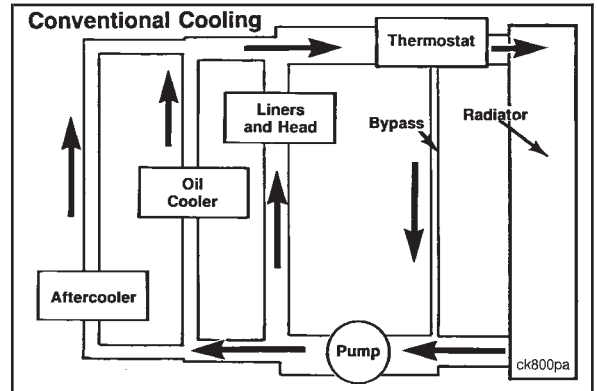


- Charge Air Cooled Engines



ck200pc

- Aftercooled Engines

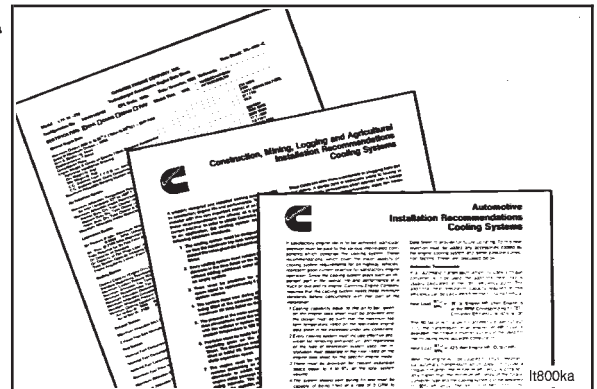


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The following publications, available through Cummins Distributors or Dealers, provide cooling system installation recommendations and specifications approved by Cummins Engine Company, Inc.:



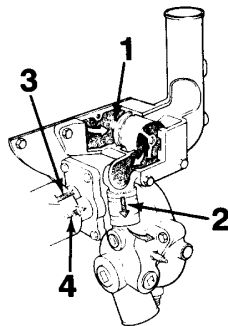
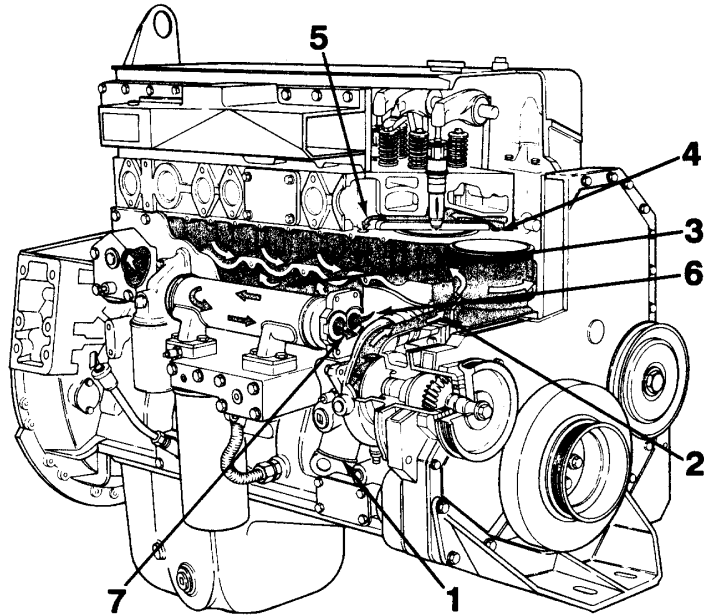
- Automotive Installation Recommendations (Cooling System), Bulletin No. 3382413.
- Construction, Mining, Logging, and Agriculture Installation Recommendations (Cooling System), Bulletin No. 3382171.
- Data Sheets for specific engine models.



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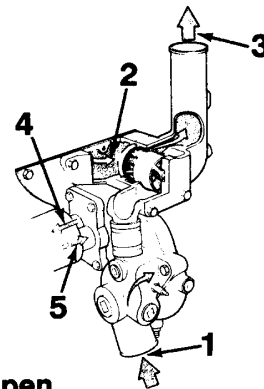
Flow Diagram, Cooling System
CHARGE AIR COOLED ENGINES

1. Water Pump Coolant Inlet
2. Coolant to Lower Manifold Cavity
3. Coolant to Cylinder Liner Block Cavity
4. Coolant to Cylinder Head
5. Coolant to Upper Manifold Cavity
6. Lower Manifold Coolant to Oil Cooler
7. Oil Cooler to Upper Manifold Cavity



Closed

1. Upper Manifold Cavity (Coolant to Thermostat)
2. Coolant By-pass (Return to Water Pump)
3. Lower Manifold Cavity to Cooler
4. Cooler to Upper Manifold Cavity (Before Thermostat)



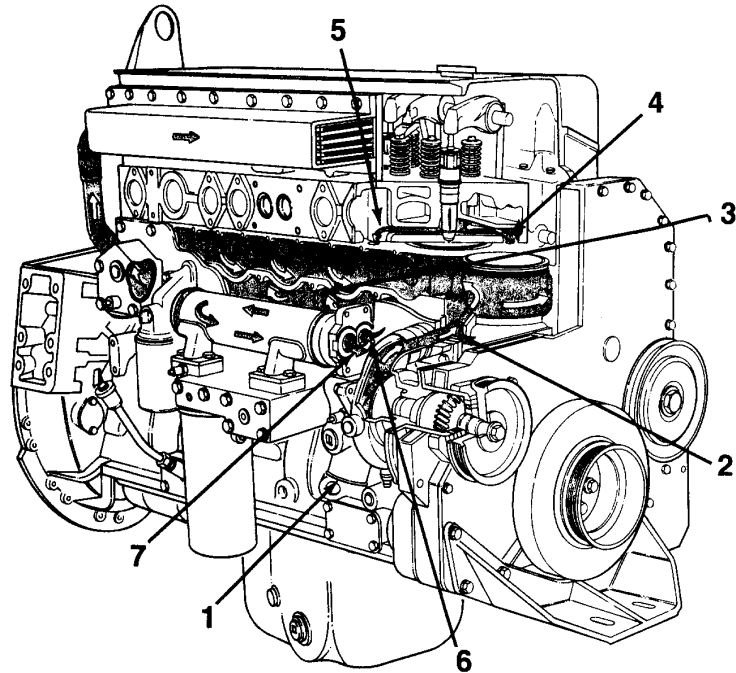
Open

1. Water Pump Coolant Inlet
2. Upper Manifold Cavity
3. Coolant Outlet
4. Lower Manifold Cavity to Cooler
5. Cooler to Upper Manifold Cavity (Before Thermostat)

AFTERCOOLED ENGINES

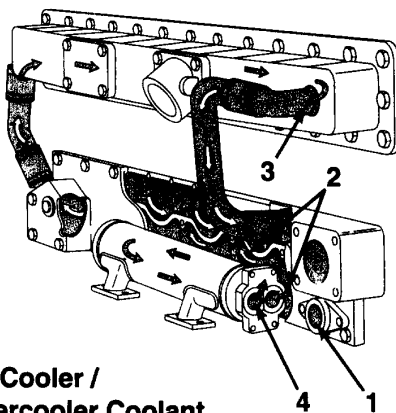
Coolant System

1. Water Pump Coolant Inlet
2. Coolant to Lower Manifold Cavity
3. Coolant to Cylinder Liner Block Cavity
4. Coolant to Cylinder Head
5. Coolant to Upper Manifold Cavity
6. Lower Manifold Coolant to Oil Cooler
7. Oil Cooler to Upper Manifold Cavity

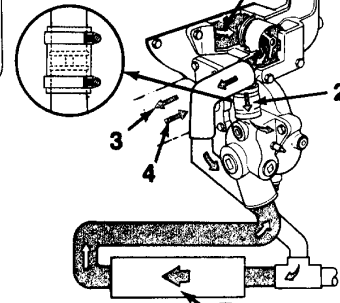


Oil Cooler / Aftercooler Coolant

1. Coolant Entry to Lower Manifold Cavity
2. Lower Manifold Coolant to Oil Cooler / Aftercooler
3. Aftercooler Coolant Outlet to Upper Manifold Cavity
4. Oil Cooler Water Outlet to Upper Manifold



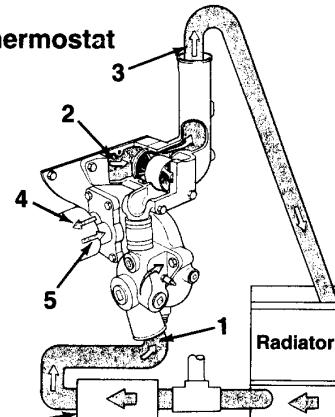
Orifice Directs Coolant Flow To The Torque Converter Cooler When Thermostat Is Closed



Closed

1. Upper Manifold Cavity (Coolant to Thermostat)
2. Coolant Bypass (Return to Water Pump)
3. Lower Manifold Cavity to Cooler
4. Cooler to Upper Manifold Cavity (Before Thermostat)

Thermostat



Open

1. Water Pump Coolant Inlet
2. Upper Manifold Cavity (Coolant to Thermostat)
3. Coolant Outlet
4. Lower Manifold Cavity to Cooler
5. Cooler to Upper Manifold Cavity (Before Thermostat)

Specifications

Cooling System

Coolant Capacity (Engine Only)

Charge Air Cooled Engines	9.5 liters [2.5 U.S. gal.]
Aftercooled Engines	12.9 liters [3.4 U.S. gal.]

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

Cylinder Block Coolant Pressure (Pressure Cap Removed):

Minimum	
Closed Thermostat - 1800 rpm - No Load	138 kPa [20 psi]
Maximum	
Closed Thermostat	275 kPa [40 psi]

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

Minimum Recommended Operating Coolant Temperature 71°C [160°F]

Maximum Allowable Deaeration Time 35 minutes

Minimum Recommended Pressure Cap 48 kPa [7 psi]

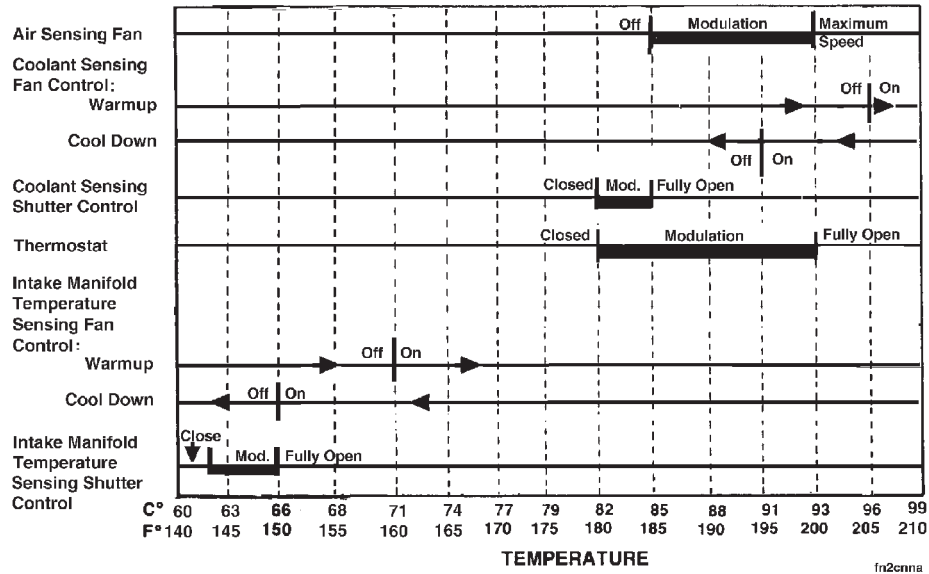
Maximum Allowable Coolant Flow to Accessories — (Liters/Min. [GPM]) 75.7 Liters [20 U.S. gal.]

Coolant Sensing Fan Control:

On	96°C [205°F]
Off	91°C [195°F]

Thermo Control Settings

The temperatures listed in this chart for coolant temperature sensing fan control and intake manifold temperature sensing fan control are correct for vehicles which allow the ECM to control the on/off operation of the cooling fan. Consult your local OEM for other types of control.



General Information

Cummins recommends the use of fully formulated antifreeze or coolant containing a precharge of Supplemental Coolant Additive (SCA). The antifreeze or coolant **must** meet the specifications outlined in The Maintenance Council (TMC) Recommended Practice (RP) 329 (ethylene glycol) or RP 330 (propylene glycol). The use of fully formulated antifreeze or coolant significantly simplifies cooling system maintenance.

Copies of TMC specifications can be obtained through Cummins Engine Company, Inc., or by contacting:

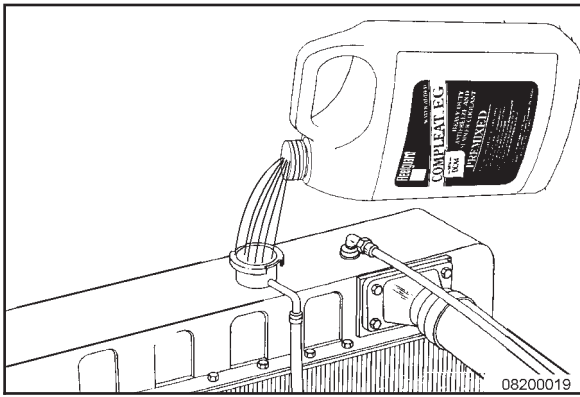
The Maintenance Council
American Trucking Association
 2200 Mill Road
 Alexandria, VA 22314-5388
 Phone (703) 838-1763
 Fax (703) 836-6070

Fully formulated **antifreeze** contains balanced amounts of antifreeze, SCA, and buffering compounds, but does **NOT** contain 50% (percent) water. Fully formulated **coolant** contains balanced amounts of antifreeze, SCA, and buffering compounds already premixed 50/50 with deionized water.

The following pages will give an explanation of water, antifreeze, and SCA's. They will also explain how to test antifreeze and SCA levels.

This section also contains information on cooling system maintenance and a coolant treatment chart that is used to determine the correct SCA service filter.

Alternative maintenance practices for cooling systems can be found in Cummins Coolant Requirements and Maintenance, Bulletin No. 3666132.



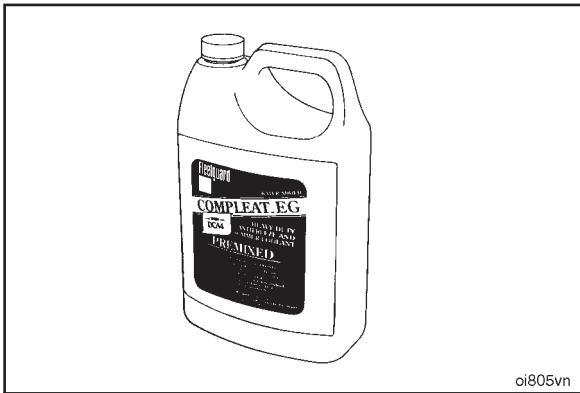
Fully Formulated Coolant/Antifreeze

Cummins Engine Company, Inc. recommends using either a 50/50 mixture of good quality water and fully formulated antifreeze, or fully formulated coolant when filling the cooling system. The fully formulated antifreeze or coolant **must** meet TMC RP 329 or TMC RP 330 specifications.

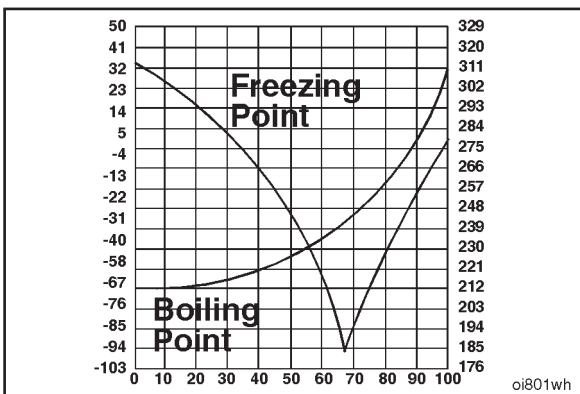
Water Quality	
Calcium Magnesium (Hardness)	Maximum 170 ppm as (CaCO ₃ + MgCO ₃)
Chloride	40 ppm as(Cl)
Sulfur	100 ppm as (SO ₄)

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Good quality water is important for cooling system performance. Excessive levels of calcium and magnesium contribute to scaling problems, and excessive levels of chlorides and sulfates cause cooling system corrosion.

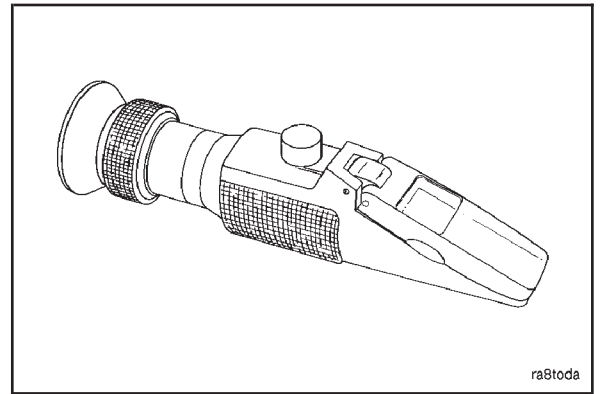


Cummins Engine Company, Inc. recommends using Fleetguard® Compleat. It is available in both glycol forms (ethylene and propylene) and complies with TMC standards.

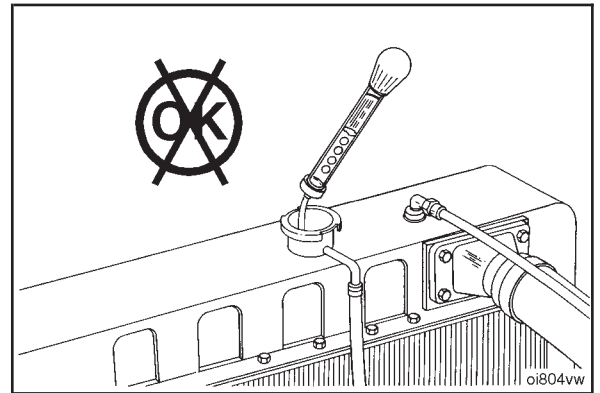


Fully formulated antifreeze **must** be mixed with good quality water at a 50/50 ratio (40 to 60% working range). A 50/50 mixture of antifreeze and water gives a -36°C [-34°F] freeze point and a boiling point of 110°C [228°F], which is adequate for locations in North America. The actual lowest freeze point of ethylene glycol antifreeze is at 68%. Using higher concentrations of antifreeze will raise the freeze point of the solution and increase the possibility of a silicate gel problem.

A refractometer **must** be used to **accurately** measure the freeze point of the coolant.



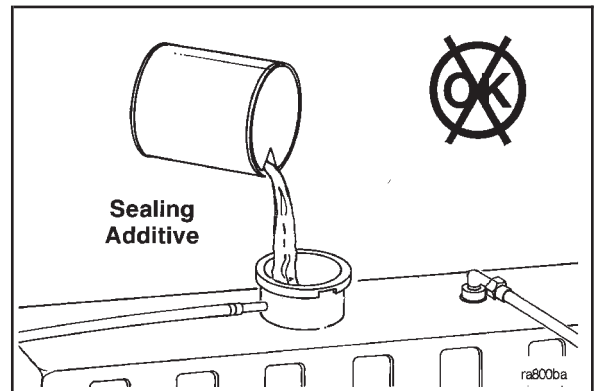
Do **not** use a floating ball hydrometer. Using floating ball hydrometers can give incorrect reading.



Cooling System Sealing Additives

Do **not** use sealing additives in the cooling systems. The use of sealing additives will:

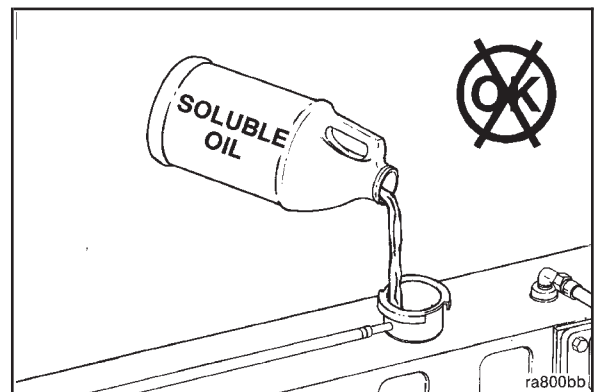
- build up in coolant low flow areas,
- clog coolant filters,
- plug radiator and oil cooler.

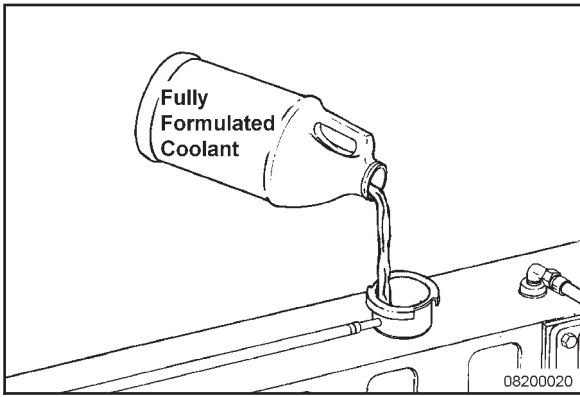


Cooling System Soluble Oils

Do **not** use soluble oils in the cooling system. The use of soluble oils will:

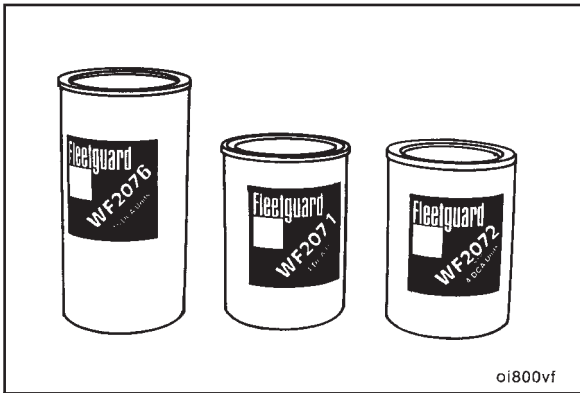
- allow cylinder liner pitting,
- corrode brass and copper,
- damage heat transfer surfaces,
- damage seals and hoses.





Supplemental Coolant Additive (SCA)

Fully formulated products contain SCA's and are required to protect the cooling system from fouling, solder blooming, and general corrosion. The cooling filter is required to protect the coolant system from abrasive materials, debris, and precipitated coolant additives.

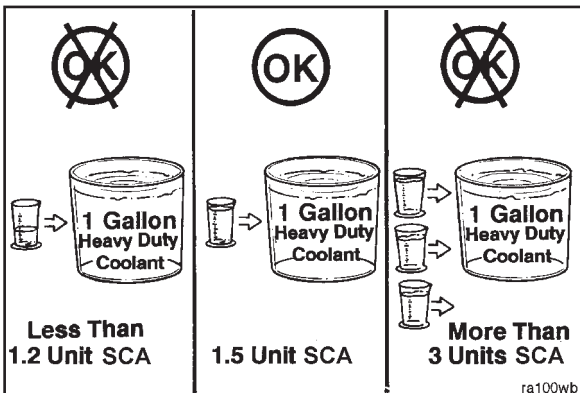


Supplemental coolant additives, or equivalent, are used to prevent liner pitting, corrosion, and scale deposits in the cooling system.

Use the correct Fleetguard® coolant filter to maintain the recommended SCA concentration in the system.

Maintain the correct concentration by changing the service filter at each oil drain interval.

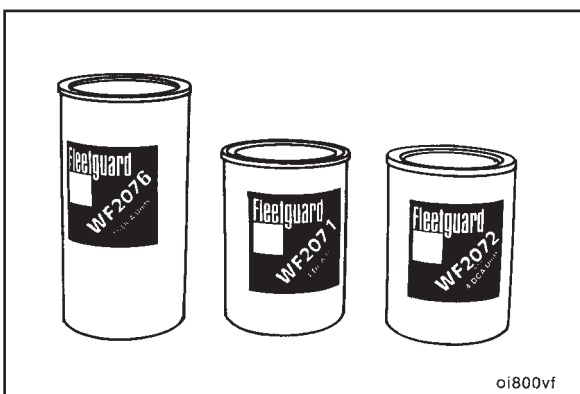
NOTE: The correct filter is determined by the total cooling system capacity and oil drain interval. Refer to the Coolant Capacity Charts.



⚠ CAUTION ⚠

Insufficient concentration of the coolant additives will result in liner pitting and engine failure.

The SCA concentration **must not** fall below 1.2 units or exceed 3 units per gallon of cooling system capacity.



Use the correct Fleetguard® coolant filter to maintain the recommended SCA concentration in the system.

Maintain the correct concentration by changing the service coolant filter at each oil drain interval.

NOTE: The correct filter is determined by the total cooling system capacity and oil drain interval.

Fleetguard® DCA4 Service Filters and Liquid Precharge

DCA4 Service Filters:		DCA (Fleetcool) Service Filters:	
Part No.	SCA Units	Part No.	SCA Units
WF2070	2	WF2050	2
WF2071	4	WF2051	4
WF2072	6	WF2052	6
WF2073	8	WF2053	8
WF2074	12	Not Available	12
WF2075	15	WF2054	15
WF2076	23	WF2055	23
WF2077	(blank filter without SCAs)	WF2077	(blank filter without SCAs)

DCA4 Liquid			DCA (Fleetcool) Liquid		
Part No.	Size	SCA Units	Part No.	Size	SCA Units
DCA60L	0.47 l [1 U.S. pt.]	5	DCA30L	0.47 l [1 U.S. pt.]	5
DCA65L	1.89 l [2 U.S. qt.]	20	DCA35L	1.89 l [2 U.S. qt.]	20
DCA70L	3.78 l [1 U.S. gal]	40	DCA40L	3.78 l [1 U.S. gal]	40
DCA75L	18.9 l [5 U.S. gal]	200	DCA45L	18.9 l [5 U.S. gal]	200
DCA80L	208 l [55 U.S. gal]	2200	DCA50L	208 l [55 U.S. gal]	2200

Maintenance Intervals for Cooling Systems up to 76 Liters [20 U.S. Gallons]

Install service filter(s) and/or liquid containing number of SCA units below:						
Service Interval			System Size in Liters [U.S. Gallons]			
Kilometers	[Miles]	[Hours]	4-19	19-38	42-57	60-76
			[1-5]	[6-10]	[11-15]	[16-20]
72001-80000	[45001-50000]	1126-1250	8	12	23	30
64001-72000	[40001-45000]	1001-1125	4	12	15	26
56001-64000	[35001-40000]	876-1000	4	8	12	23
48001-56000	[30001-35000]	751-875	4	6	12	20
40001-48000	[25001-30000]	626-750	4	6	10	18
32001-40000	[20001-25000]	501-625	2	6	8	15
24001-32000	[15001-20000]	376-500	2	4	6	12
16001-24000	[10001-15000]	251-375	2	4	6	8
0-16000	[0-10000]	0-250	2	2	4	6

Maintenance Intervals for Cooling System up to 1514 Liters [400 U.S. Gallons]

Install service filter(s) and/or liquid containing number of SCA units below:										
Service Interval	System Size in Liters [U.S. Gallons]									
	79-144	117-189	193-284	288-378	382-568	572-757	761-946	950-1135	1139-1325	1329-1574
Hours	[21-30]	[31-50]	[51-75]	[76-100]	[101-150]	[151-200]	[201-250]	[251-300]	[301-350]	[351-400]
751-1000	25	50	80	100	150	200	250	300	350	400
501-750	20	35	60	75	110	150	190	225	260	300
251-500	15	25	40	50	75	100	125	150	175	200
0-250	10	15	20	25	40	50	65	75	90	100

Notes:

- A. Consult the vehicle equipment manufacturer’s maintenance information for total cooling system capacity.
- B. When draining and replacing the coolant, **always** pre-charge the cooling system to a SCA level of 1.5 units per gallon. This concentration level **must never** be allowed to go below 1.2 units and **must** be controlled when the level is greater than 3 units. Action needed when the level goes below 1.2 is a filter and liquid pre-charge; from 1.2 to 3.0 units, filter only; above 3.0, test at every oil change until level falls to 3.0 or below.

NOTE: When performing service which requires draining the cooling system, take special precautions to collect it in a clean container, seal it to prevent contamination, and save for reuse.

- C. Change coolant filters at each oil change to protect the cooling system. Consult the coolant capacity chart to determine the correct coolant filter for a given cooling system capacity and oil drain interval.

Testing SCA Concentration Level CC-2602 Test Kit

Carefully follow the instructions to test the coolant and take the appropriate action recommended by the kit.

Precautions and Instructions for Proper Kit Use

- The coolant sample to be tested **must** be between 10° and 54°C [50° and 130°F]. If the sample is too cold or too hot, you will get incorrect results.
- To get the best color match results, compare test strip pads to the color chart in daylight or under cool white fluorescent lighting. If unsure about a specific color match when a test does fall between two colors on the color chart, choose the lower numbered block. It is safer to underestimate your results than to overestimate.
- The test strips do have a limited shelf life and are sensitive to humidity and extreme heat. Proper handling and storage is necessary to protect the life of the strips.
- Keep the cap tightly sealed on the test strip bottle except when removing a strip. Store away from direct sunlight and in an area where the temperature will generally stay below 32°C [90°F].
- Do **not** use the test strips after the expiration date stamped on the bottle.
- Discard the kit if any of the pads on the unused strips have turned light brown or pink.
- Use one strip at a time and take care **not** to touch any of the pads on the strip. Doing so will contaminate the pads and affect the test results.
- If the strip container is left uncapped for 24 hours, moisture in the air will render the strips useless, although no discoloration will be evident.
- Only use the color chart supplied with the kit.
- Clean and dry the sample cup and syringe after each use. This will prevent contaminating future samples.
- Following the correct test times is very important. Use a clock or stopwatch.

Test Intervals

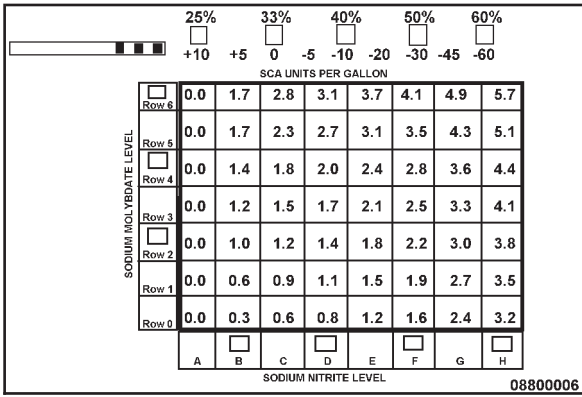
Testing is recommended if the operator is **not** sure of his cooling system condition due to leaks, uncontrolled topping off of the system, or major coolant loss.

Testing is also recommended twice a year to monitor the SCA level. If the SCA level is above 3 units, test at subsequent oil drain intervals until the concentration is back under 3 units. When the concentration is back under 3 units, start installing the correct service filters at each drain interval.

If the concentration is below 1.2 units per gallon, replace the filter and precharge with liquid.

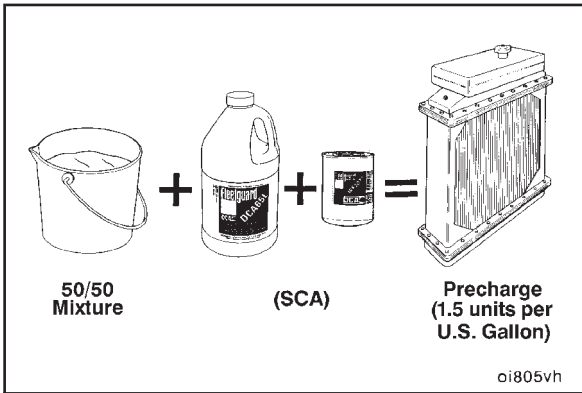
If the concentration is 1.2 to 3 units per gallon, replace the filter.

If the concentration is above 3 units per gallon, do **not** replace the service filter. Test the coolant at subsequent oil drain intervals until the concentration is back under 3 units. When the concentration is back under 3 units, start installing service filters at each oil change interval.



NOTE: Do not utilize the test kit to maintain minimum SCA concentration levels (i.e., 1.5 units).

NOTE: In some instances the A or B reading can be high. However, it is the combined reading that is important. **So, always follow the chart.**



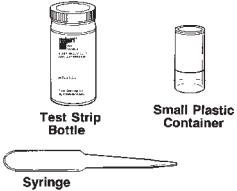
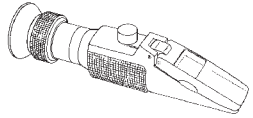
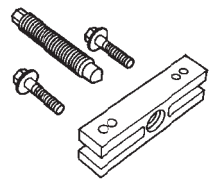
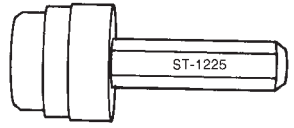
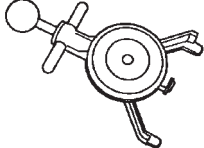

Coolant Replacement Requirements

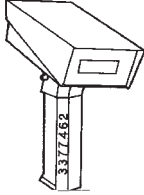
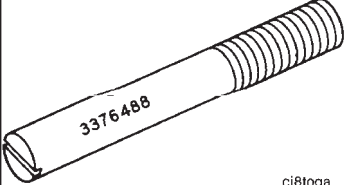
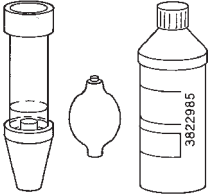
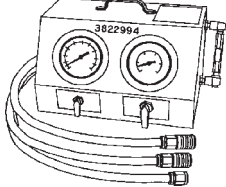
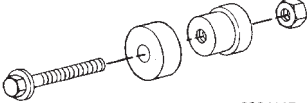
Drain and flush the cooling system after 6,000 hours, or 2 years of service. Refill with either new **fully formulated coolant** or a 50/50 mixture of good quality water and fully formulated antifreeze, and install the correct service coolant filter.

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

Service Tools Cooling System

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

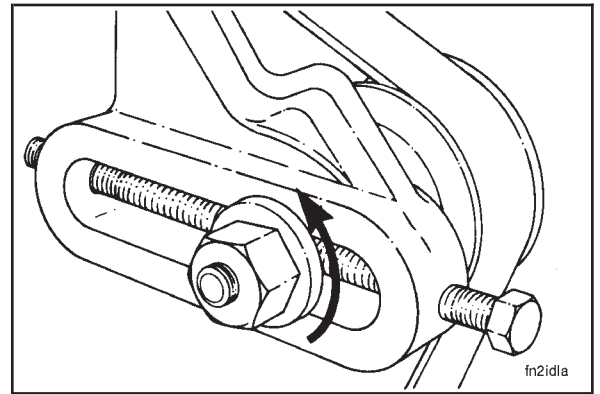
Tool No.	Tool Description	Tool Illustration
CC-2602	<p>Cooling System Test Kit</p> <p>The Fleetguard® Coolant Test Kit is used to check the concentration of coolant additives in the cooling system.</p>	 <p>Test Strip Bottle</p> <p>Small Plastic Container</p> <p>Syringe</p>
CC-2800	<p>Refractometer</p> <p>The Fleetguard® Refractometer is used to measure the freeze point protection and antifreeze concentration.</p>	 <p>ra800a</p>
ST-647	<p>Standard Puller</p> <p>Remove the stamped steel water pump pulley. Use with two capscrews 5/16 X 18 X 2.</p>	 <p>ad8toga</p>
ST-1225	<p>Thermostat Seal Mandrel</p> <p>Install the thermostat seal in the thermostat housing.</p>	 <p>ST-1225</p> <p>th2togb</p>
ST-1293	<p>Belt Tension Gauge</p> <p>Measure the fan drive v-ribbed belt tension.</p>	 <p>fa8togc</p>
3376326	<p>Pulley Installation Tool</p> <p>Install drive pulleys. Use in conjunction with Part No. 3377401 Adapter.</p>	 <p>ad8togb</p>

Tool No.	Tool Description	Tool Illustration
3377462	<p>Digital Optical Tachometer Used to measure RPM of a viscous fan.</p>	 <p>3377462</p>
3376488	<p>Guide Pin Two guide pins are used to install the water header plate.</p>	 <p>3376488</p>
3822985	<p>Combustion Gas Leak Test Kit Includes: Part No. 3822986 Test Fluid, Part No. 3822987 Adapter, and Part No. 3877612 Instructions.</p>	 <p>3822985</p>
3822994	<p>Coolant Pressure/Temperature/Flow Analyzer Kit Includes: Part No. 3822995 Pressure Gauge, Part No. 3822996 Temperature Gauge, Part No. 3822997 Flow Sight Glass, Part No. 3822998 Compuchek® Fitting (Female) and Part No. 3377613 Instructions. Optional: Part No. 3823099, Hose Extension Kit, is also available.</p>	 <p>3822994</p>
3824117	<p>Bearing Installation Tool Used to replace the water pump drive needle bearing in the gear housing.</p>	 <p>3824117</p>

Drive Belt, Cooling Fan (008-002)

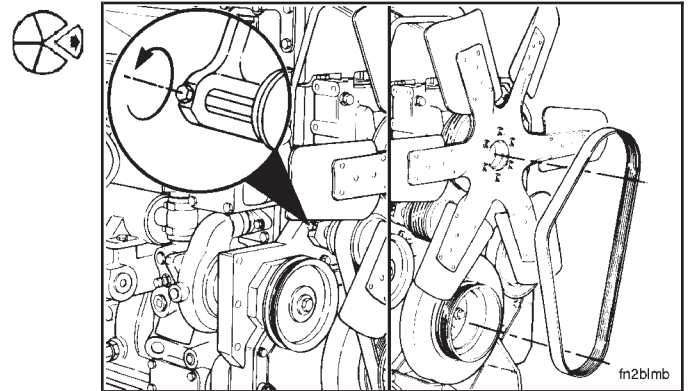
Remove (008-002-002)

Loosen the fan idler pulley shaft locknut.



Turn the adjusting screw **counterclockwise** to release the belt tension.

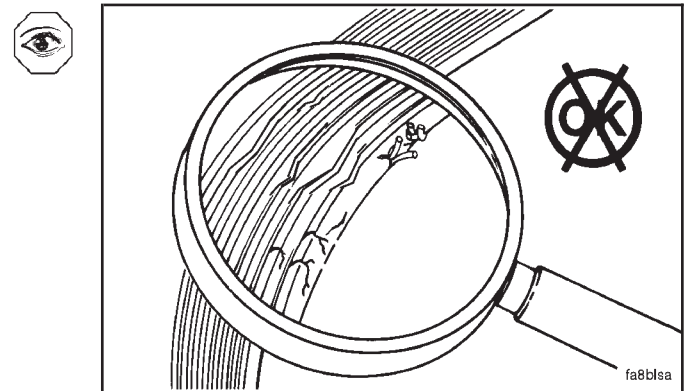
Move the fan idler pulley and fan pulley centers as close as possible. The belt can then be removed without excessive force.



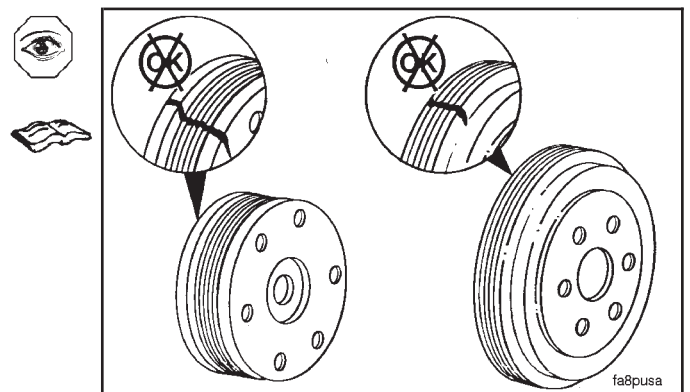
Inspect for Reuse (008-002-007)

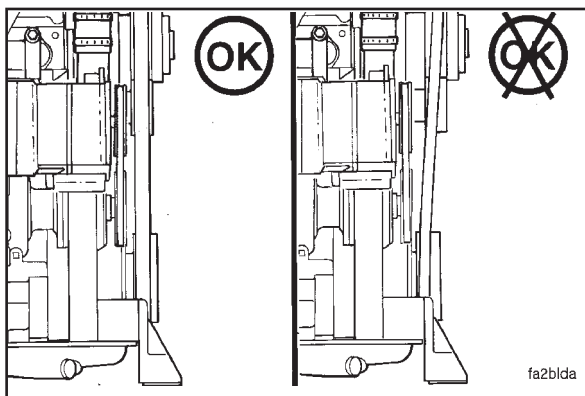
Visually inspect the belt for:

- Cracks
- Glazing
- Tears or cuts
- Excessive wear

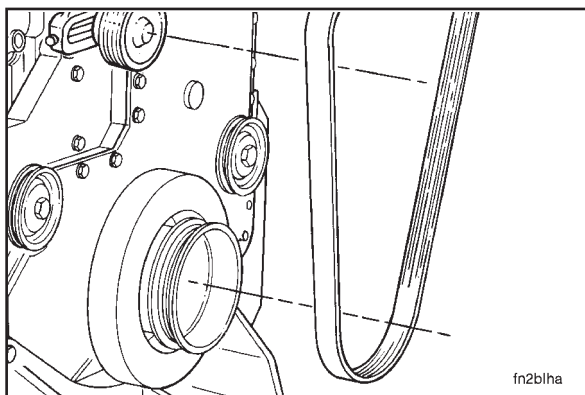


Visually inspect the fan idler pulley and the fan drive pulley for cracks or broken grooves. Replace the pulleys if necessary. Refer to Procedures 008-030 and 008-039.





Visually inspect pulley alignment. Replace the fan idler pulley and fan hub pulley if they are **not** in alignment. Refer to Procedures 008-030 and 008-039.

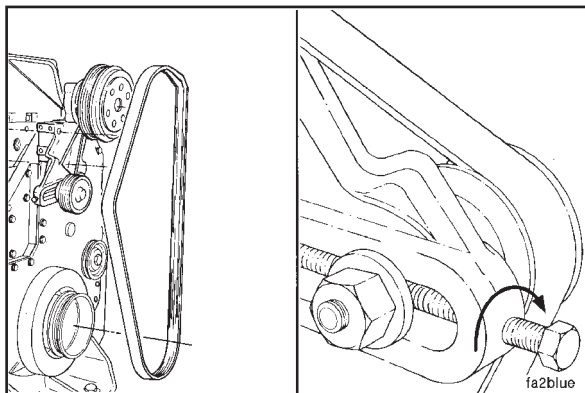


Install (008-002-026)

CAUTION

To prevent damage to the pulley and new belt, do not roll the belt over the pulley or pry it on with a tool.

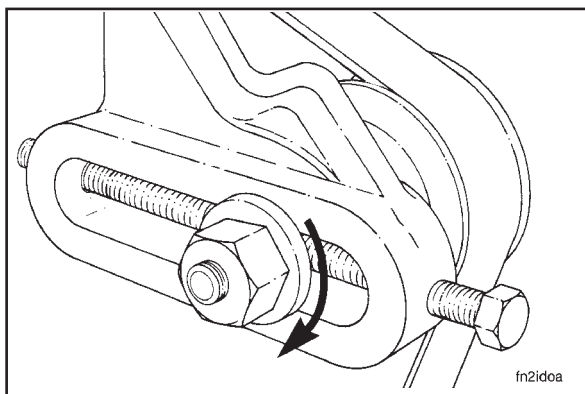
Install a new fan belt on the pulleys.



Use belt tension gauge, Part No. ST-1293, to measure the belt tension. Refer to Drive Belt Tension in Section V for the correct belt tension for the belt you are installing.

Turn the adjusting screw to adjust the belt tension.

NOTE: A belt is considered used if it has been in operation 10 minutes or longer. If used belt tension is below the minimum value, tighten the belt to the maximum value. Replace the belt if it will **not** maintain correct tension.



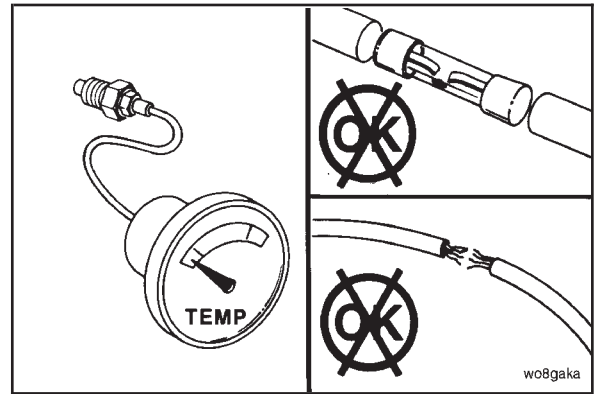
Tighten the idler pulley shaft locknut.

Torque Value: 190 N•m [140 ft-lb]

Coolant Temperature Gauge (008-004) Initial Check (008-004-001)

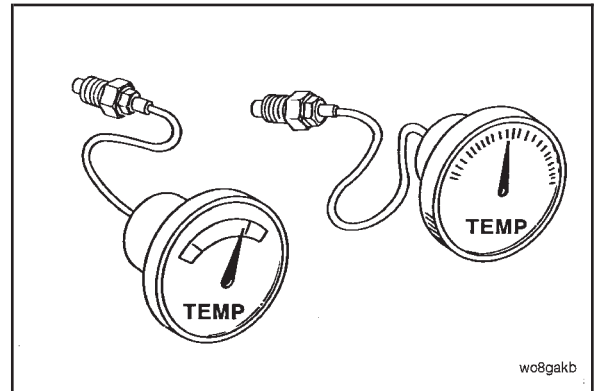
Check for a blown fuse.

Check the wiring from the gauge to the sending unit for a broken connection.



Use a temperature gauge of known accuracy to check the existing gauge.

Replace a faulty gauge.



Coolant Filter (008-006) Remove (008-006-002)

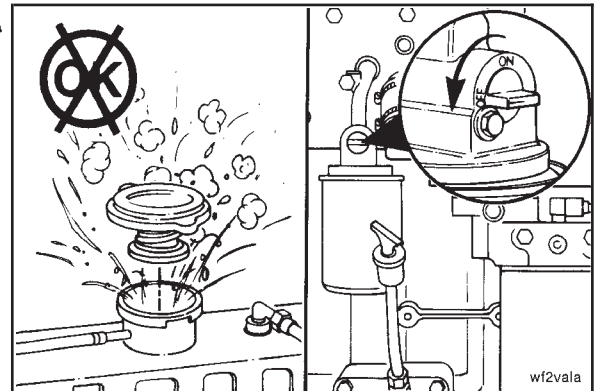


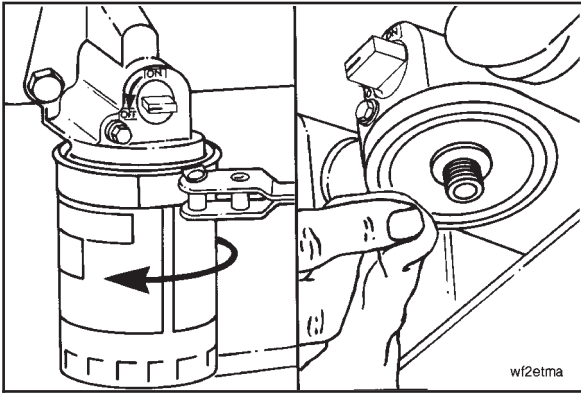
Do not remove the radiator cap from a hot engine. Hot steam will cause serious personal injury. Remove the coolant system pressure cap and close the shutoff valve(s), if equipped, before removing the coolant filter. Failure to do so can result in personal injury from heated coolant spray.

Do **not** use force to open or close the shutoff valve. If the valve does **not** turn freely, refer to Procedure 008-007.

Remove the radiator pressure cap.

Turn the valve on the coolant filter head to the "OFF" position.



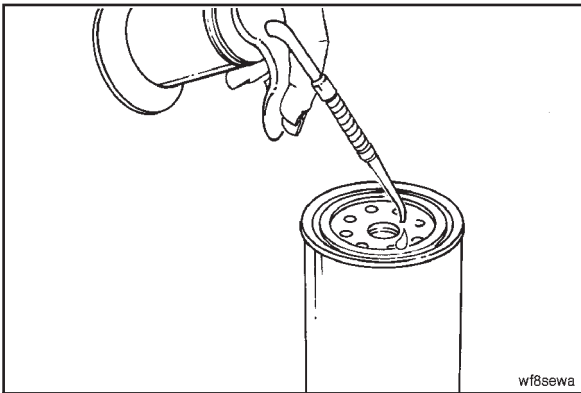


⚠ WARNING ⚠

There could be slight coolant leakage with the valve in the "OFF" position. Use caution when cleaning the gasket surface to avoid contact with hot coolant. Failure to do so can result in personal injury from heated coolant.

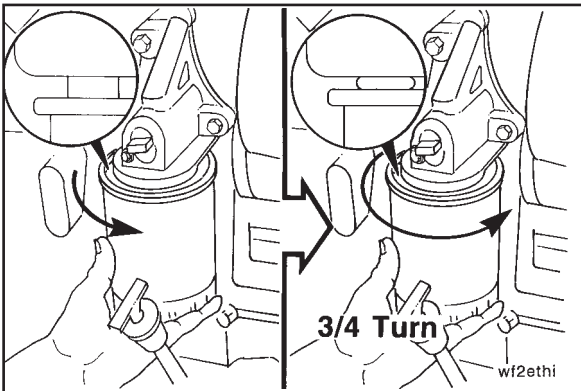


Remove and discard the coolant filter. Clean the gasket surface.



Install (008-006-026)

Apply a film of lubricating oil to the gasket sealing surface before installing the new coolant filter.



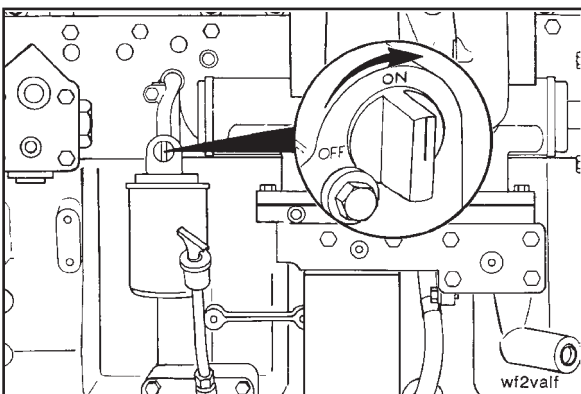
⚠ CAUTION ⚠

Mechanical over-tightening can distort the filter threads or damage the filter head.



Install the new filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten the filter an additional one-half to three-fourths of a turn, or as specified by the filter manufacturer.



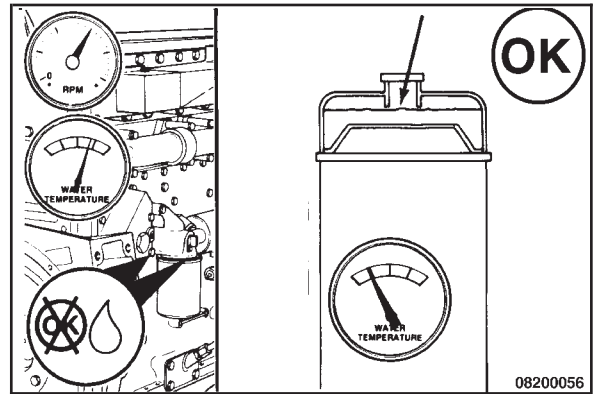
⚠ CAUTION ⚠

The valve must be in the "ON" position to prevent engine damage.

Turn the valve on the filter head to the "ON" position and install the coolant system pressure cap.

Operate the engine and check for leaks.

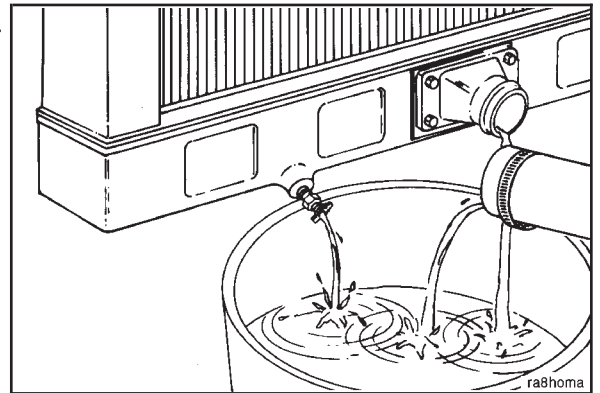
After the air has been purged from the system, check the coolant level again.



Coolant Filter Head (008-007)

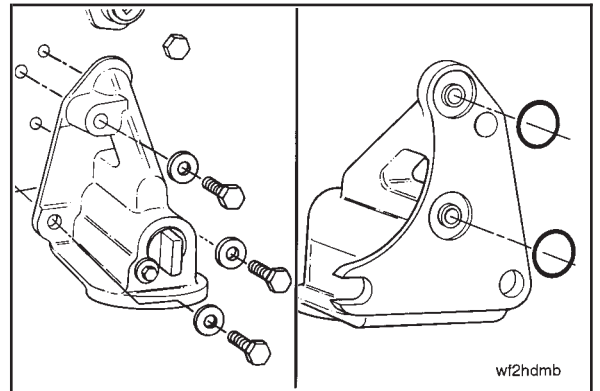
Remove (008-007-002)

Drain the cooling system. Refer to Procedure 008-018-005.



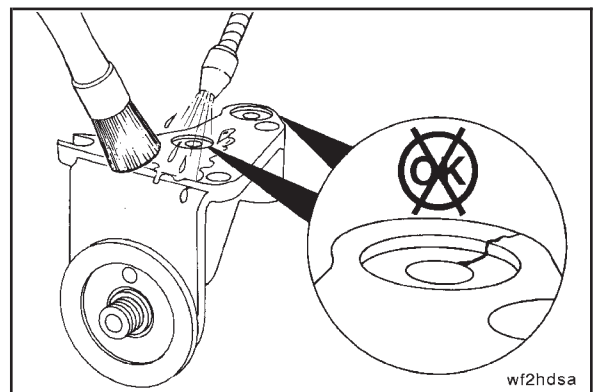
Remove the three capscrews and the filter head.

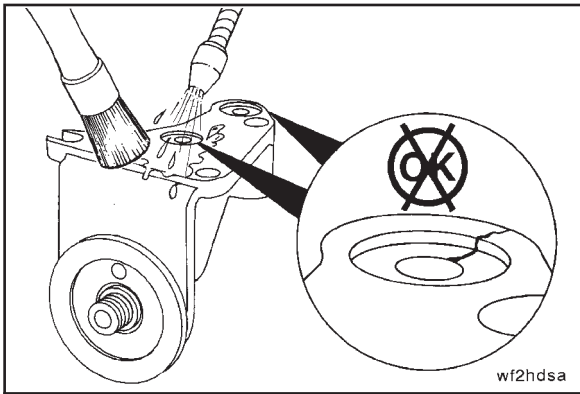
Remove the two o-rings.



Clean (008-007-006)

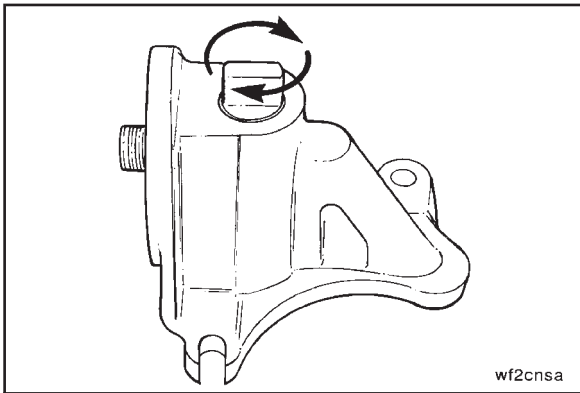
Use solvent to clean the filter head. Dry with compressed air.



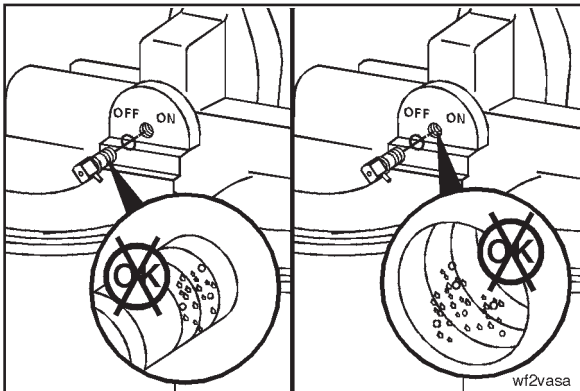


Inspect for Reuse (008-007-007)

Visually inspect the filter head for cracks or other damage.



Turn the control valve by hand. If the valve does **not** rotate freely, remove and inspect the valve.



To remove the valve, remove the capscrew and pull the valve out of the housing.

Remove the o-ring from the valve.

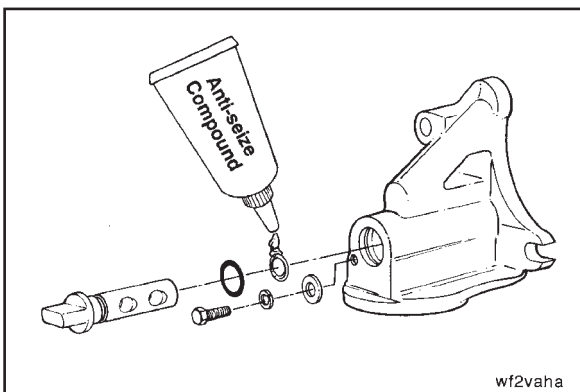


Inspect the valve for corrosion or pitting.

Inspect the housing bore for corrosion or pitting.



Clean or replace the valve and housing if necessary.



Install (008-007-026)

Install a new o-ring on the valve.

Lubricate the o-ring with a film of anti-seize compound.



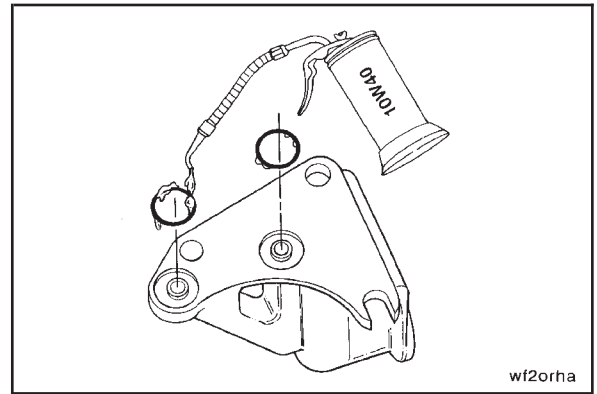
Install the valve in the filter head.

Tighten the capscrew.



Torque Value: 10 N•m [90 in-lb]

Use clean 15W-40 oil to lubricate the two new o-rings.
Install the o-rings on the filter head.



▲ CAUTION ▲

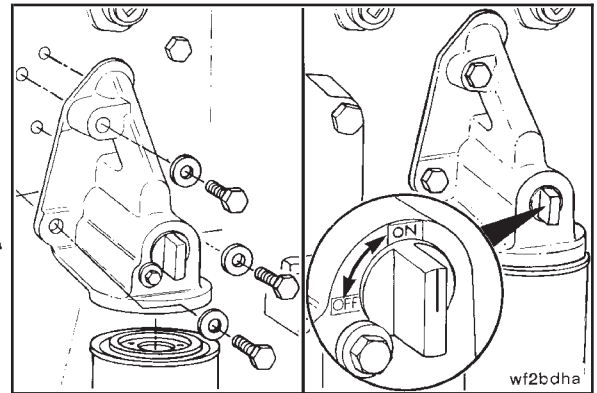
The control valve must be in the “ON” position to prevent engine damage.

Install the filter head and filter if removed.

Tighten the capscrews.

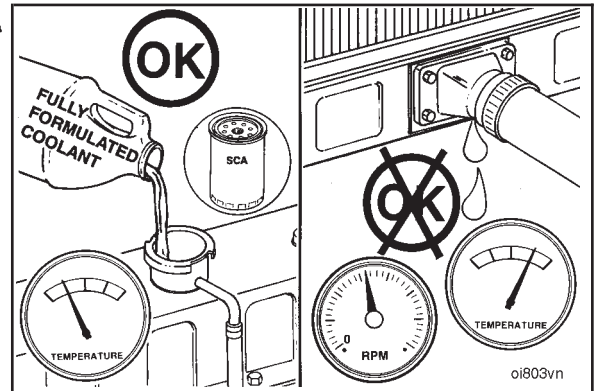
Torque Value: 54 N•m [40 ft-lb]

Turn the control valve to the “ON” position.



Fill the cooling system. Refer to Procedure 008-018-028.

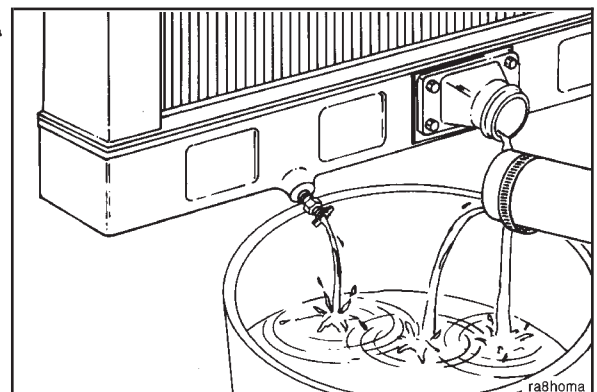
Operate the engine until it reaches a temperature of 80°C [180°F] and check for coolant leaks.

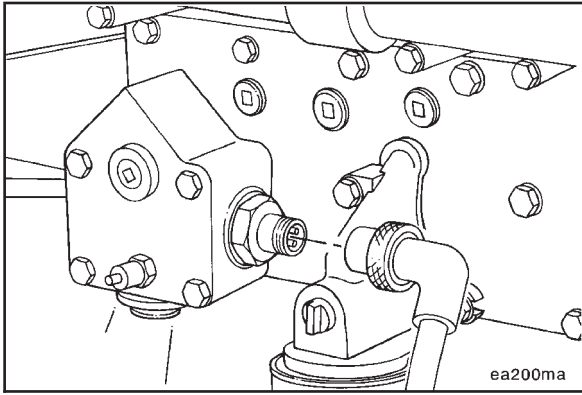


Coolant Heater Housing (008-012)

Remove (008-012-002)

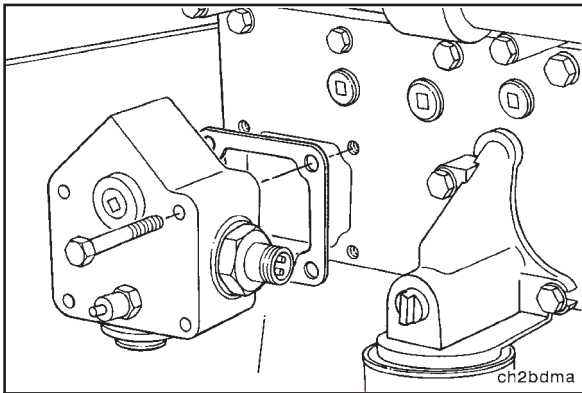
Drain the cooling system. Refer to Procedure 008-018-005.





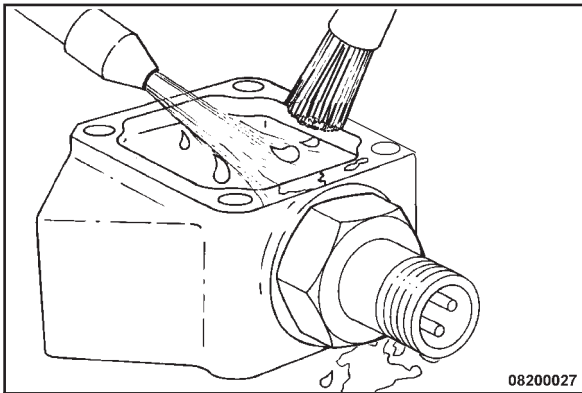
Disconnect the electrical wiring from the cylinder block heater, if used.

Remove any additional fittings or accessories from the housing.



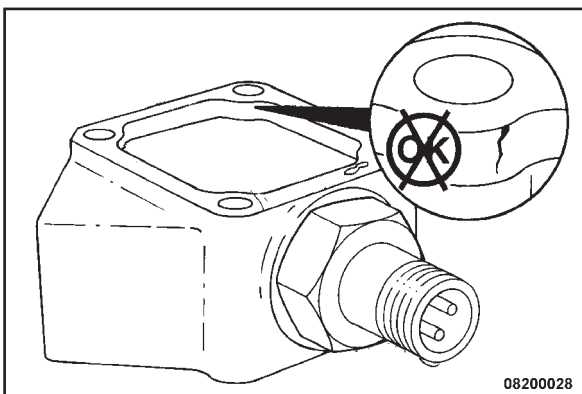
Remove the four mounting capscrews from the heater housing.

Remove the heater housing and gasket.



Clean (008-012-006)

Use solvent to clean the heater housing. Dry with compressed air.



Inspect for Reuse (008-012-007)

Visually inspect the housing for cracks or other damage.

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

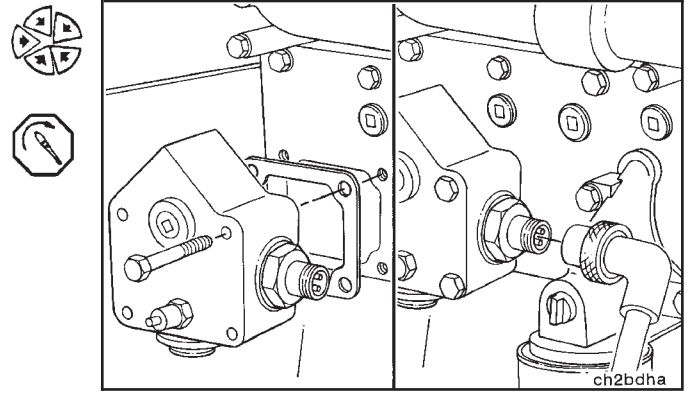


Install (008-012-026)

Use a new gasket to install the heater housing.
Install the four mounting capscrews and tighten.

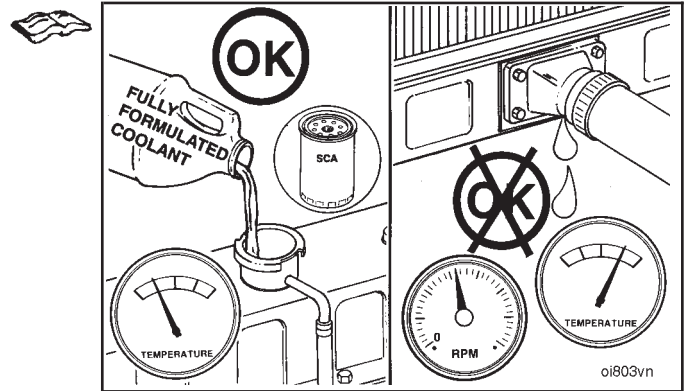
Torque Value: 54 N•m [40 ft-lb]

Connect the electrical wiring to the heater, if used.



Fill the cooling system. Refer to Procedure 008-018-028.

Operate the engine until it reaches a temperature of 80°C [180°F], and check for leaks.

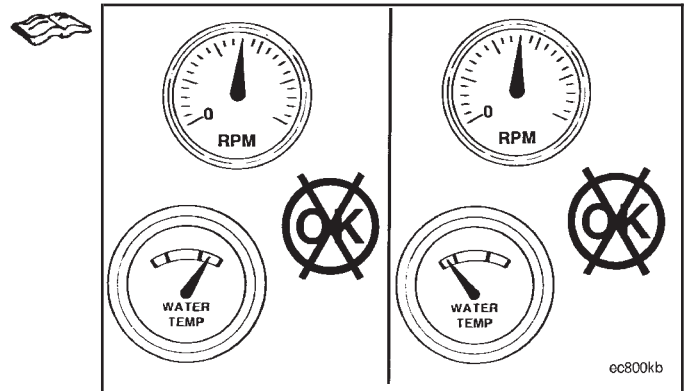


Coolant Thermostat (008-013)

Leak Test (008-013-014)

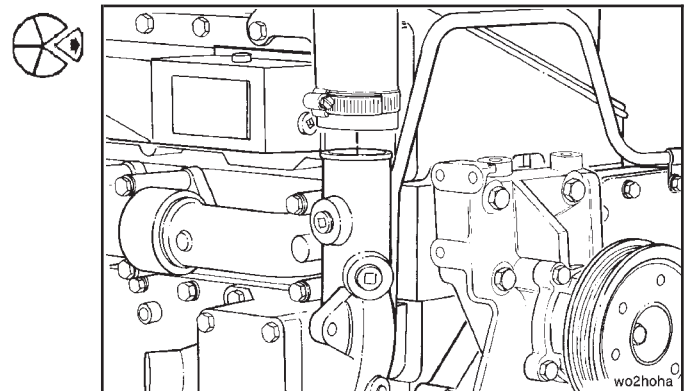
The engine thermostat and thermostat seal **must** operate properly in order for the engine to operate in the most efficient heat range. Overheating or overcooling will shorten engine life.

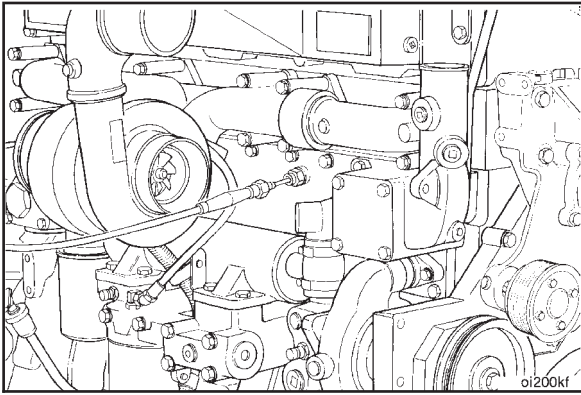
Refer to Procedure 008-016 to inspect the thermostat seal.



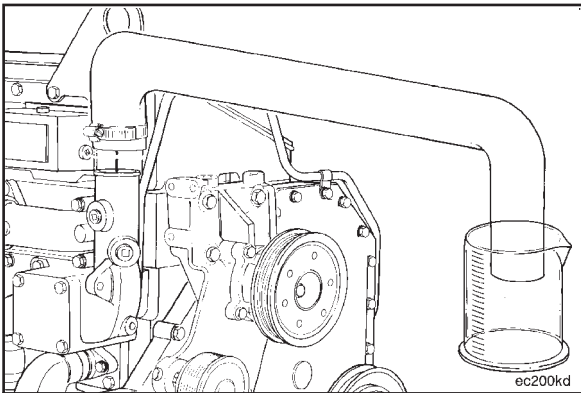
Complete this test with the engine coolant temperature below 50°C [120°F]. Hot steam can cause serious personal injury.

Remove the radiator hose from the thermostat housing.





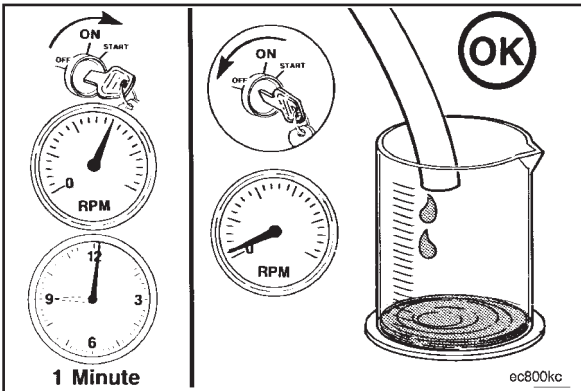
Install a thermocouple or temperature gauge which is known to be accurate in the water header plate or engine side of the thermostat housing.



Install a hose of the same size on the thermostat housing outlet long enough to reach a remote dry container used to collect coolant.

Install and tighten a hose clamp on the housing outlet.

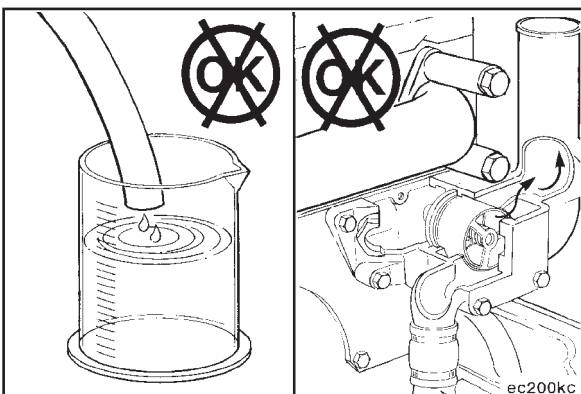
Place the other end of the hose in a dry container.



Operate the engine at rated rpm for one (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. ounces].



If more than 100 cc [3.3 fl. ounces] of coolant is collected, the thermostat or thermostat seal is leaking and **must** be replaced. Refer to Procedure 008-016 to replace the thermostat seal.



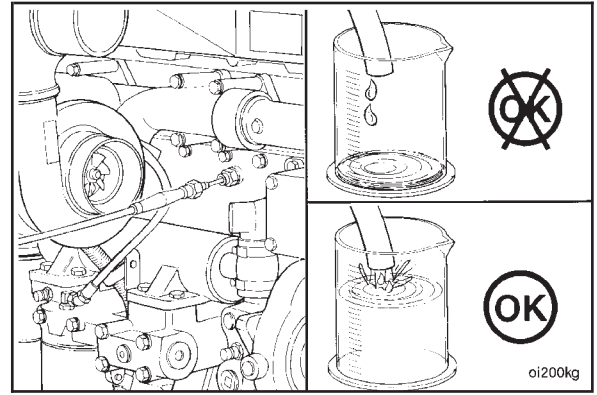
Complete the following test in-chassis to test the thermostat opening temperature.

Start the engine and monitor the water temperature gauge and the container.

Thermostat Initial Opening Temperature		
°C		°F
81	MIN	178
83	MAX	182

Shut off the engine when the coolant starts to flow.

If coolant does **not** start flowing into the container during the initial opening temperature range, the thermostat **must** be replaced.

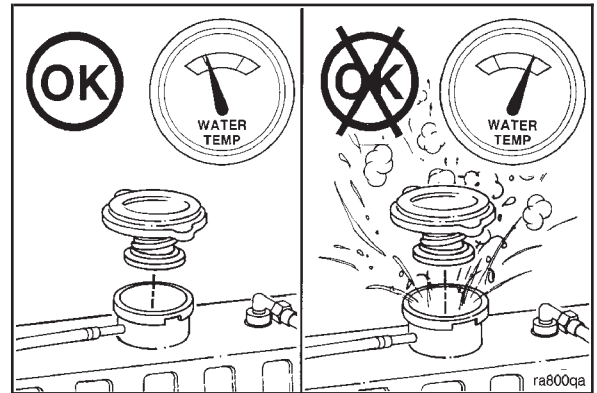


Remove (008-013-002)



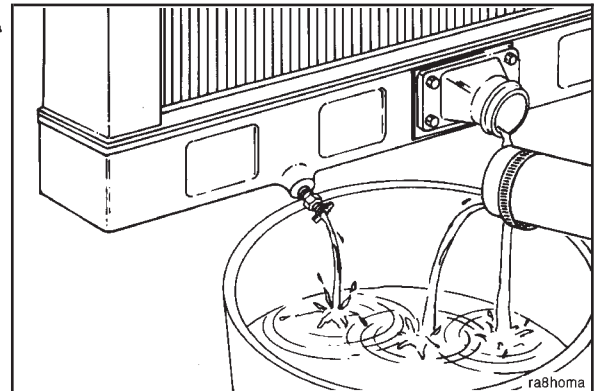
Do not remove the radiator cap from a hot engine. Wait until the temperature is below 50°C [120°F] before removing the coolant system pressure cap. Failure to do so can cause serious personal injury from heated coolant spray.

Remove the radiator cap after the engine is cool.



NOTE: If the coolant will **not** be reused, dispose of the coolant in accordance with federal, state, and local environmental regulations.

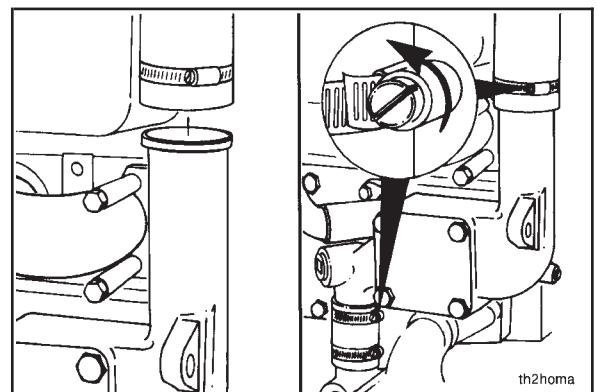
Drain the cooling system. Refer to Procedure 008-018-005.

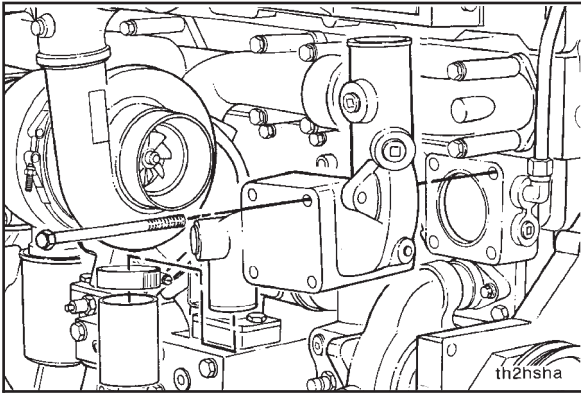


Remove the upper radiator hose from the thermostat housing.

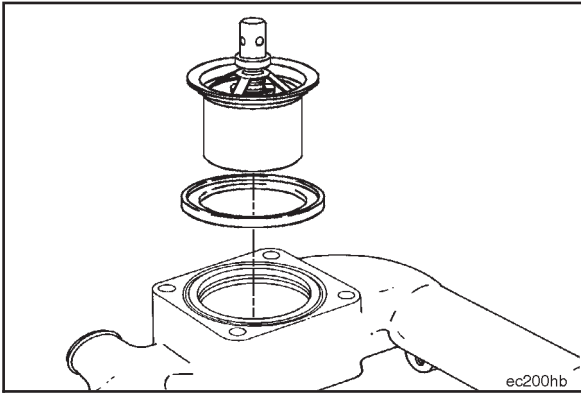
Loosen the coolant bypass hose clamps.

NOTE: Some models could have a converter cooler disc located in the bypass hose. Refer to Procedure 008-065.

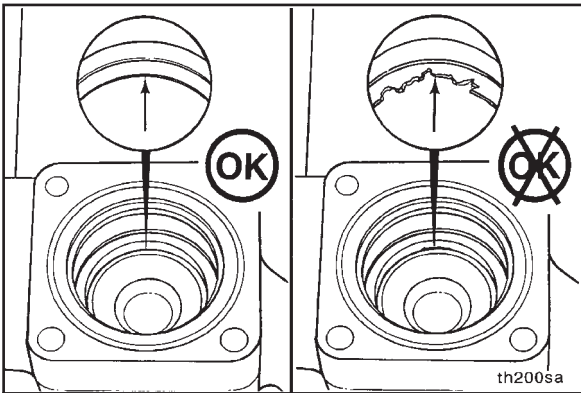




Remove the four thermostat housing mounting capscrews and the thermostat housing.



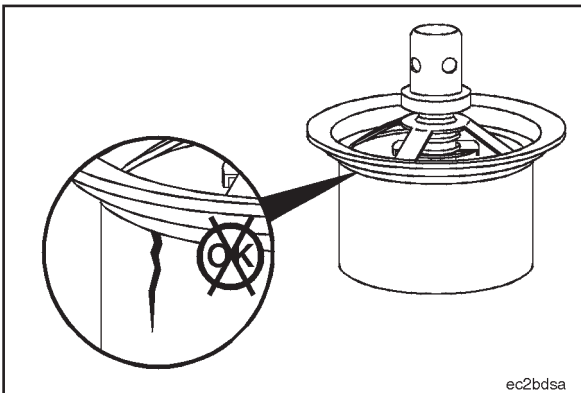
Remove the thermostat from the housing.



Inspect for Reuse (008-013-007)

Visually inspect the thermostat seal for cracks, corrosion, or other damage.

If the seal is damaged, it **must** be replaced. Refer to Procedure 008-016.

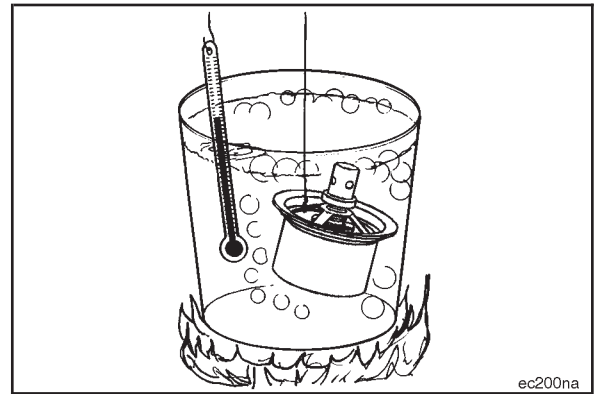


Visually inspect the thermostat for damage.

Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.

NOTE: Do **not** allow the thermostat or thermometer to touch the container.

Heat the water and check the thermostat as follows:

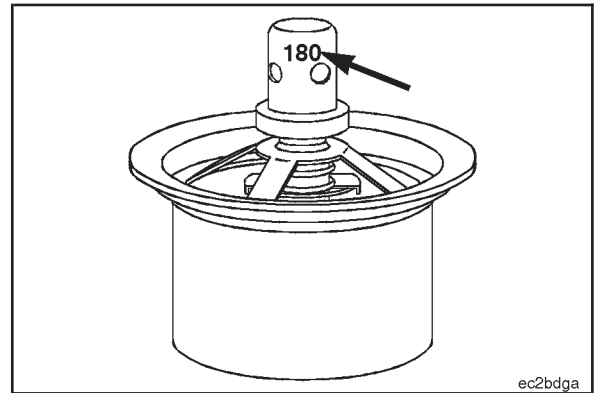


The nominal operating temperature is stamped on the thermostat.

- Thermostat **must** begin to open within 1°C [2°F] of nominal temperature.
- Thermostat **must** be fully open within 12°C [22°F] of nominal temperature.

The fully open distance between the thermostat flange and housing is 11 mm [0.435 inch].

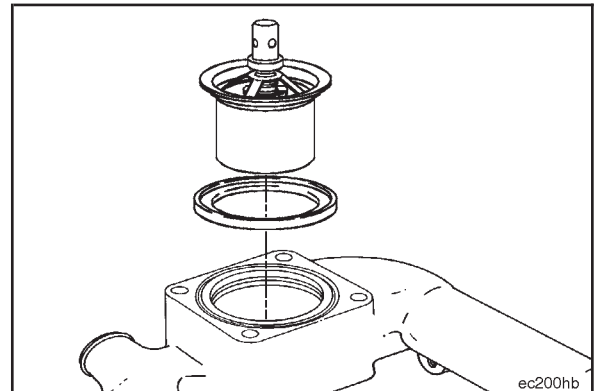
If the thermostat operates properly and more than 100 cc [3.3 fl. ounces] leakage is detected during in-chassis test, replace the thermostat seal. Refer to Procedure 008-016.



Install (008-013-026)

Install the thermostat in the housing.

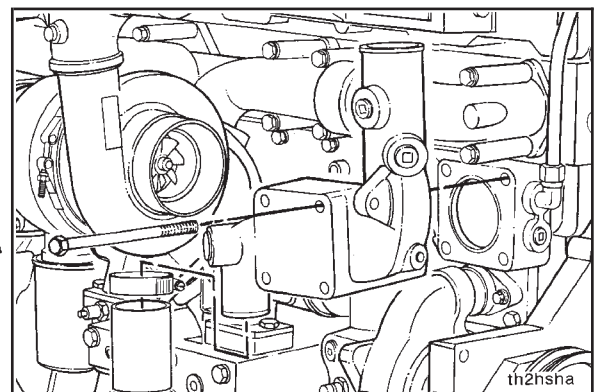
Install a new seal in the groove on the thermostat housing mounting surface.

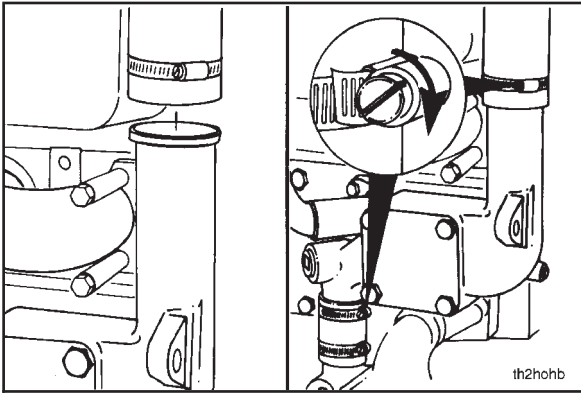


Install the hose on the thermostat housing bypass outlet.
Install the thermostat housing and four mounting capscrews.

Torque Value: 54 N•m [40 ft-lb]

NOTE: If a torque converter cooler disc is used in the coolant bypass hose, refer to Procedure 008-065.



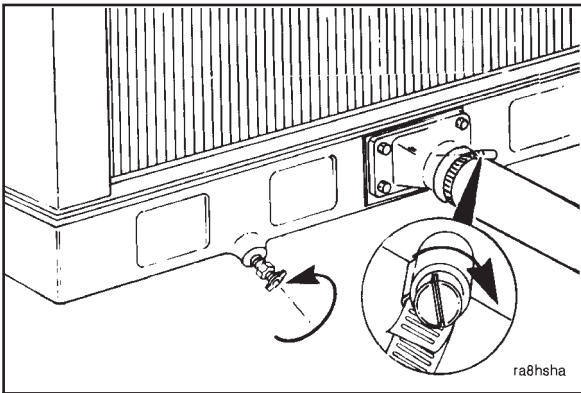


Install the upper radiator hose to the thermostat housing outlet. Refer to the manufacturer's specifications for the correct torque value.



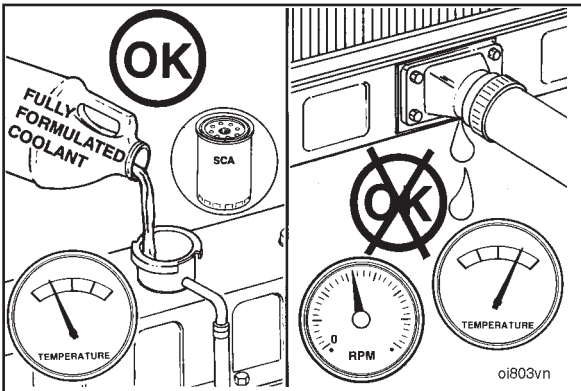
Tighten the coolant bypass hose clamps.

Torque Value: 3 N•m [30 in-lb]



Close the radiator draincock and install the lower radiator hose.

Tighten the hose clamp. Refer to the manufacturer's specifications for the correct torque value.

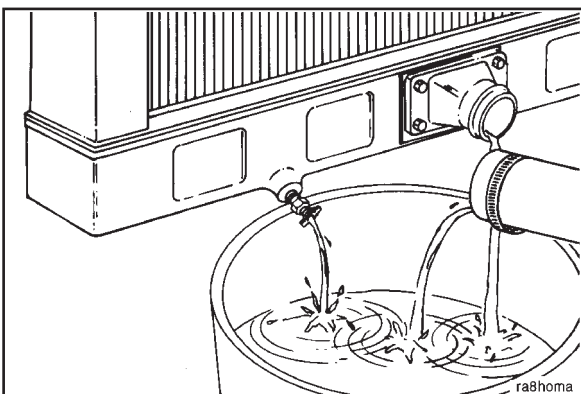


The correct concentration of coolant additives **must** be used in the cooling system. Refer to Section V.



Fill the cooling system.

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



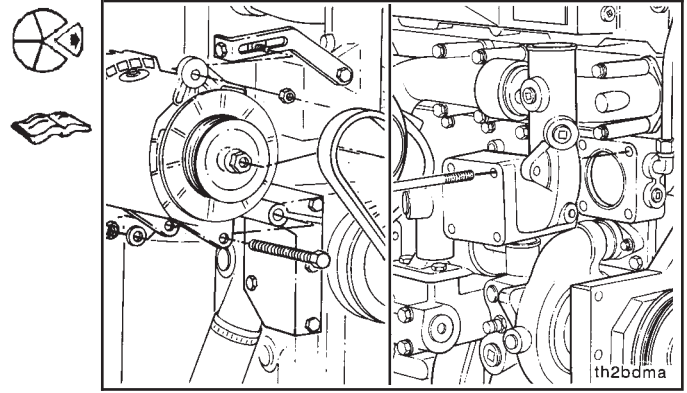
Coolant Thermostat Housing Support (008-015)

Remove (008-015-002)

Drain the cooling system. Refer to Procedure 008-018-005.

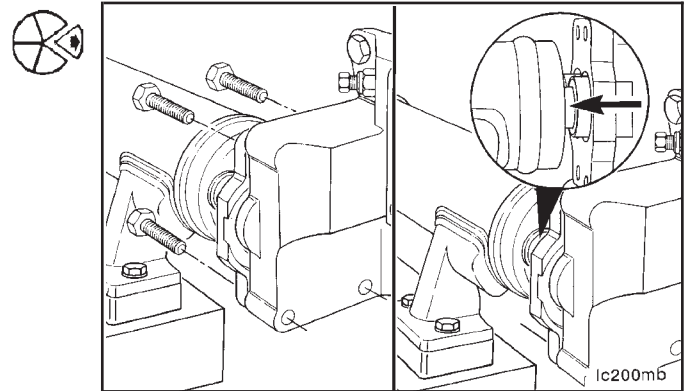
Remove the alternator drive belt and the alternator. Refer to Procedures 013-005-002 and 013-001-002.

Remove the thermostat housing and bypass hose. Refer to Procedure 008-014-002.

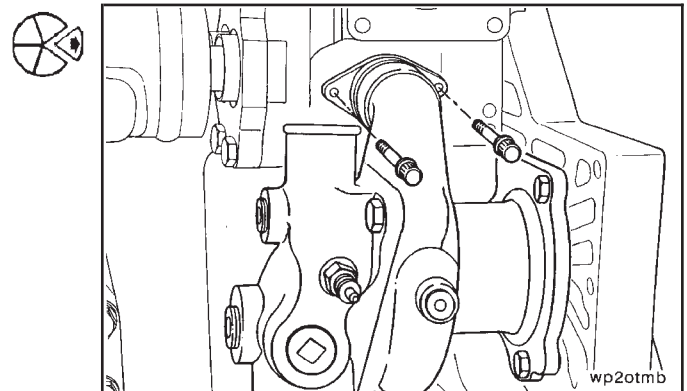


Remove the four lubricating oil cooler thermostat support flange capscrews.

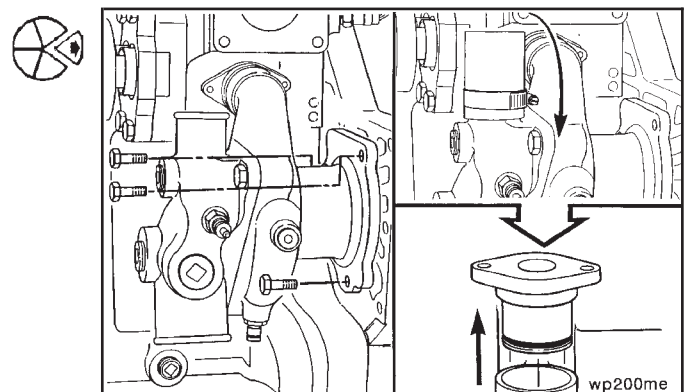
Push the water transfer tube connections into the lubricating oil cooler as far as possible.

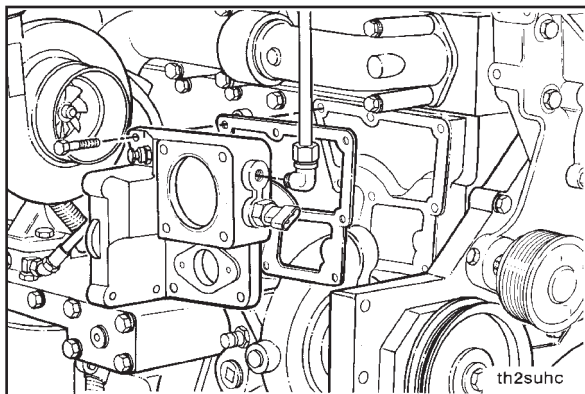


Remove the two water transfer tube mounting capscrews.



Remove the three water pump mounting capscrews.
Twist the water pump outward and remove the water transfer tube from the water pump body.

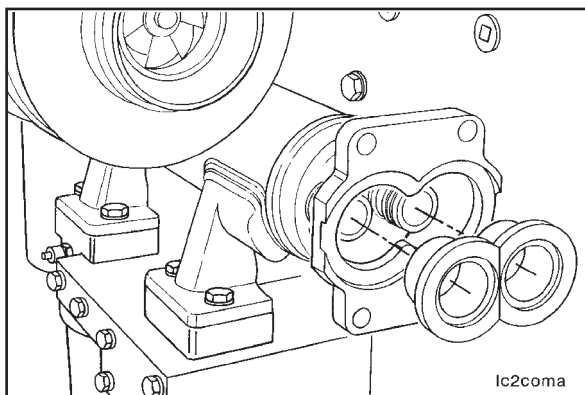




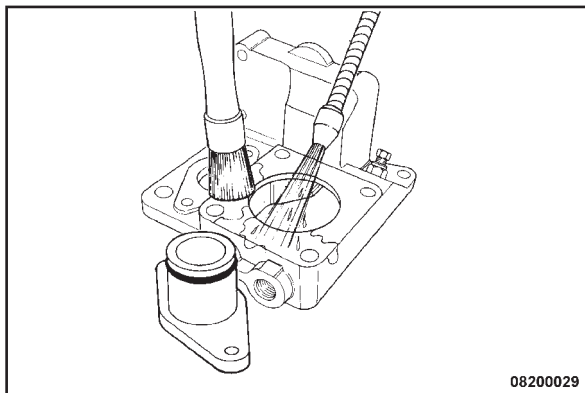
Remove the air compressor coolant supply line.

Remove the coolant temperature sensor.

Remove the remaining capscrews and the thermostat housing support.



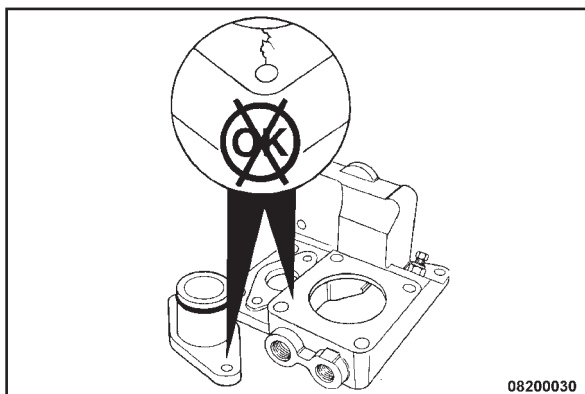
Remove the lubricating oil cooler water connection tubes from the cooler.



Clean (008-015-006)

Use solvent to clean the lubricating oil cooler water transfer tubes, water pump water transfer tubes, and the thermostat housing support.

Dry with compressed air.



Inspect for Reuse (008-015-007)

Visually inspect the water transfer tubes and thermostat housing support for cracks or damage.

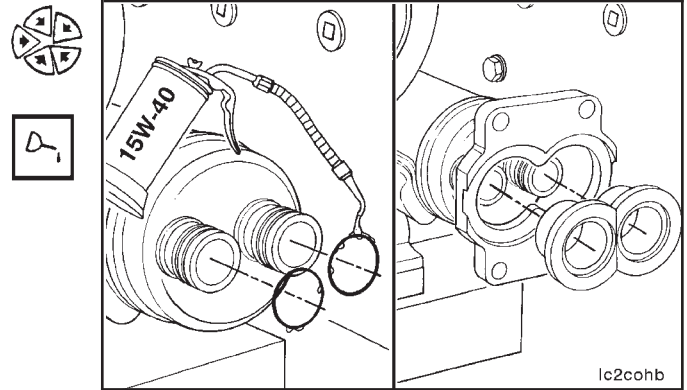
If any parts are damaged, they **must** be replaced.

Install (008-015-026)

Install new o-rings on the lubricating oil cooler water connection tubes.

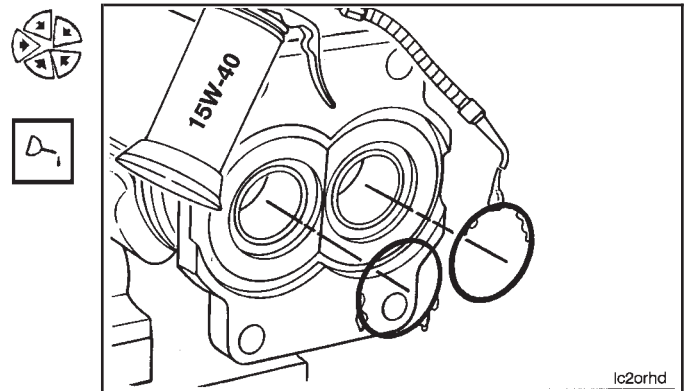
Use clean 15W-40 engine oil to lubricate the o-rings.

While holding the connection flange in place, install the water connections into the lubricating oil cooler. The straight edges of the connection **must** face each other.



Install two new o-rings on the end of the lubricating oil cooler water tube connections.

Lubricate the o-rings with clean 15W-40 engine oil.

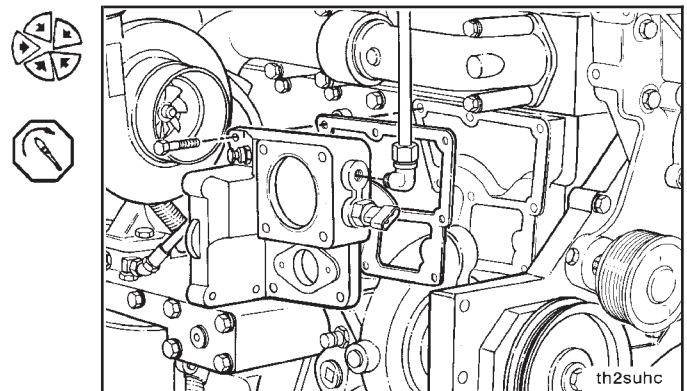


Use a new gasket and install the thermostat housing support and capscrews.

Torque Value: 54 N•m [40 ft-lb]

Install the air compressor coolant supply line.

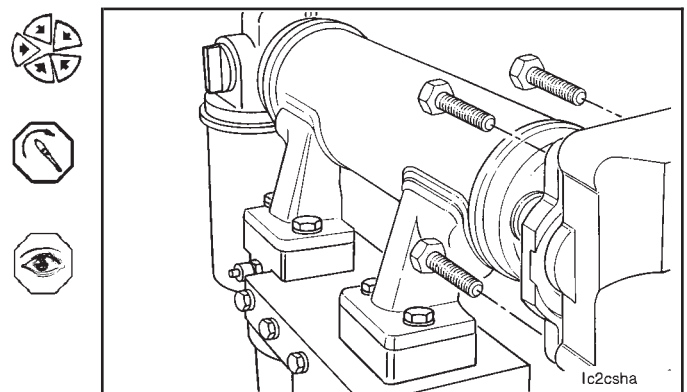
Install the coolant temperature sensor.

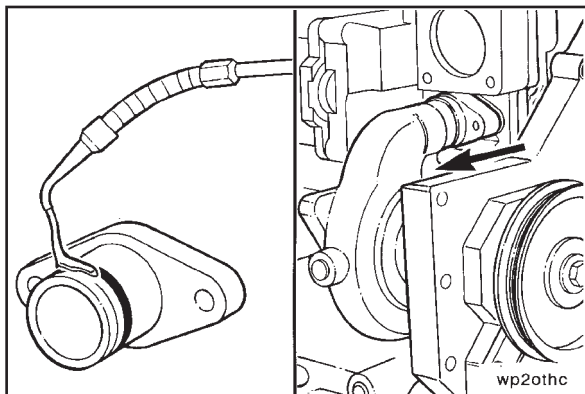


Install the four mounting flange capscrews. Alternately and evenly tighten the four capscrews.

Torque Value: 47 N•m [35 ft-lb]

NOTE: Be sure the o-rings on the end of the connection tubes are located correctly.

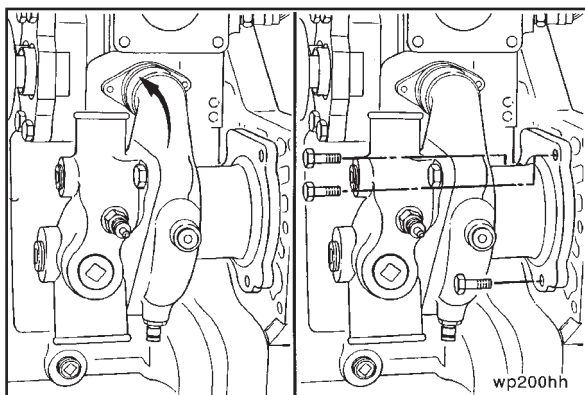




Install a new o-ring on the water pump water transfer tube.
Use clean 15W-40 oil to lubricate the o-ring.

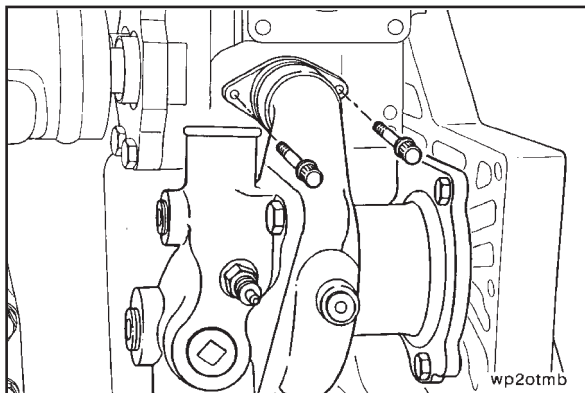


Install the water transfer tube and o-ring assembly in the water pump body.



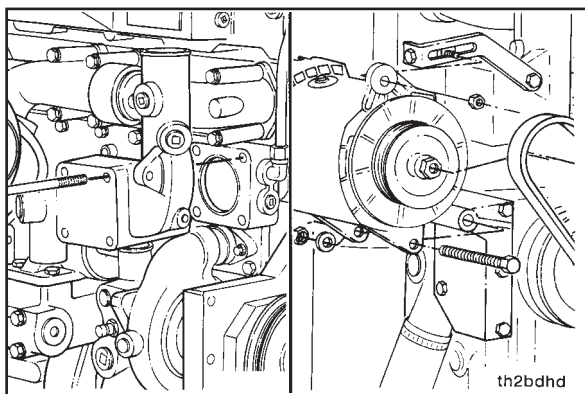
Rotate the water pump inward and install the three water pump mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]



Use a new gasket and install the water pump water transfer tube mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]

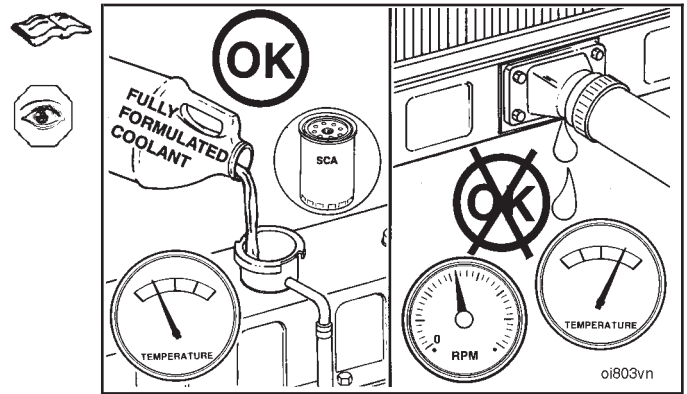


Install the thermostat and thermostat housing. Refer to Procedure 008-014-026.

Install the alternator and drive belt. Refer to Procedures 013-001-026 and 013-005-026.

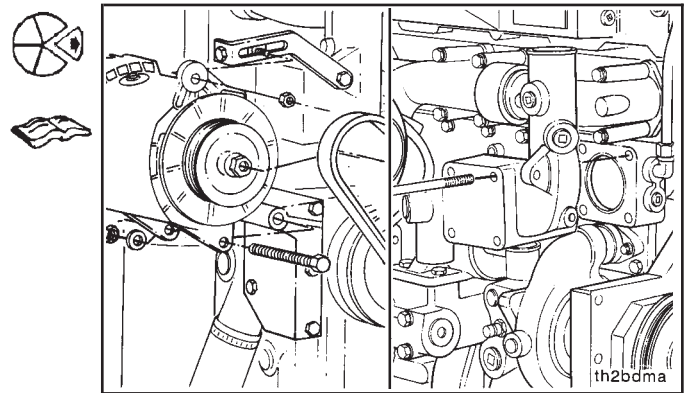


Fill the cooling system. Refer to Procedure 008-018-028.
Operate the engine until it reaches a temperature of 80°C [180°F] and check for coolant leaks.



Coolant Thermostat Seal (008-016) Remove (008-016-002)

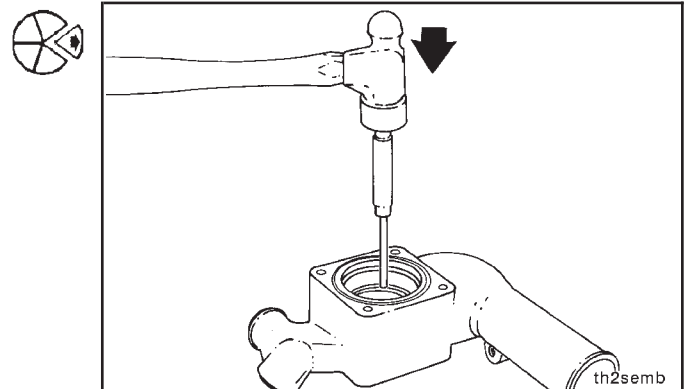
Remove the thermostat. Refer to Procedure 008-013-002.



⚠ CAUTION ⚠

Do not damage the thermostat housing when removing the thermostat seal.

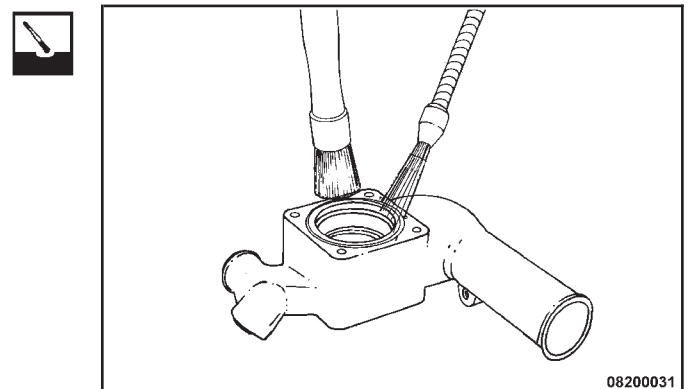
Use a punch and hammer to remove the seal from the housing.

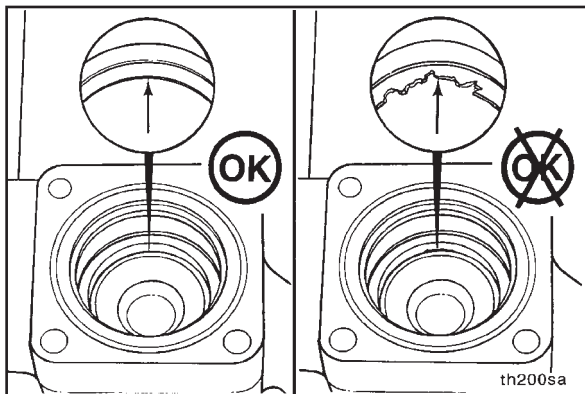


Clean (008-016-006)

Use solvent to clean the thermostat housing.

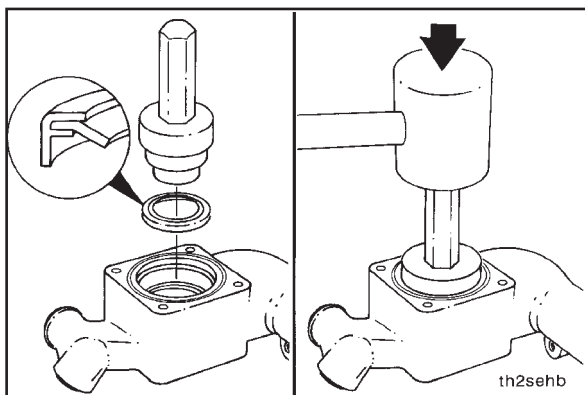
Dry with compressed air.





Inspect for Reuse (008-016-007)

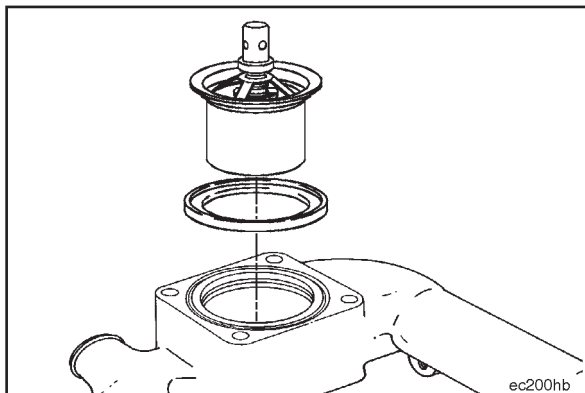
Visually inspect the thermostat housing for cracks, pitting, or other damage.



Install (008-016-026)

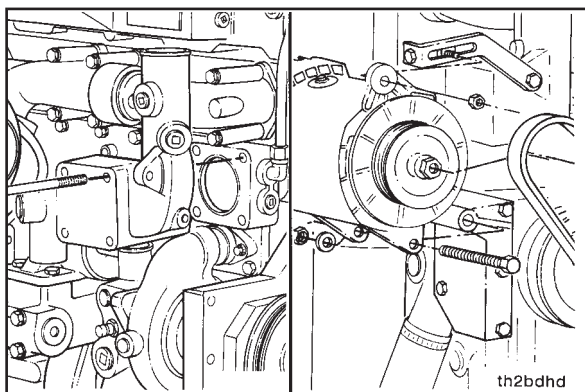
When installing a new seal, the flat side of the seal **must** be facing the mandrel.

Use thermostat seal mandrel, Part No. ST-1225, and a hammer to install the seal.



Install the thermostat in the housing.

Install a new seal in the groove on the thermostat housing mounting surface.



Install the hose on the thermostat housing bypass outlet.

Install the thermostat housing and four mounting cap screws.



Torque Value: 54 N•m [40 ft-lb]

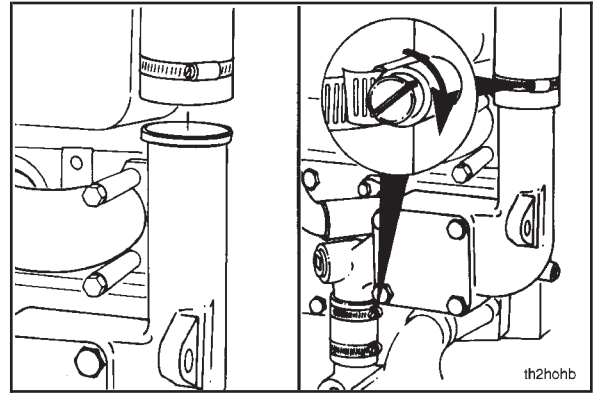
NOTE: If a torque converter cooler disc is used in the coolant bypass hose, refer to Procedure 008-065.



Install the upper radiator hose to the thermostat housing outlet.

Tighten all hose clamps.

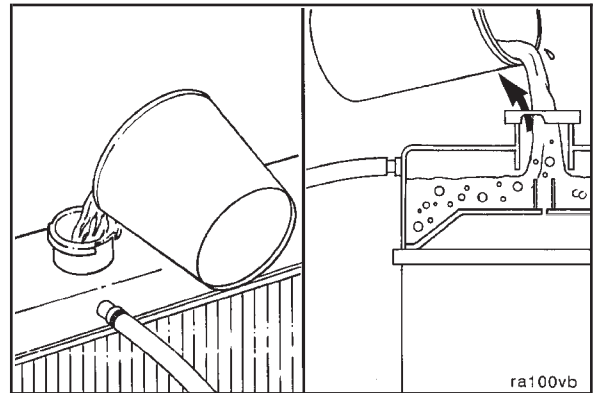
Torque Value: 3 N•m [30 in-lb]



Coolant Vent Lines (008-017)

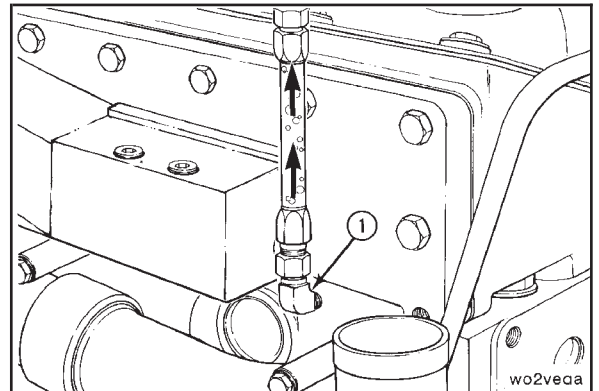
Initial Check (008-017-001)

The system **must** be designed to allow air to escape while filling.

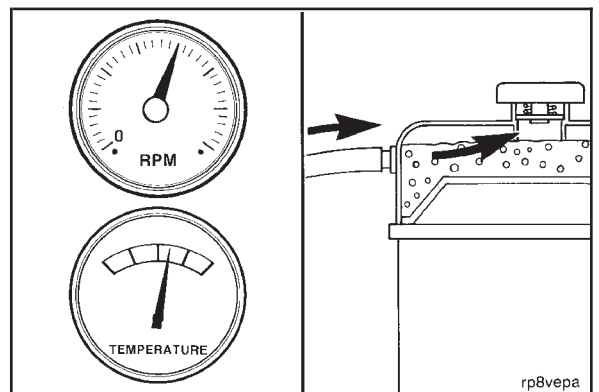


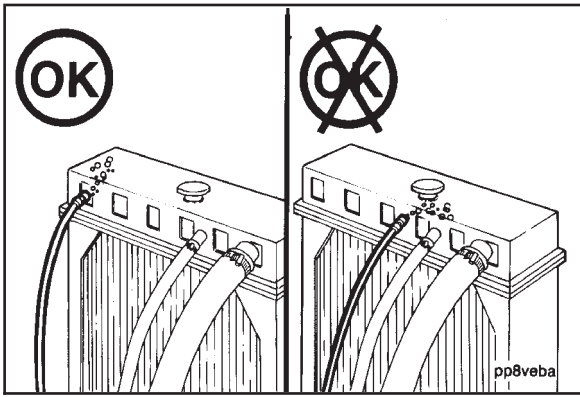
The cooling system vent line is routed from the cylinder head (1) to the radiator fill or auxiliary tank above the coolant level.

Use No. 4 flexible hose.



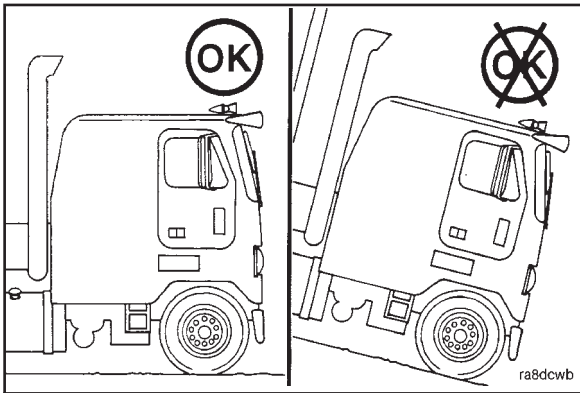
During engine operation, coolant will continue to flow through the engine vent line to remove air from the coolant.





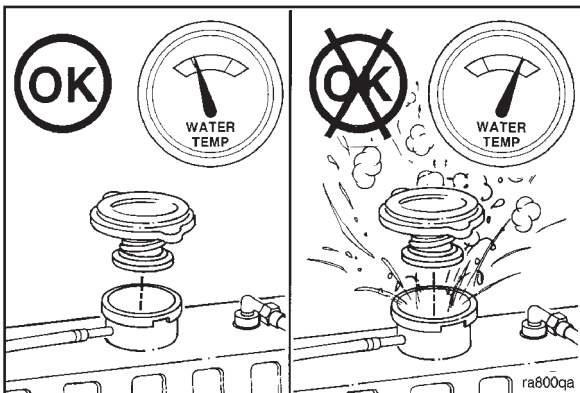
Do **not** route the fill or vent line in a manner which will allow air to be trapped in the system.

Route the vent line away from the fill line as far as possible to prevent turbulence in the fill line.



Cooling System (008-018) Drain (008-018-005)

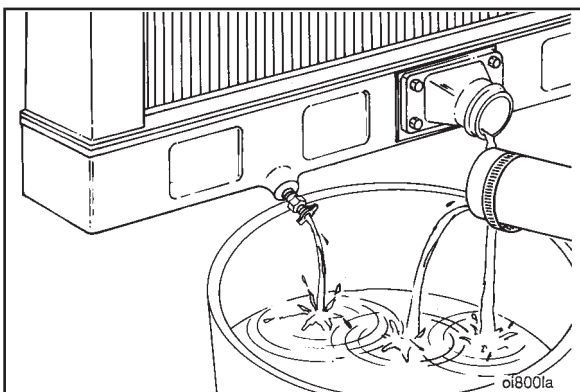
Position the vehicle on level ground.



▲ WARNING ▲

Check the coolant level only when the engine is stopped. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.

Remove the radiator cap after the engine is cool.



Drain the cooling system as follows:

- Open the radiator draincock
- Remove the lower radiator hose

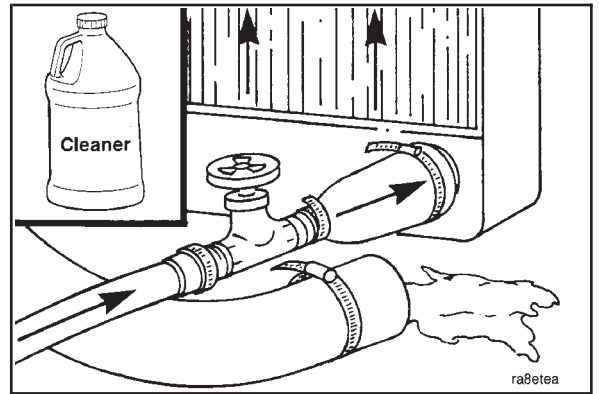
NOTE: If the coolant is **not** going to be reused, dispose of used coolant and antifreeze in accordance with federal, state and local regulations.

Clean (008-018-006)



Do not use caustic cleaners in the cooling system. Aluminum components will be damaged.

The cooling system **must** be clean to work correctly and to eliminate buildup of harmful chemicals.

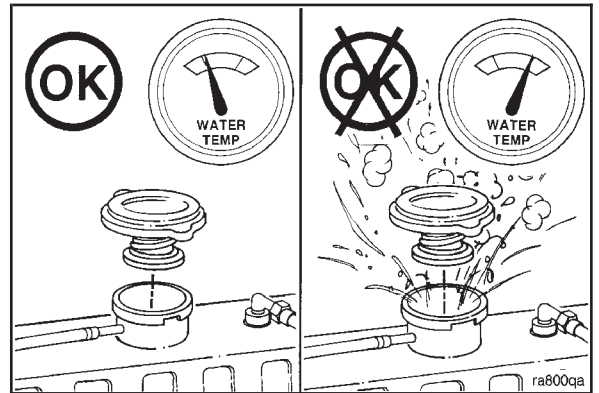


RESTORE is a heavy duty cooling system cleaner which removes corrosion products, silicate gel and other deposits. The performance of RESTORE is dependent on time, temperature, and concentration levels. An extremely scaled or flow restricted system, for example, can require higher concentrations of cleaners, 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.



Wait until the temperature is below 50°C [120°F] before removing the coolant system pressure cap. Failure to do so can cause personal injury from heated coolant spray.

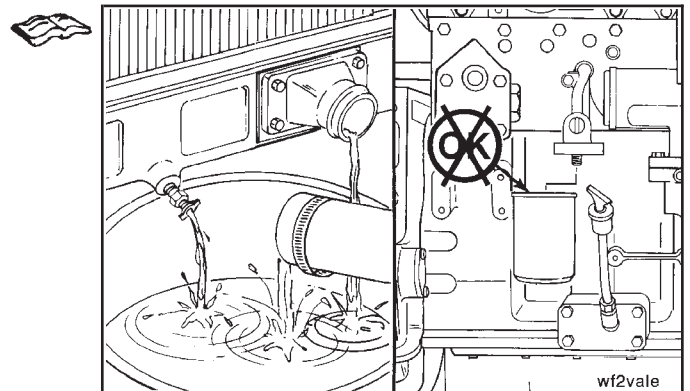
Remove the radiator cap.

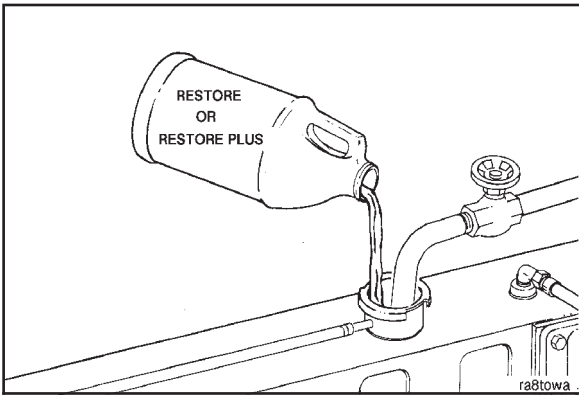


NOTE: Dispose of used antifreeze and coolant in accordance with federal, state, and local environmental regulations.

Drain the cooling system. Refer to Procedure 008-018-005. Do **not** allow the cooling system to dry out.

Do **not** remove the coolant filter.



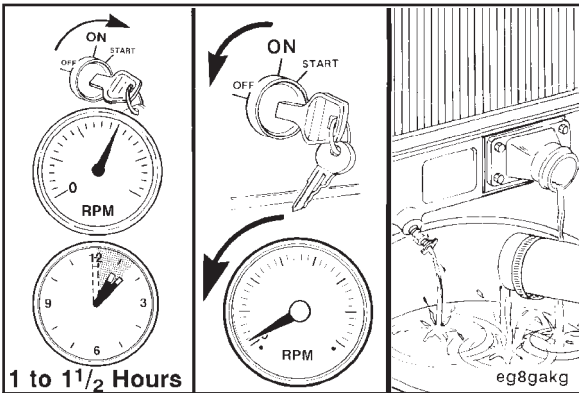


CAUTION

Fleetguard® RESTORE contains no antifreeze. Do not allow the cooling system to freeze during the cleaning operation.

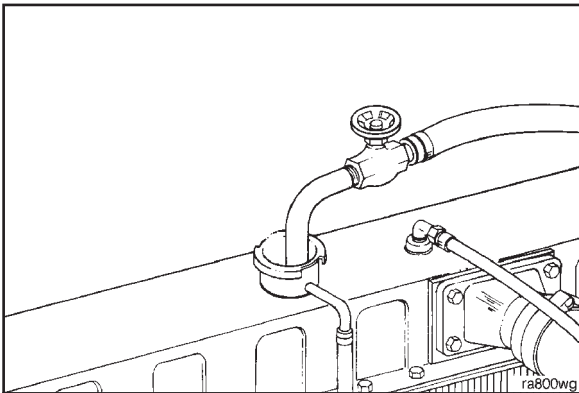
Immediately add 3.8 liters [1 U.S. gal.] of Fleetguard® RESTORE, RESTORE PLUS, or equivalent, for each 38 to 57 liters [10 to 15 U.S. gal.] of cooling system capacity, and fill the system with plain water.

Turn the heater temperature switch to high to allow maximum coolant flow through the heater core. The blower does not have to be on.

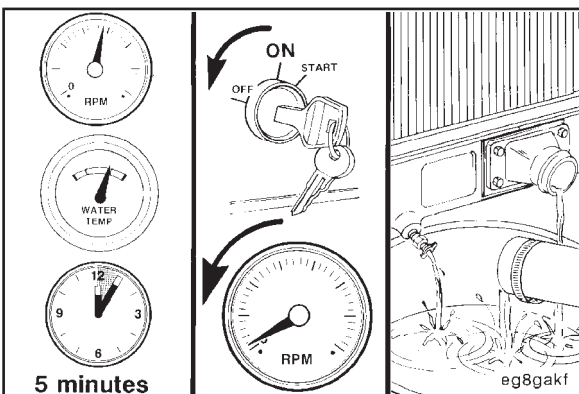


Operate the engine at normal operating temperatures, at least 85°C [185°F], for 1 to 1-1/2 hours.

Shut off the engine and drain the cooling system. Refer to Procedure 008-018-005.



Fill the cooling system with clean water.



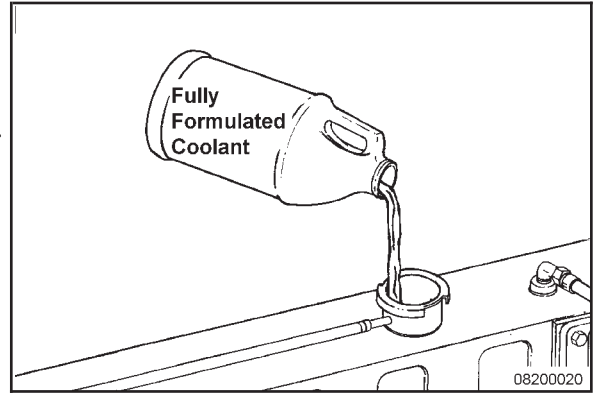
Operate the engine at high idle for five minutes with the coolant temperature above 85°C [185°F].

Shut off the engine and drain the cooling system. Refer to Procedure 008-018-005.

If the water being drained is still dirty, the system **must** be flushed again until the water is clean.

Fill the cooling system with **Fully Formulated Coolant** or a 50/50 mixture of **Fully Formulated Antifreeze** and good quality water. Refer to Procedure 008-018-028. Use a service filter to bring the coolant to the correct SCA concentration level. Refer to Fleetguard® DCA4 Service Filters and Liquid Precharge in the General Information portion of this section for the correct filter to use.

Install the pressure cap. Operate the engine until it reaches a temperature of 80°C [180°F], and check for coolant leaks.



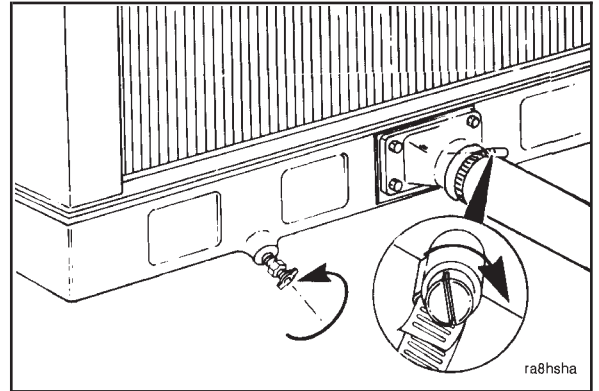
Fill (008-018-028)

Close the radiator draincock.

Install the lower radiator hose.

Tighten the hose clamp.

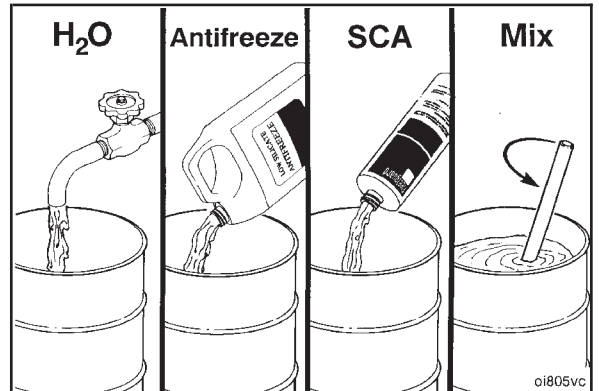
Torque Value: 5 N•m [40 in-lb]



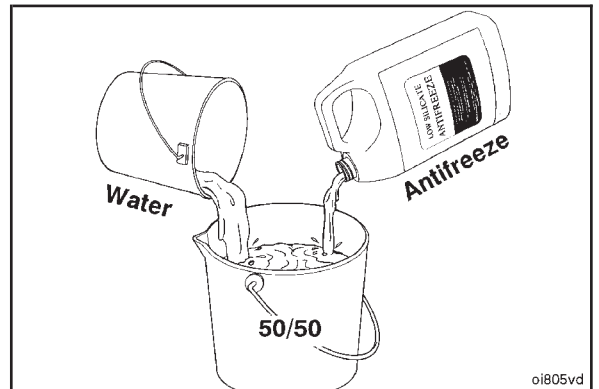
Proper mixing of coolant is required:

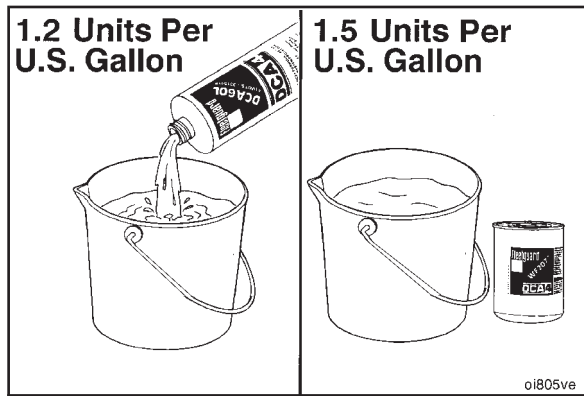
- Pour water into the container
- Add low-silicate antifreeze
- Add DCA4 liquid
- Thoroughly blend the components

Following the correct order for mixing the coolant will prevent additive dropout during the mixing process.

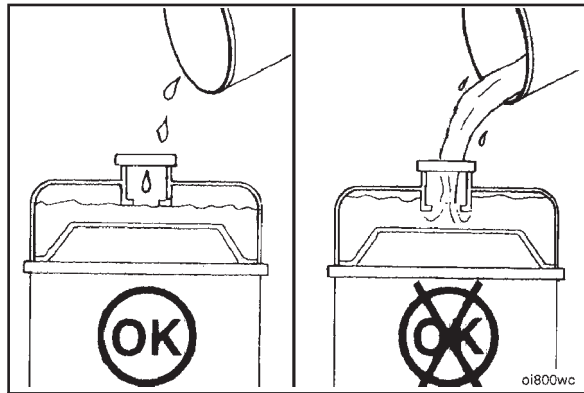


Low-silicate antifreeze **must** be used at a 50/50 ratio to give adequate freeze point and boiling point protection. Also, the use of low-silicate antifreeze minimizes the chance of having a silicate gel problem.

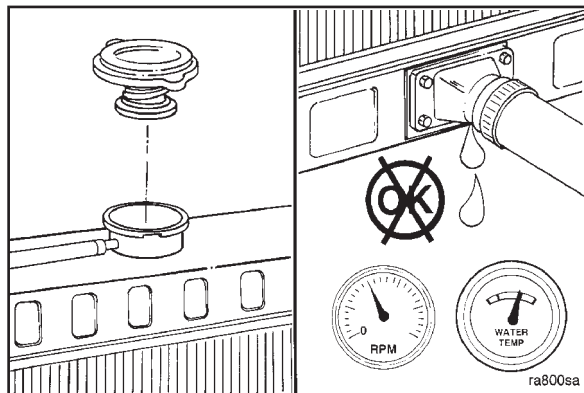




The cooling system **must** be precharged with SCA. Add 1 pint of DCA4 liquid (5 units) for each 4 gallons of coolant (1.2 units per gallon). In addition, a service coolant filter containing 1 unit of DCA4 for each 4 gallons of coolant **must** be installed. This will result in a total precharge of approximately 1.5 DCA4 units per gallon of coolant. Refer to the Coolant Capacity Charts at the beginning of this section for correct filter selection.



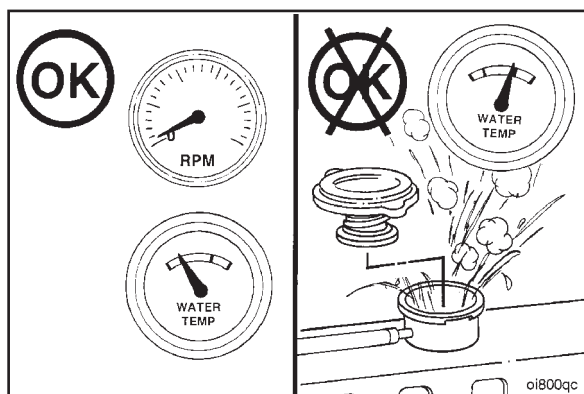
Fill the system with coolant until the level is at the bottom of the radiator fill neck.



Install the radiator fill cap.



Operate the engine until it reaches a temperature of 80°C [180°F], and check for leaks.



▲ WARNING ▲

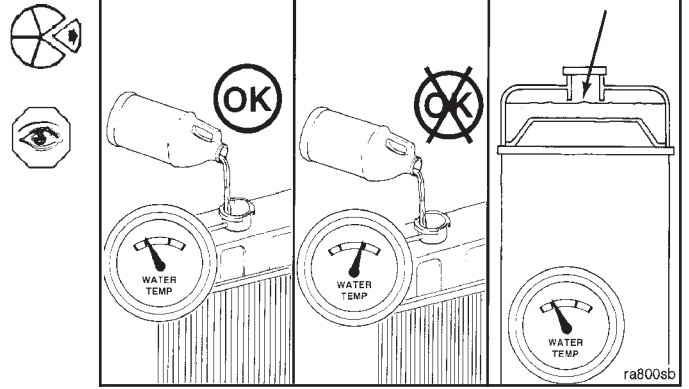
Check the coolant level only when the engine is stopped. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.

Shut off the engine and allow it to cool.

⚠ CAUTION ⚠

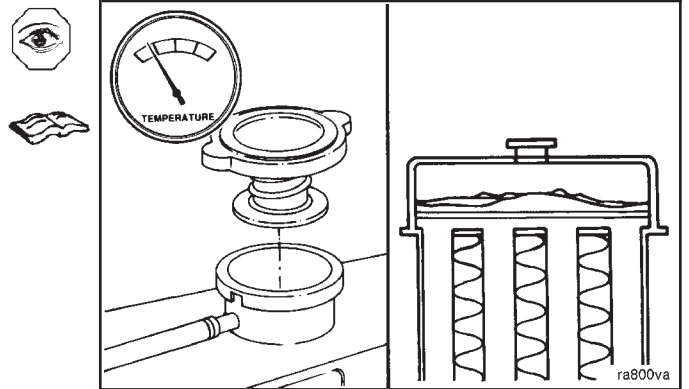
Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool below 50°C [120°F] before adding coolant.

Remove the radiator or fill cap and check the coolant level. Add coolant if necessary.



Pressure Test (008-018-013)

Check the coolant level and fill if necessary. Refer to Procedure 008-018-028.



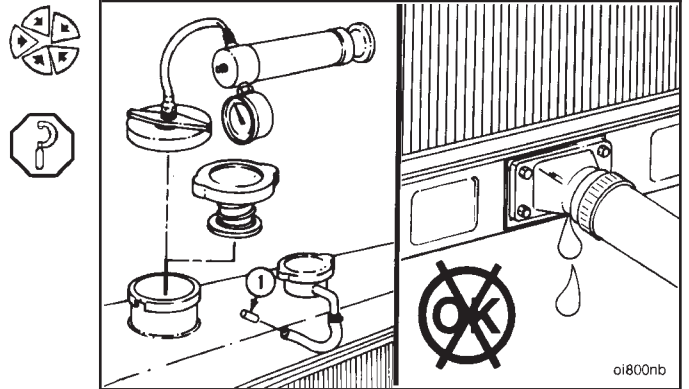
⚠ CAUTION ⚠

Do not apply more than 138 kPa [20 psi] air pressure to the cooling system. The water pump seal can be damaged.

If the radiator is equipped with a pressure relief valve, plug the overflow line (1).

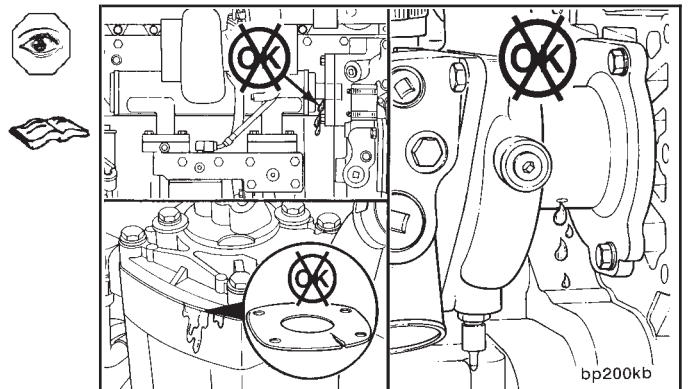
Install the pressure tester on the radiator fill neck or surge tank, if equipped, and apply air pressure.

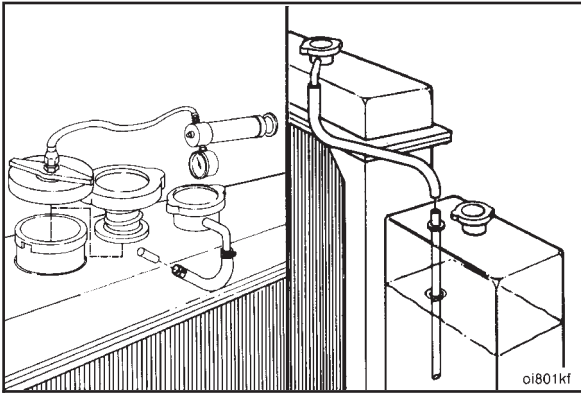
Air Pressure 138 kPa [20 psi]



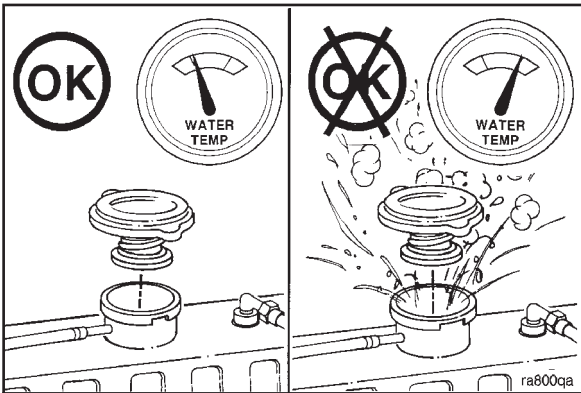
Inspect the following for coolant leaks and repair if necessary:

- Lubricating oil cooler (Refer to Procedure 007-003)
- Water pump (Refer to Procedure 008-062)
- Air compressor head gasket. (Refer to Procedure 012-007)





Remove the pressure test equipment and connect the relief valve and surge tank, if equipped.



Cooling System - Air or Combustion Gas Test (008-019)

Initial Check (008-019-001)

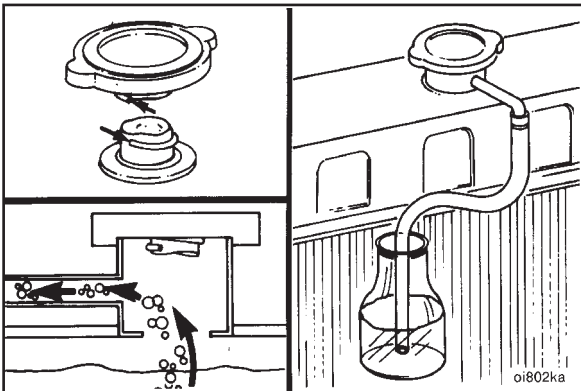
Air in Cooling System



WARNING

Wait until the temperature is below 50°C [120°F] before removing the coolant system pressure cap. Failure to do so can cause personal injury from heated coolant spray.

Allow the engine to cool and remove the radiator cap.

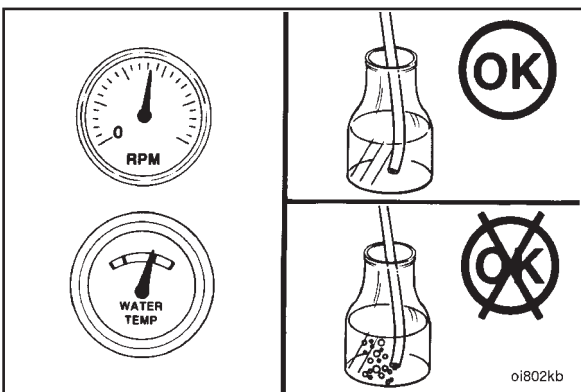


NOTE: The pressure cap **must** make a tight seal.

Install a radiator pressure cap which has had the spring and pressure relief valve removed.

Attach a rubber hose to the radiator overflow connection.

Place the free end of the hose in a container of water.

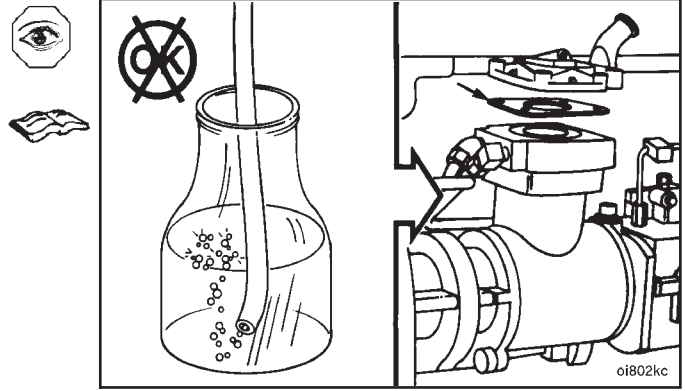


Operate the engine at rated rpm until it reaches a temperature of 80°C [180°F] with the thermostat open.

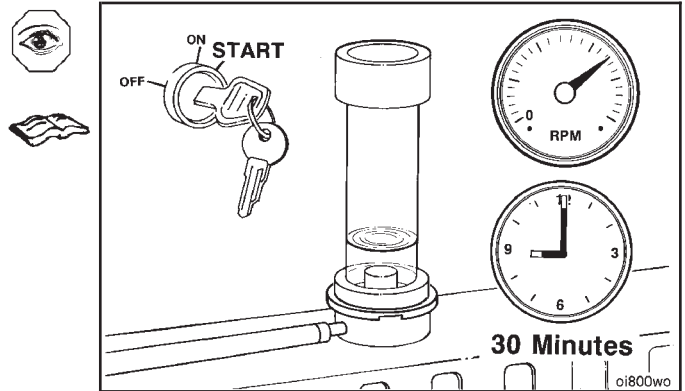
Check for a continuous flow of air bubbles from the hose in the water container.

A continuous flow of air bubbles can be caused by one of the following:

- Fan, shutter, or heater air control thermostat valve leaking air. Refer to the Leak Test for Fan, Shutter, or Heater Air Control Valve, Procedure 008-019-014.
- An air compressor cylinder head leak. Refer to the Leak Test for Air Compressor, Procedure 008-019-014..

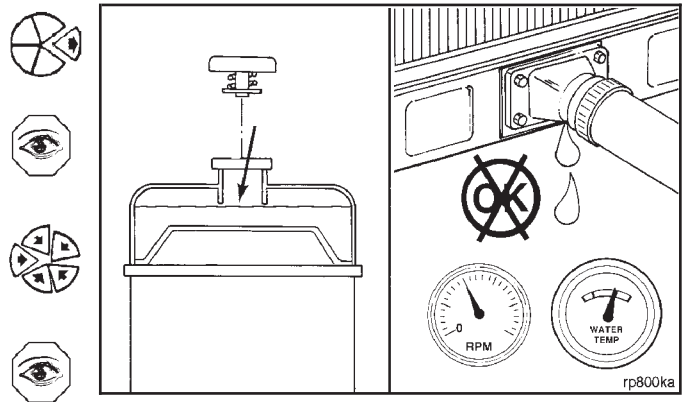


If one of the air control valves or the air compressor was **not** the source of air entering the cooling system, perform the Combustion Gas Leak test outlined in Procedure 008-019-014.



If no air is found in the cooling system, do the following:

- Remove the test equipment.
- Check the coolant level and fill if necessary.
- Install the radiator pressure cap.
- Operate the engine until it reaches a temperature of 80°C [180°F], and check for coolant leaks.

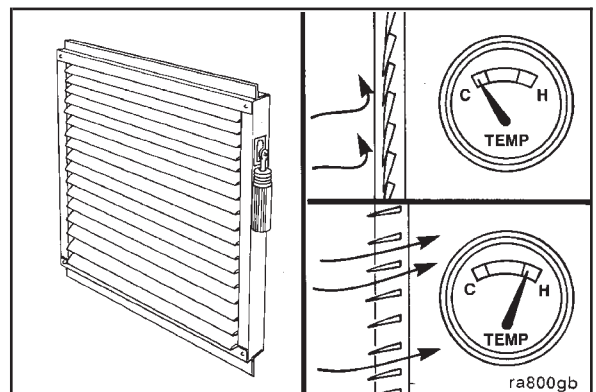


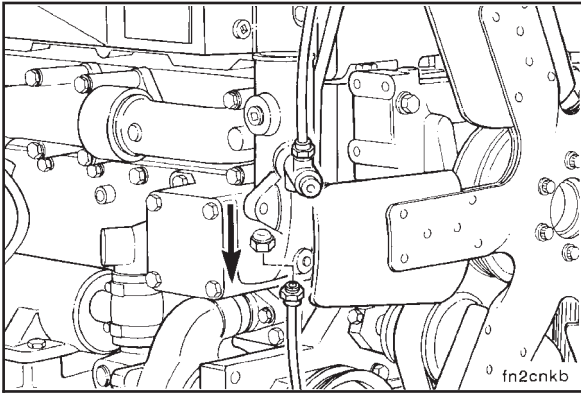
Leak Test (008-019-014)

Fan, Shutter, or Heater Air Control Valve

⚠ CAUTION ⚠

The engine can overheat with the fan control or the shutter air control valve disconnected. Monitor the engine coolant temperature while performing this test. The coolant temperature must not exceed 100°C [212°F].



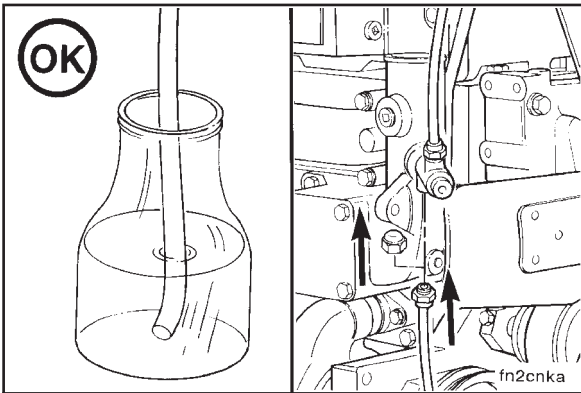


Disconnect the vehicle air supply hose to the fan, the shutter, and the heater air control valve.

Install a plug in the air supply hose.

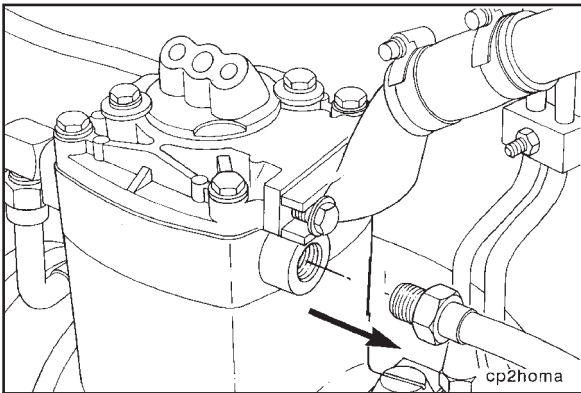


If the vehicle is equipped with more than one air control valve, check only one valve at a time.



Repeat the test for air in the cooling system as previously described in Procedure 008-019-001. If no air is found in the cooling system with the air control valve(s) isolated, install a new control valve.

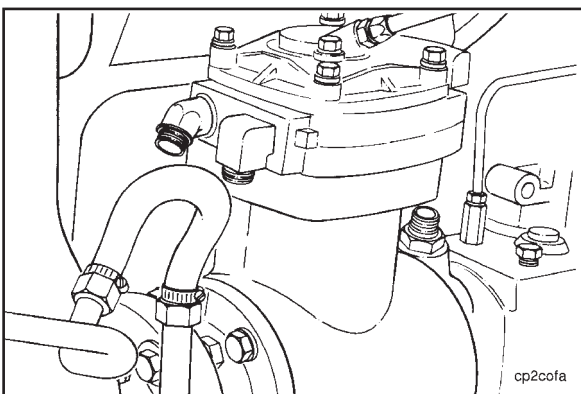
NOTE: Start the engine and run for five minutes before testing for air in the coolant. This will allow any trapped air to purge from the system.



Air Compressor



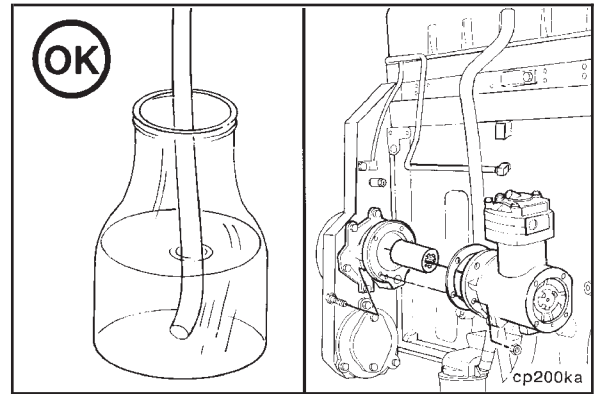
The air compressor discharge line must be disconnected at the compressor to allow the compressor to discharge air to the atmosphere to prevent the compressor from overheating during this next test. Do not run the engine over 5 minutes with components isolated from the cooling system. Component damage can occur.



Disconnect the coolant supply and the return tubes from the air compressor. Use a short piece of hose to connect the tubes together to prevent coolant loss during engine operation.



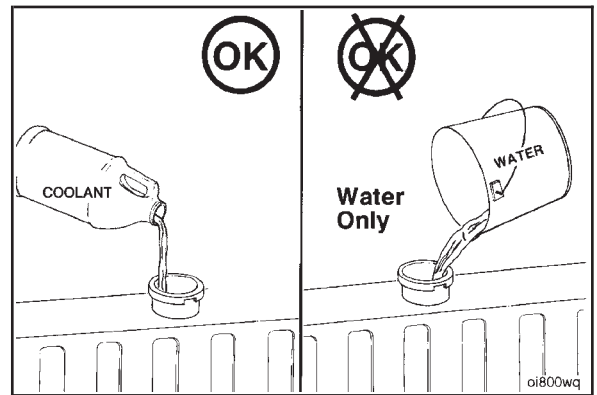
Repeat the test for air in the cooling system as previously described in Procedure 008-019-001. If no air is found in the cooling system with the air compressor isolated, repair or replace the air compressor. Refer to Section 12.



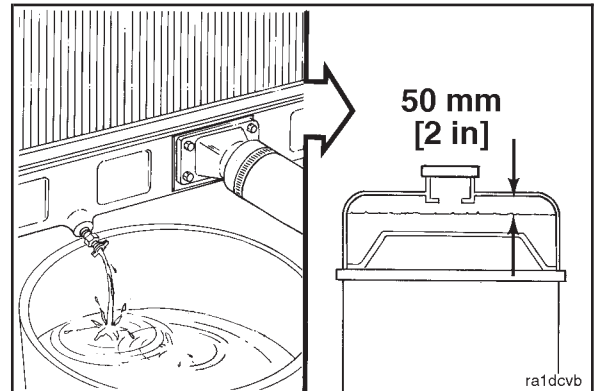
Combustion Gas Leak

Use combustion gas leak test kit, Part No. 3822985 or equivalent, to test for combustion gases in the cooling system.

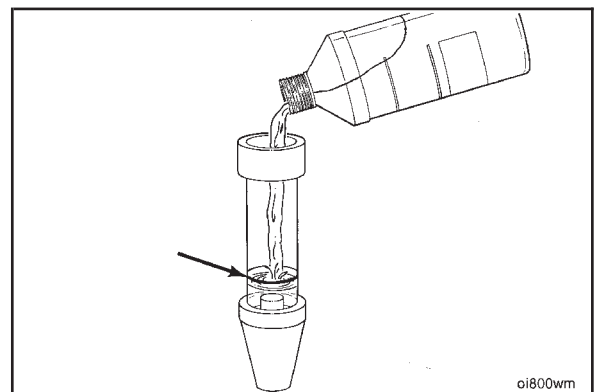
It is recommended that the cooling system contain a mixture of 50 percent antifreeze and 50 percent water during the combustion gas leak test. The use of water only can result in a color change in the test fluid from blue to turquoise or light green during the test. This is **not** an indication of a combustion gas leak.

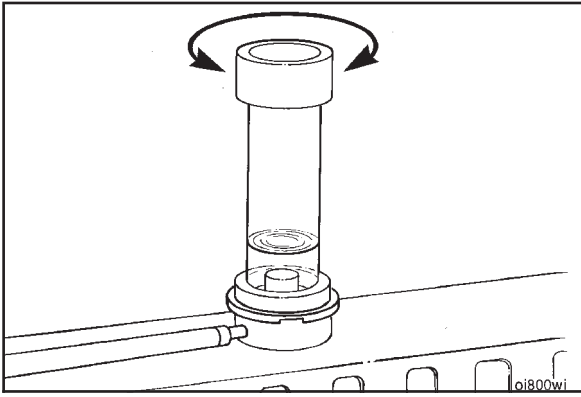


Drain the coolant level down approximately 50 mm [2 in] below the radiator cap seal ledge in the radiator fill neck.

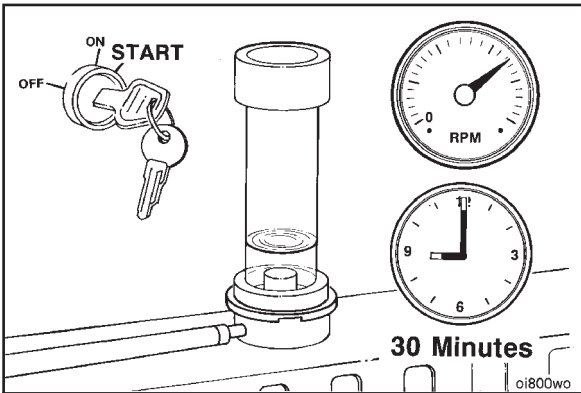


Pour the test fluid into the combustion gas leak test instrument until it is up to the yellow fill line on the instrument.

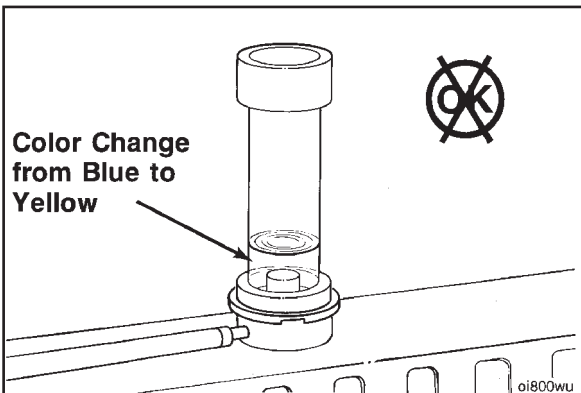




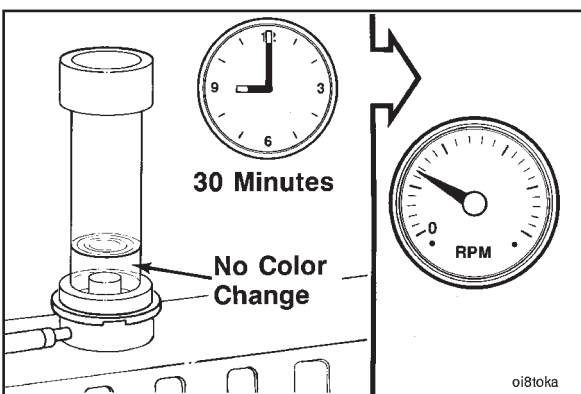
Insert the rubber tip of the combustion gas leak test instrument in the radiator fill neck. Hold the instrument down firmly while turning back and forth to make sure that an air tight seal is formed between the tester and radiator fill neck.



Start the engine and run at high idle for approximately 30 minutes. Monitor the engine temperature and color of the test fluid during engine operation. Do **not** allow the engine temperature to exceed 100°C [212°F] during the test.

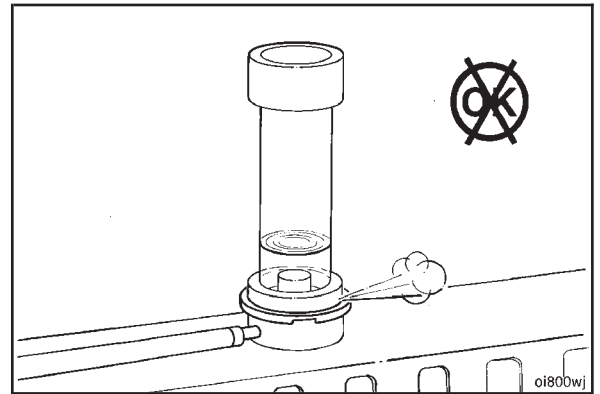


If the color of the test fluid changes from blue to yellow anytime during the test, combustion gases are leaking into the cooling system. Discontinue the test if the color of test fluid changes from blue to yellow.



If the color of the test fluid does **not** change from blue to yellow during the 30 minute test period, return the engine to low idle.

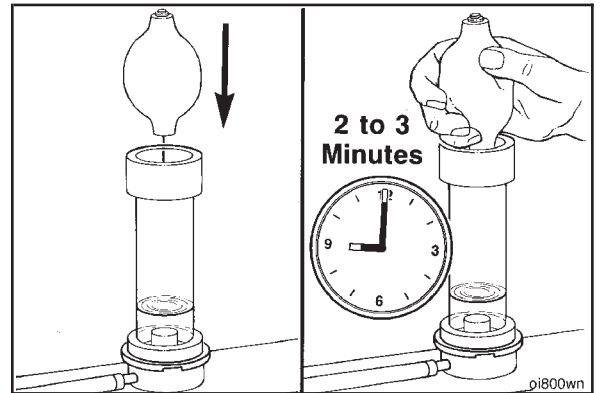
Check the test instrument to make sure that it is firmly sealed in the radiator fill neck.



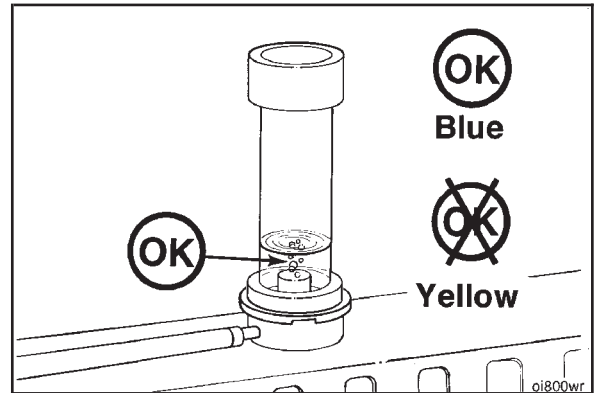
Insert the tip of the rubber ball into the hole in the top of the test instrument. Squeeze the rubber ball 2 to 3 minutes to draw air from the radiator through the test fluid.



If the color of the test fluid remains blue, combustion gases are **not** entering the cooling system. If the color of the test fluid changes from blue to yellow, combustion gases are entering the cooling system. Further investigation is required to determine the source of the combustion leak.



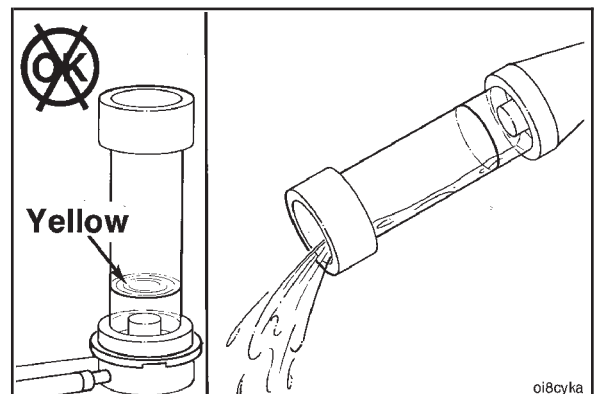
As the cooling system warms up to operating temperature, air will be expelled through the combustion gas tester in the form of bubbles in the test fluid. This is due to normal expansion of the coolant. Do **not** mistake the presence of air bubbles in the tester as combustion gases, or air leaks into the cooling system. A change in the color of the test fluid from blue to yellow is the only indication of combustion gas in the cooling system.

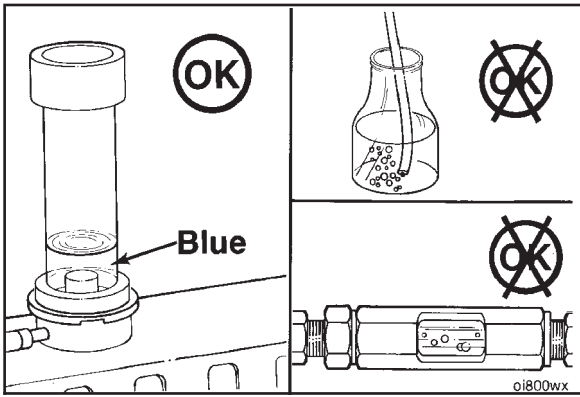


A positive result from the combustion gas leak tester indicates the following:

- Cylinder liner protrusion incorrect. Refer to Procedure 001-064.
- Cylinder head gasket or cylinder head casting leakage. Refer to Procedure 002-004.
- Injector sleeve leakage. Refer to Procedure 002-004.
- Cracked cylinder liner. Refer to Procedure 001-028.

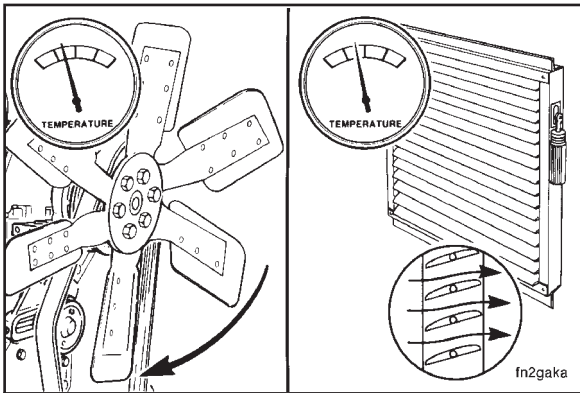
NOTE: Discard the test fluid if it has indicated positive.





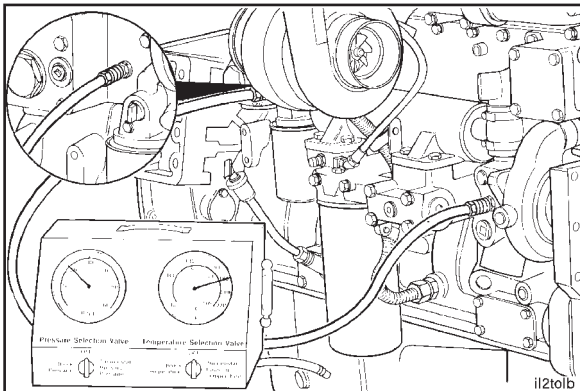
A negative result from the combustion gas leak tester coupled with a continuous flow of air bubbles from the previous test indicates the following:

- Defective fan, shutter, or heater air control valve
- Air compressor head or head gasket leakage
- Air entrained due to a bad radiator check valve or incorrect fill

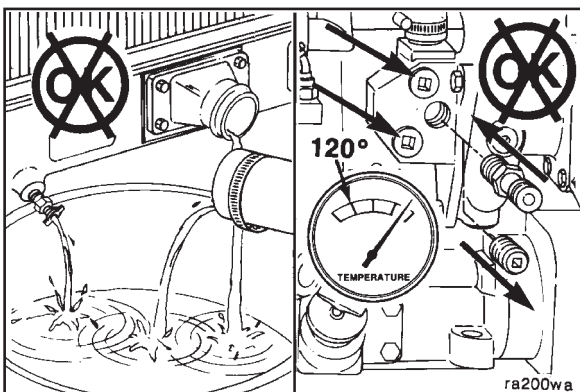


Cooling System Diagnostics (008-020) General Information

This procedure tests the correct operation of the fan, shutter, coolant temperature gauge, and thermostat. It also checks for combustion leaks into the cooling system, coolant flow through the filter, and entrained air in the system. Carefully read and understand all the following steps before beginning the troubleshooting procedure.



This is a free running (non-dyno) test. It requires the use of the coolant pressure/temperature/flow analyzer kit, Part No. 3822994, and the proper installation of the cooling system Compuchek® fittings located on the engine.



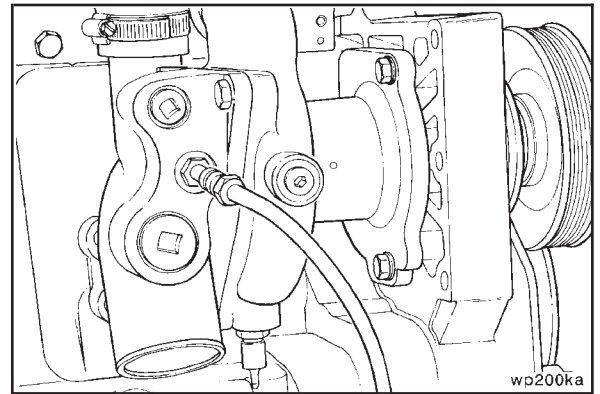
▲ WARNING ▲

Do not attempt to install fittings unless the coolant temperature is below 49°C [120°F]. Failure to do so can cause personal injury from heated coolant.

The coolant **must not** be drained to install the fittings. Draining the engine can introduce air into the system and give false results.

Required Engine Sensor Fittings:

The water pump inlet pressure line of the analyzer kit **must** be installed on the water pump inlet Compuchek® fitting on the rear cover of the water pump.

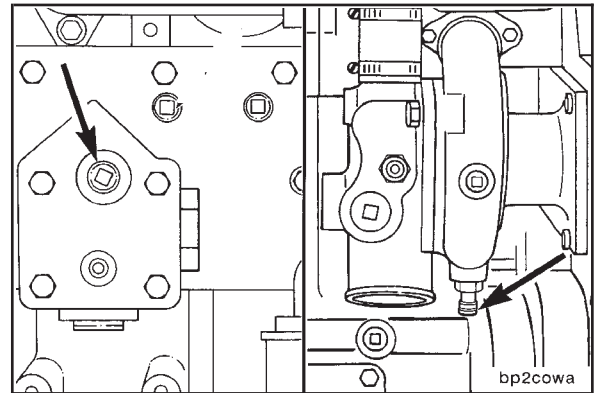


The thermostat housing pressure line of the analyzer kit can be installed in one of the following Compuchek® fitting locations:

- The heater housing on the rear of the water header plate.
- The outlet fitting on the water pump.

This connection will enable the operator to record cylinder block pressure.

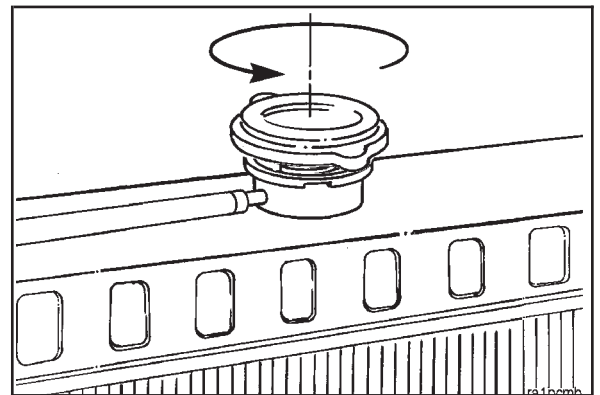
The remaining line of the analyzer kit **must** be plugged.



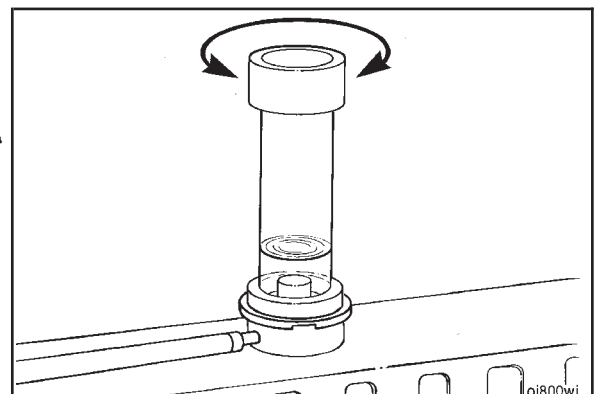
Setup (008-020-011)

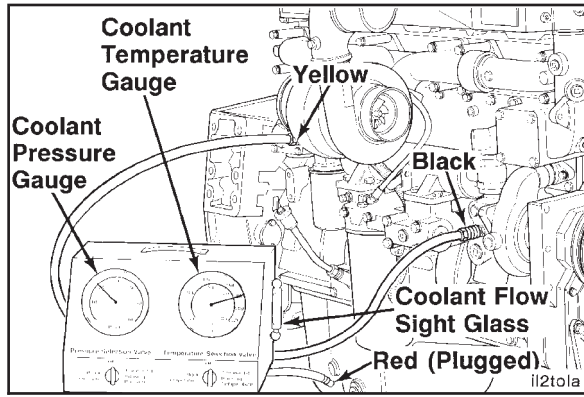
Remove the radiator cap and leave it off for the following test.

NOTE: All cab heaters and air conditioners **must** be turned off, and the engine fan control **must** be turned to the "Automatic" position if applicable.



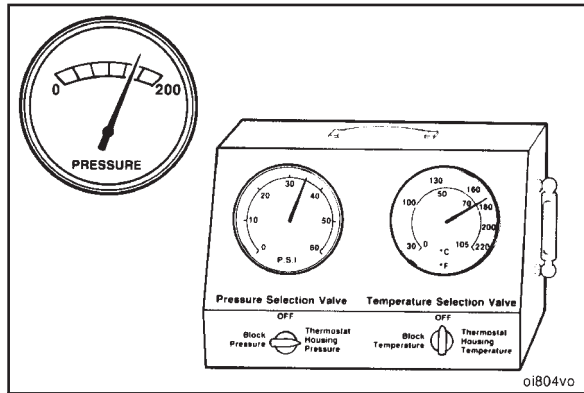
Install the combustion gas leak test instrument, Part No. 3822985. Refer to Procedure 008-019.





Install the analyzer kit, Part No. 3822994.

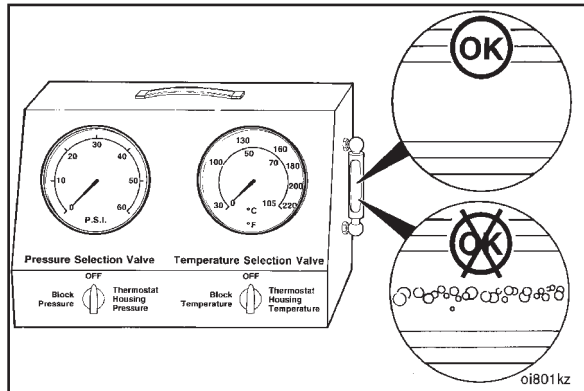
- Red Line - Plugged
- Yellow Line - Cylinder Block Pressure
- Black Line - Water Pump Inlet



Test (008-020-012)

Pressure Readings - Turn the pressure selection valve to the position corresponding to the desired reading. Turn the temperature selection valve to the "OFF" position.

NOTE: When the cylinder block pressure reading is taken, the valve **must** be turned to the thermostat housing pressure location. This is due to the different hose connection used on the M11 and L10 engines.



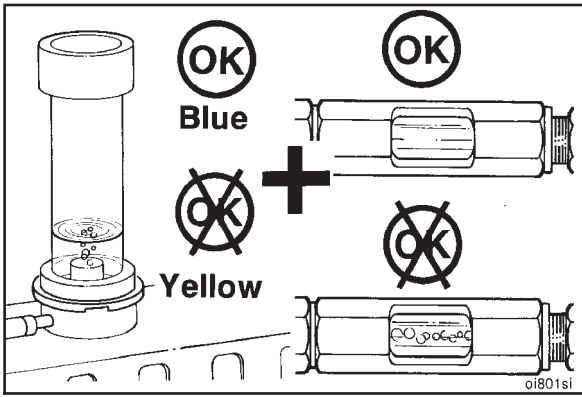
Monitor the sight glass installed on the service tool throughout the test. If air is observed, finish the test and examine the combustion leak tester. This will determine the origin of the leak. Refer to Procedure 008-019.

Temperature Readings - There will be temperature fluctuations when switching the temperature selection valve. This fluctuation is normal, and is caused by temperature loss in the line. The temperature will stabilize after a few seconds.

Operational Worksheet

Fill in the blanks with the test data as the test is being run. Mark when the radiator line gets hot, when the fan starts operating, and when the shutters open.

Temperature			Pressure				
Thermostat Housing	Cylinder Block	Cab Gauge	Cylinder Block	Radiator "In Line" Starts Getting Hot	Fan Starts Operating	Shutters Open	Notes
140			_____	_____	_____	_____	Engine at high idle throughout test
145				_____	_____	_____	Monitor for air through-out test
150			_____	_____	_____	_____	
155	_____	_____		_____	_____	_____	Start monitoring radiator "in" line
160			_____	_____	_____	_____	
165				_____	_____	_____	Check water filter
170			_____	_____	_____	_____	
175				_____	_____	_____	
180			_____	_____	_____	_____	
185	_____	_____		_____	_____	_____	
190			_____	_____	_____	_____	
195			_____	_____	_____	_____	
200			_____	_____	_____	_____	
205				_____	_____	_____	Cool engine down

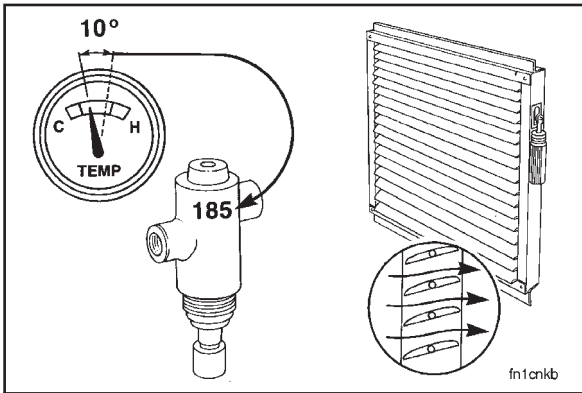


Analyzing the Data (008-020-055)

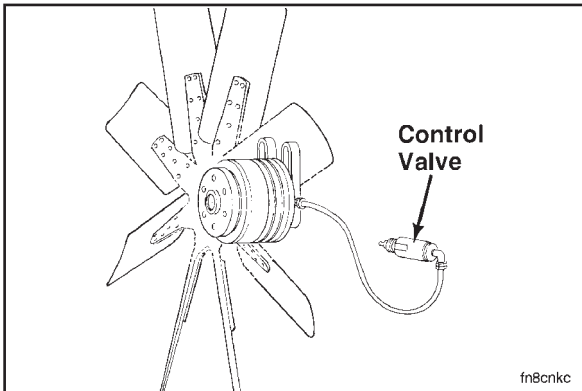


Check the color of fluid in the combustion gas leak tester. This information, along with the sight glass observations, will help isolate the source of air in the cooling system, if any. Refer to Procedure 008-019.

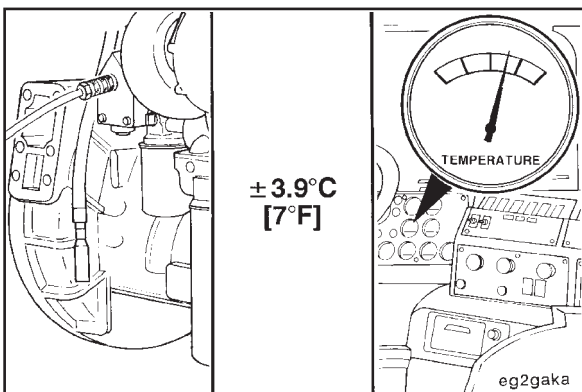
Do **not** rule out combustion gas leaks if the combustion gas leak test does **not** indicate a combustion gas leak. The test kit is **not** sensitive enough to detect very small combustion gas leaks.



Check the recorded coolant temperature when the shutters are opened. Compare this value to that which is stamped on the shutter control. Cummins Engine Company, Inc. recommends that the shutters open at 85°C [185°F].



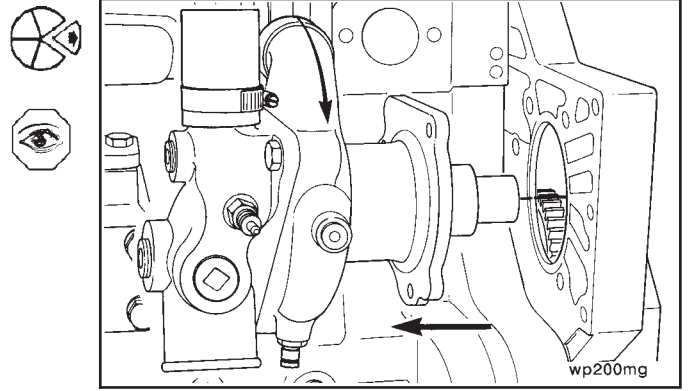
Check the recorded coolant temperature when the fan is engaged. Compare this value to that which is stamped on the fan control. Cummins Engine Company, Inc. recommends that the fan engage at 96°C [205°F].



Compare the cab temperature gauge reading with the block temperature. Replace the cab temperature gauge if it is **not** within the manufacturer's specifications of the correct reading. If no manufacturer's specifications are available, replace the gauge if it is **not** $\pm 3.9^{\circ}\text{C}$ [7°F] of the correct reading.

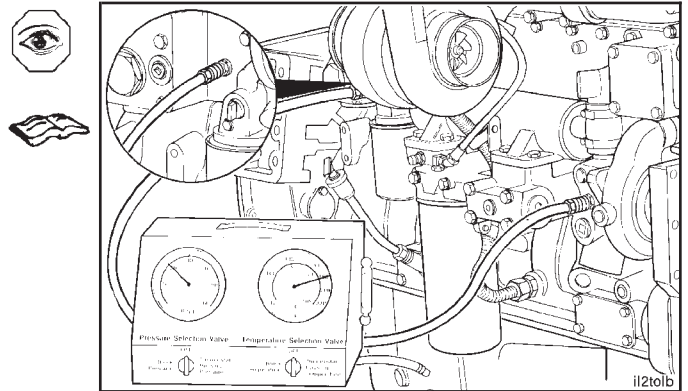
Read the recorded block pressure at 60°C [140°F]. If the block pressure is less than 138 kPa [20 psi] at high idle and without a pressure cap, check the following:

- Remove the water pump and inspect the impeller integrity, and for slippage on the shaft.



If there is a drop in block pressure of more than 34 kPa [5 psi] during the test, check the following:

- Air in the system. Refer to Procedure 008-019.
- Incorrect initial cooling system fill.
- Less than 50/50 antifreeze mixture, or the engine is at high altitude.

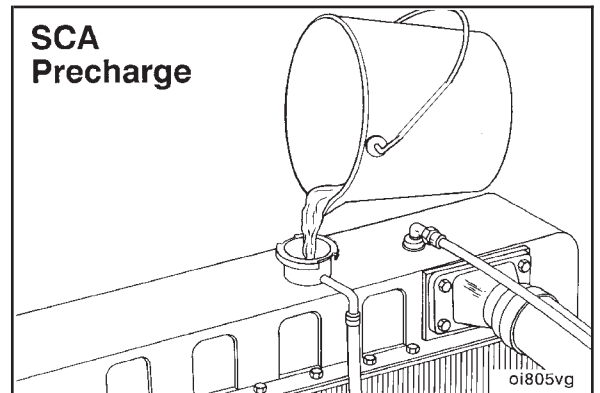


Cooling System Precharge (008-021)

General Information

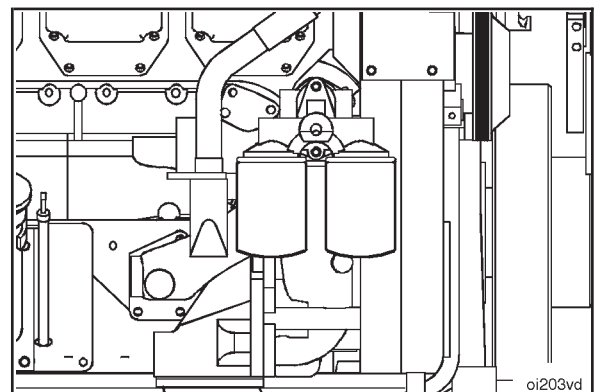
Correct use of SCAs in conjunction with proper maintenance practices are needed to protect engines from cooling system problems. The system **must** be precharged with the correct number of units of SCA.

Cummins/Fleetguard® uses the SCA unit to define the required concentration level to protect against liner pitting.



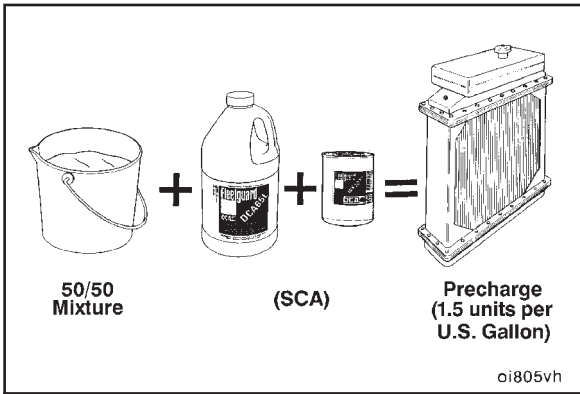
Factory Precharge Method (008-021-271)

New engines have a DCA4 coolant filter installed at the factory that will precharge the cooling system to the correct SCA concentration of approximately 1.5 units per gallon.



Customer Precharge Method (008-021-272)

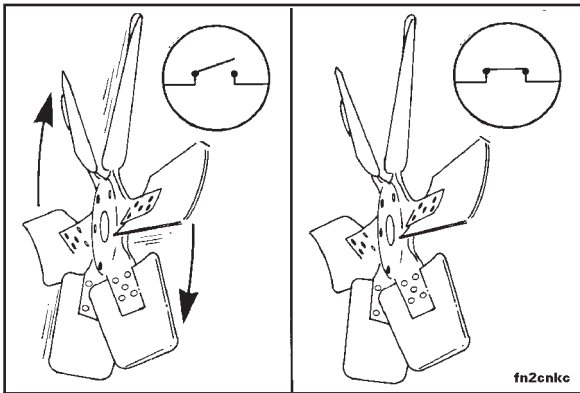
When coolant is replaced in the field, it **must** be replaced with **fully formulated coolant** or a 50/50 mixture of good quality water and **fully formulated antifreeze** and the correct service coolant filter. Refer to Specifications at the front of this section for correct requirements.



Fan Clutch, Air-Disengaged (008-024) General Information

On CELECT™ and CELECT™ Plus engines, all fan clutches can be controlled by the electronic control module (ECM). The ECM is programmed to turn the fan ON when 0 VDC (normally open switch) is applied to the fan clutch relay, and turn the fan OFF when 12 VDC (normally closed switch) is applied to the fan clutch relay.

The following fan clutch checks are for fan clutches wired to the electronic controlled fuel system. Refer to the vehicle manufacturer's specifications to determine the installation of the fan clutch.

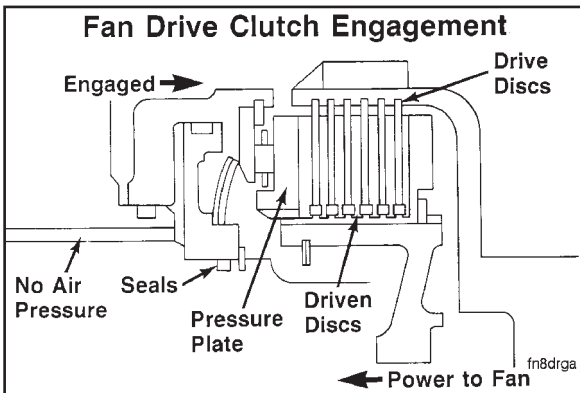


Maintenance Check (008-024-008)

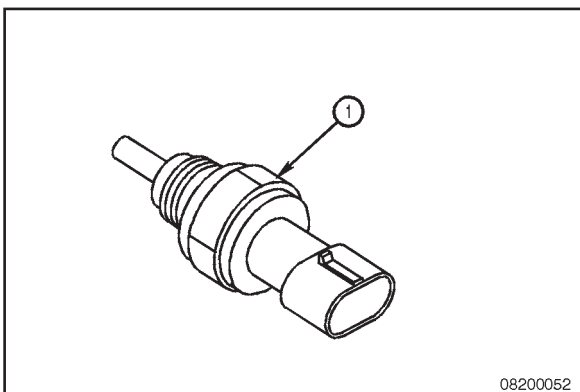
This type of fan clutch is engaged by spring tension and is disengaged by air pressure.

This type of fan clutch requires air pressure for free rotation. In the event of air pressure loss, the fan will be engaged.

Air pressure of 480 to 830 kPa [70 to 120 psi] is required to override the clutch spring tension to disengage the fan.



If the fan does **not** operate within the temperature range indicated on the coolant temperature sensor, the fan clutch and the controls **must** be checked. Refer to the fan clutch manufacturer's service manual.

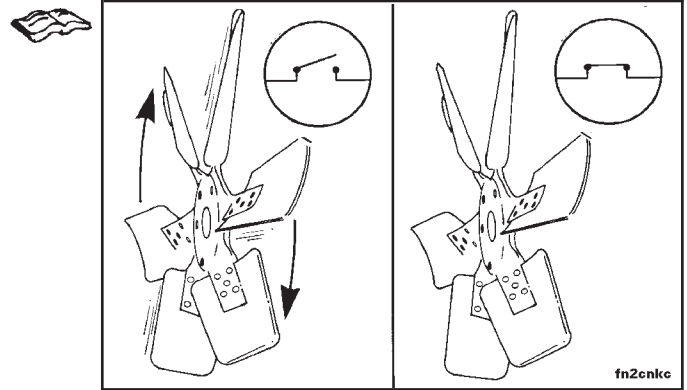


Fan Clutch, Air-Engaged (008-025)

General Information

On CELECT™ and CELECT™ Plus engines, all fan clutches can be controlled by the electronic control module (ECM). The ECM is programmed to turn the fan ON when 0 VDC (normally open switch) is applied to the fan clutch relay, and turn the fan OFF when 12 VDC (normally closed switch) is applied to the fan clutch relay.

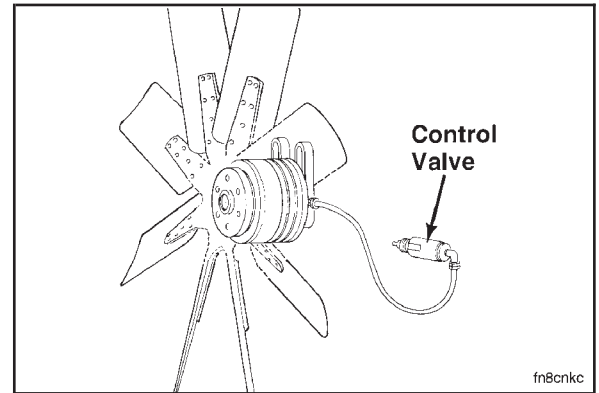
The following fan clutch checks are for fan clutches wired to the electronic controlled fuel system. Refer to the vehicle manufacturer's specifications to determine the installation of the fan clutch.



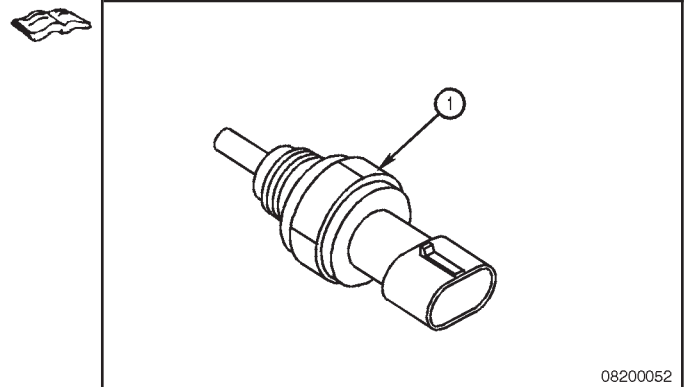
Maintenance Check (008-025-008)

This type of fan clutch is engaged by air pressure and is disengaged by spring tension.

Air pressure of 620 to 830 kPa [90 to 120 psi] is required to override the clutch spring tension to engage the fan.



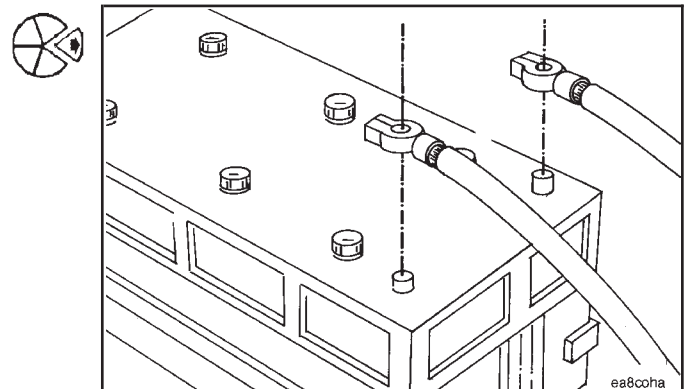
If the fan does **not** operate within the temperature range indicated on the coolant temperature sensor, the fan clutch and the controls **must** be checked. Refer to the fan clutch manufacturer's service manual.

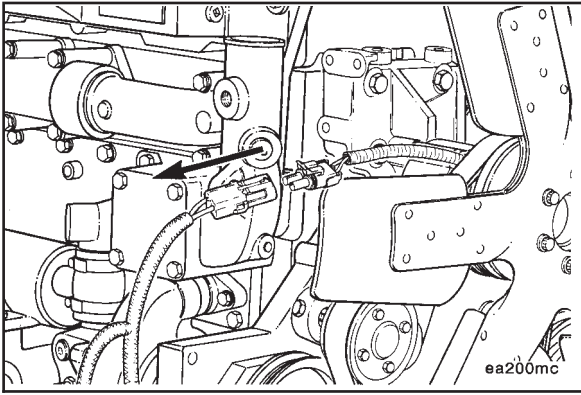


Fan Clutch, Electric (008-026)

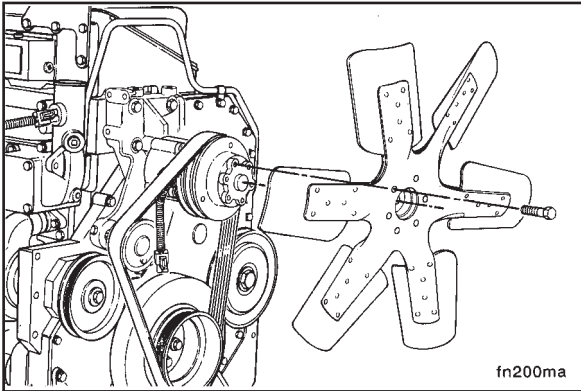
Remove (008-026-002)

Disconnect the electrical connections, negative (-) cable first, from the batteries.

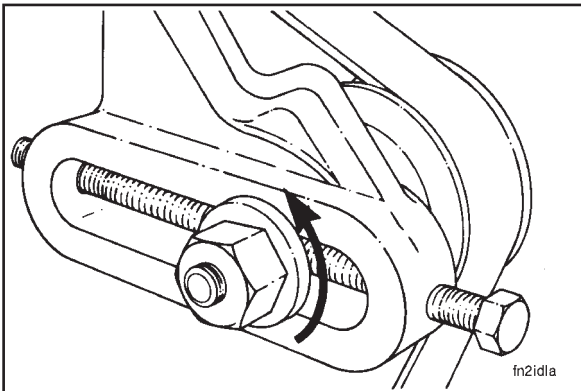




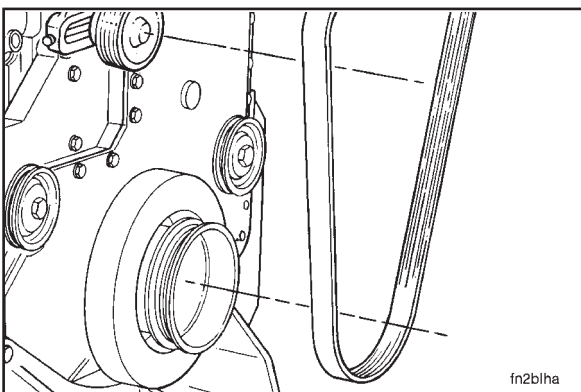
Disconnect the fan clutch connector on the base harness from the fan clutch.



Remove the fan from the engine.

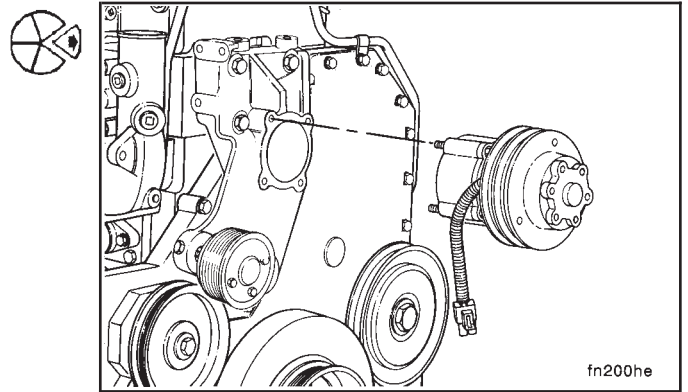


Loosen the fan idler pulley shaft locknut.
Turn the adjusting screw **counterclockwise** to release the fan belt tension.



Remove the fan drive belt.

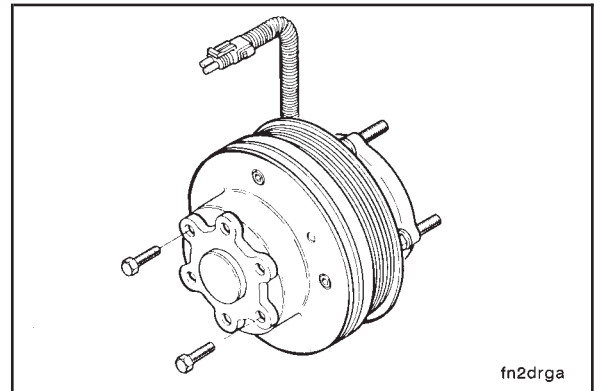
Remove the fan hub, clutch and capscrews from the engine.



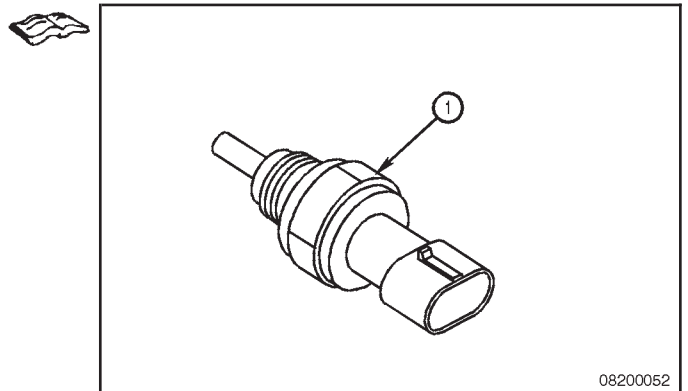
Inspect for Reuse (008-026-007)

This type of fan clutch is activated when 12 VDC from the vehicle electrical system is applied.

The clutch will disengage when 0 VDC is applied.

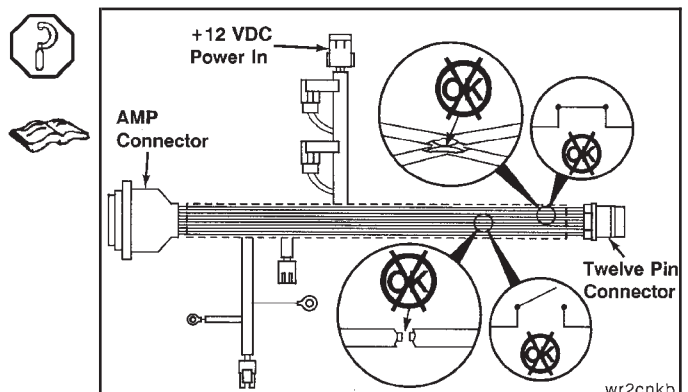


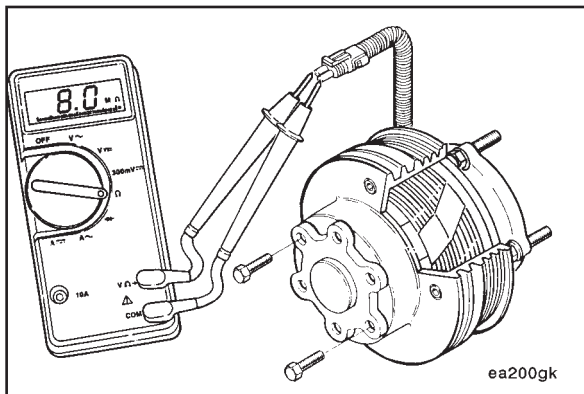
If the fan does **not** operate within the temperature range on the coolant temperature sensor, the fan clutch and the controls **must** be checked.



Electrical Connections

Visually inspect wires and harnesses to ensure none are broken or shorted. Replace harnesses or wires that are broken. Refer to Procedure 008-069.



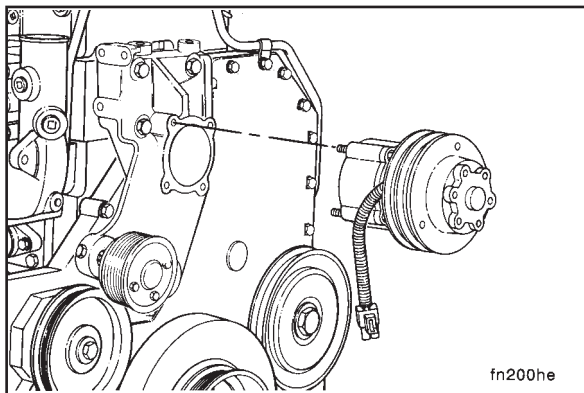


Electromagnetic Coil

The Cummins electric fan clutch contains an electromagnetic coil. If the fan is **not** operating, and all electrical circuits are OK, the coil can have an open circuit.

Measure the continuity across the isolated coil. Connect one volt-ohm meter lead to pin A in the fan clutch connector. Connect the other lead to pin B.

The resistance **must** be approximately 8 ohms. If the resistance is **not** 8 ohms, replace the fan clutch.

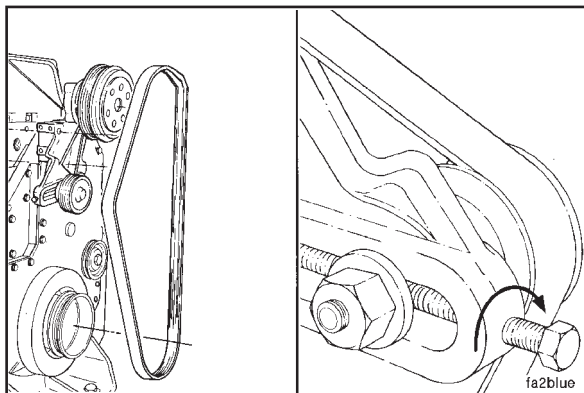


Install (008-026-026)

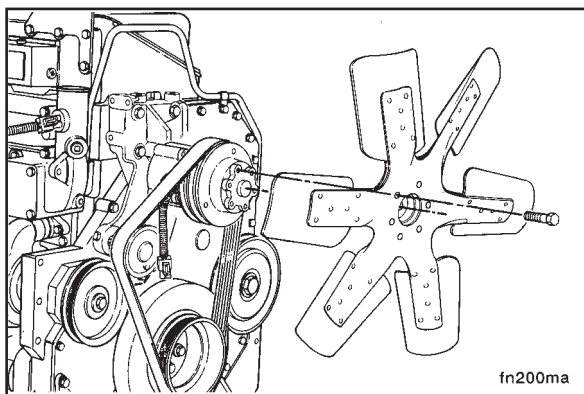
Install the fan hub, clutch, and capscrews. Tighten the capscrews alternately and evenly.



Torque Value: 47 N•m [35 ft-lb]



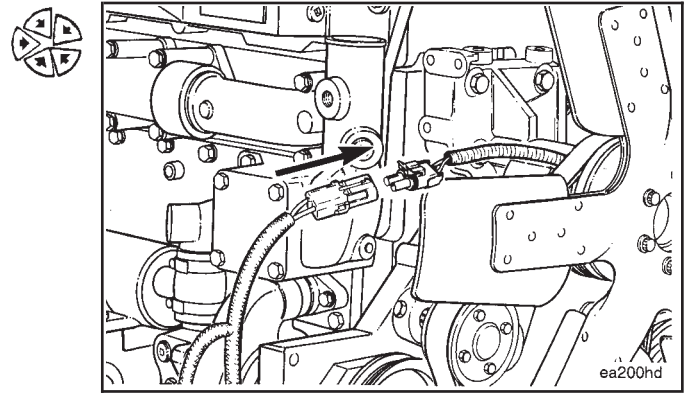
Install the fan belt on the engine. Refer to Procedure 008-002-026.



Install the fan and capscrews. Tighten the capscrews to the fan manufacturer's specifications.



Connect the fan clutch connector on the base harness to the fan clutch.

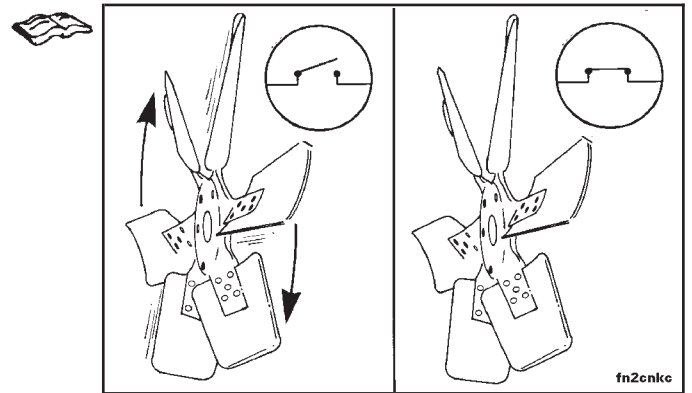


Fan Clutch, On-Off (008-027)

General Information

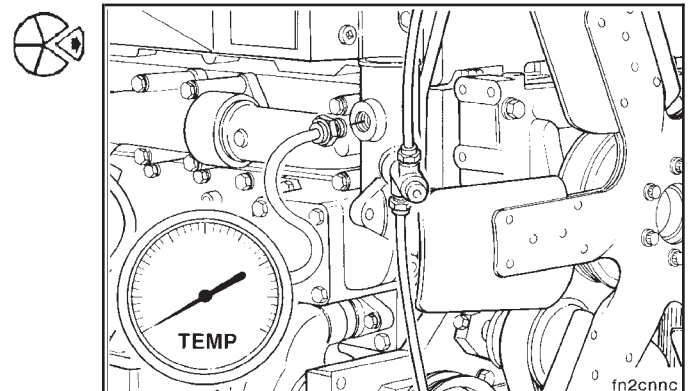
On CELECT™ and CELECT™ Plus engines, all fan clutches can be controlled by the electronic control module (ECM). The ECM is programmed to turn the fan ON when 0 VDC (normally open switch) is applied to the fan clutch relay, and turn the fan OFF when 12 VDC (normally closed switch) is applied to the fan clutch relay.

The following fan clutch checks are for fan clutches wired to the electronic controlled fuel system. Refer to the vehicle manufacturer's specifications to determine the installation of the fan clutch.

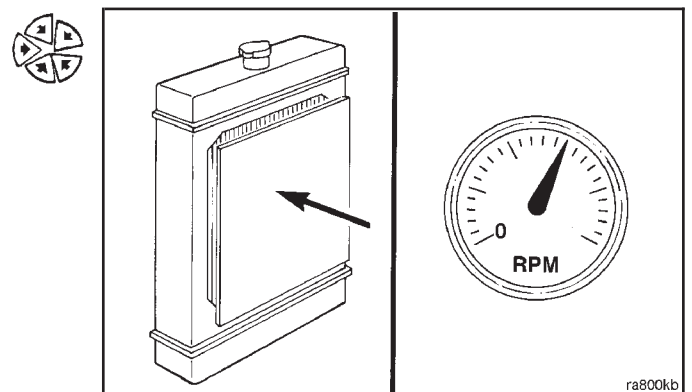


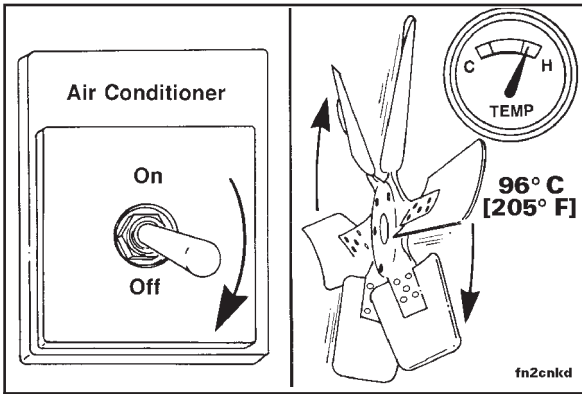
Initial Check (008-027-001)

Remove the shutter stat from the thermostat housing, if equipped, and install a master temperature gauge which is known to be accurate. A thermocouple can be used.



Restrict the radiator air flow.
Operate the engine at rated rpm.

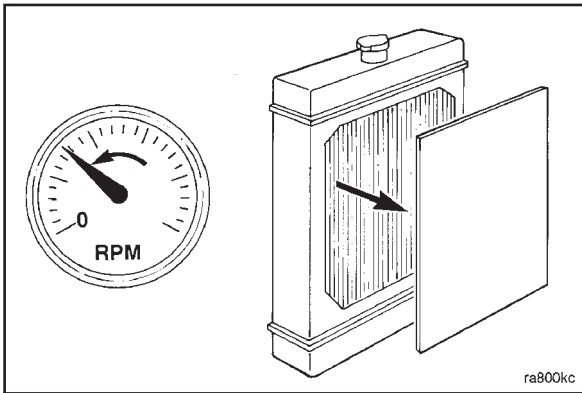




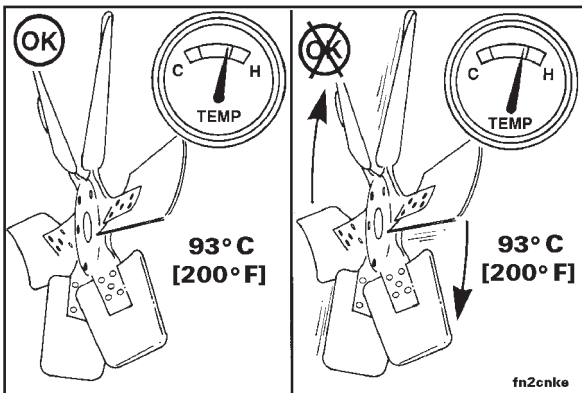
If the vehicle is air conditioned, make sure the air conditioning is turned off to prevent continuous operation of the fan. When the coolant temperature reaches 96°C [205°F], check for fan engagement.

NOTE: The temperature given for fan engagement is for fans controlled by the ECM.

NOTE: Fan noise and air flow increase when the fan clutch engages.

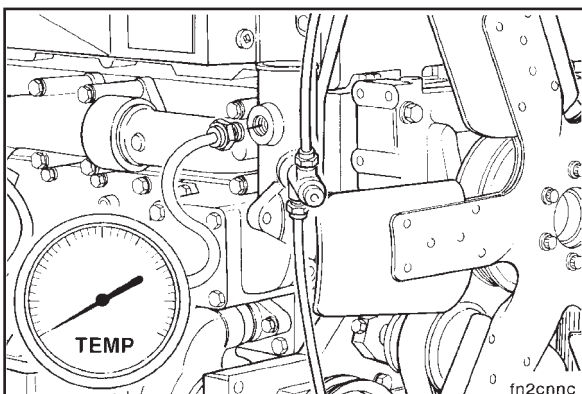


Return the engine to idle and remove the radiator air restriction.



The fan clutch **must** disengage before the coolant temperature drops to 93°C [200°F]. Cummins Engine Company, Inc. recommends the fan disengage at 3°C [6°F] below the temperature stamped on the fan temperature sensor.

NOTE: The temperature given for fan disengagement is for fans controlled by the ECM.



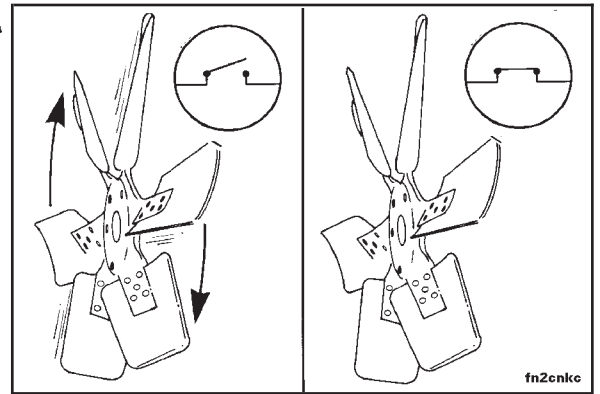
Remove the temperature gauge or thermocouple and install the shutter stat, if used.

Fan Clutch, Viscous (008-028)

General Information

On CELECT™ and CELECT™ Plus engines, all fan clutches can be controlled by the electronic control module (ECM). The ECM is programmed to turn the fan ON when 0 VDC (normally open switch) is applied to the fan clutch relay, and turn the fan OFF when 12 VDC (normally closed switch) is applied to the fan clutch relay.

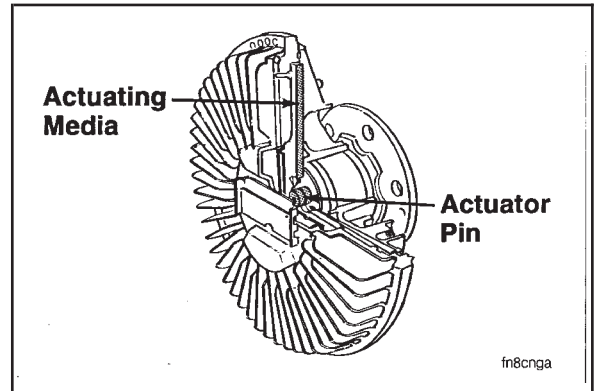
The following fan clutch checks are for fan clutches wired to the electronic controlled fuel system. Refer to the vehicle manufacturer's specifications to determine the installation of the fan clutch.



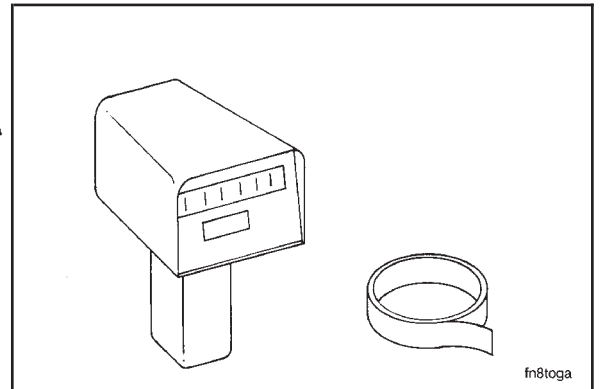
Initial Check (008-028-001)

Viscous fan drives are used as a power-saving device activated by a built-in sensor behind the radiator used to monitor air temperature.

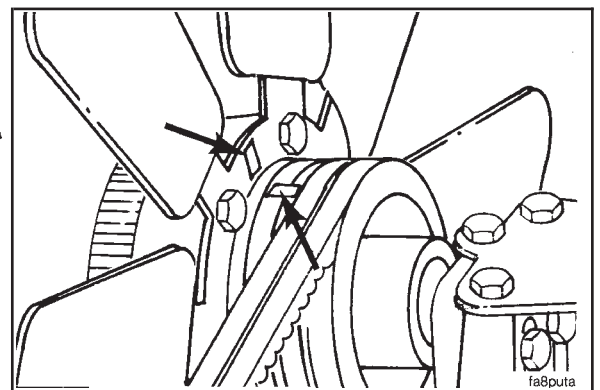
When the air temperature reaches a specific level, depending on the temperature setting of the sensor used, the temperature-sensing control moves an actuator that allows viscous fluid to engage the fan drive and increase the fan speed.

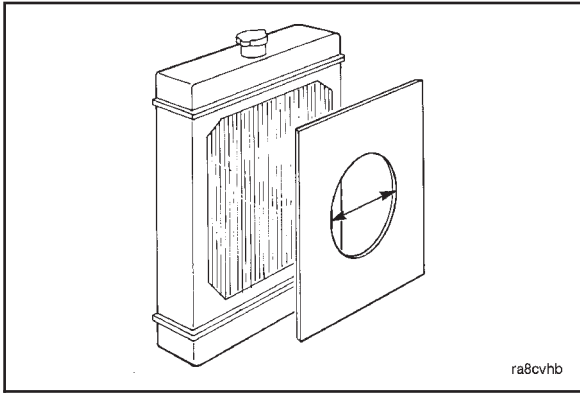


Use a fan rpm measuring device to check the operation of the viscous fan hub. A strobe or digital optical tachometer, Part No. 3377462, can be used.



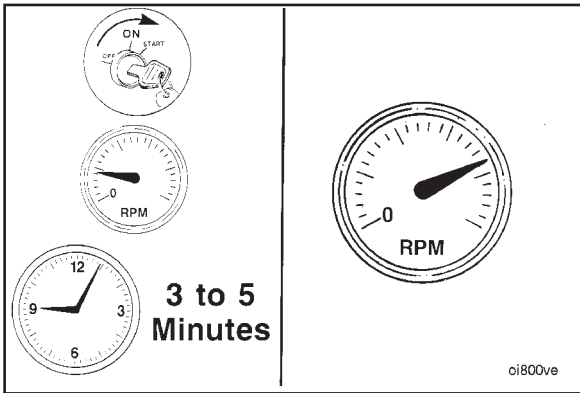
Mark a spot on the fan hub pulley and one fan blade so the measuring device can determine the pulley and the fan speed. Reflective tape, Part No. 3377464, in digital optical tachometer, Part No. 3377462, can be used to mark the fan blade and the pulley. (Refer to Service Tools Instruction, Bulletin No. 3377544, for more information.)





While the engine is still warm and the vehicle is shut off, cover the radiator grill.

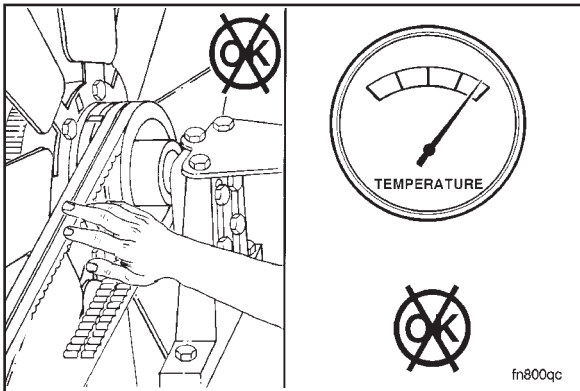
Leave a hole approximately 0.3 m [1-foot] in diameter in the cardboard to allow some air flow to the viscous fan hub.



Start the engine. Idle the engine for 3 to 5 minutes. Lock the throttle in a "HIGH IDLE" position.

Use the PTO option to operate the engine at maximum PTO engine rpm.

Refer to the CELECT™ Plus System Troubleshooting and Repair Manual, Bulletin No. 3666139.

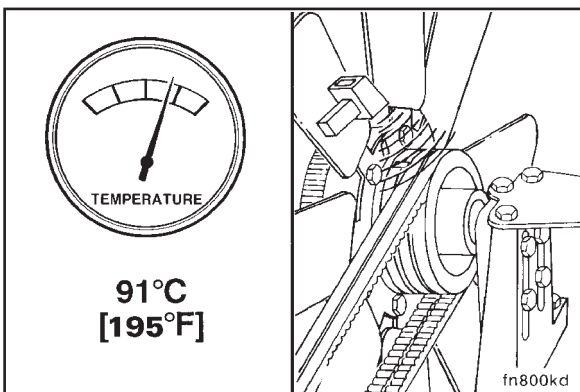


⚠ WARNING ⚠

The fan will engage when the engine is started. To avoid personal injury, do not put your hands in the path of the rotating fan. Do not wear jewelry or loose or torn clothing.

⚠ CAUTION ⚠

Do not exceed 100°C [212°F] coolant temperature. Higher coolant temperatures can damage the engine.



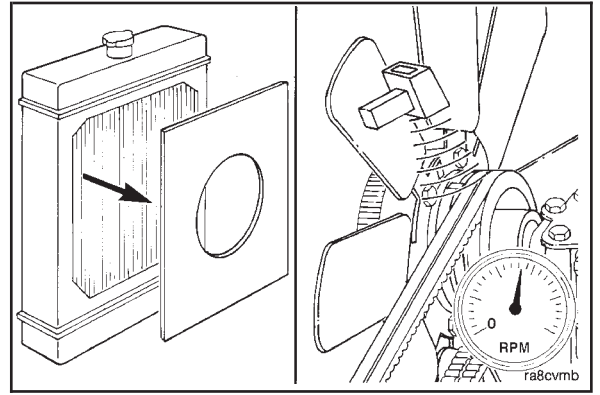
When the coolant temperature reaches 91°C [195°F], measured fan speed **must** reach a minimum of 85 percent of the pulley speed.

Measure the fan speed divided by the fan hub (pulley) speed. The dividend **must** be greater than or equal to 0.85.

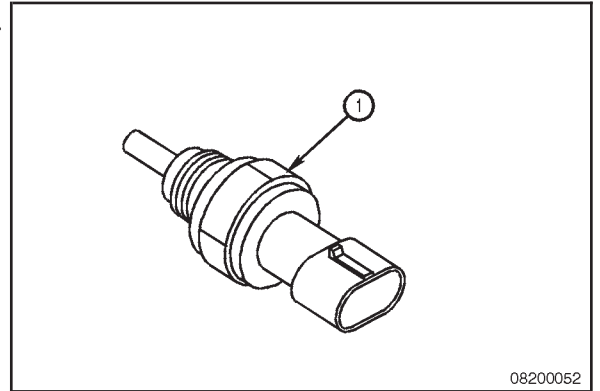
$$\frac{\text{Measured Fan Speed}}{\text{Fan Hub (Pulley Speed)}} > 0.85$$

While the engine is still at high idle, remove the radiator grill cover. The fan speed **must** begin to decrease after one minute and eventually drop to a maximum of 50 percent of the input pulley speed.

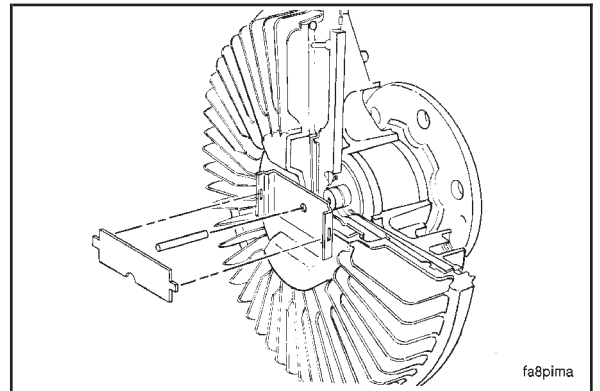
If the viscous fan hub fails this test, have it checked by an authorized fan hub dealer for repair or replacement.



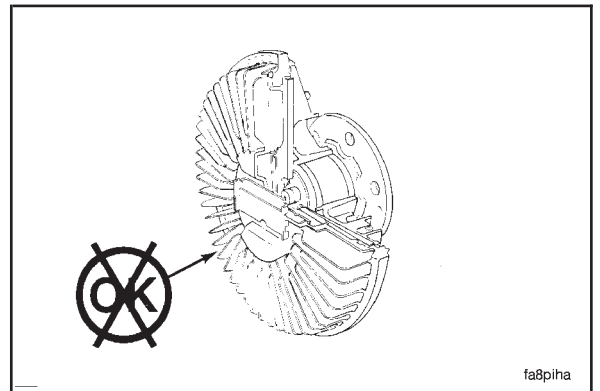
If the fan does **not** operate within the temperature range indicated on the coolant temperature sensor, the fan clutch and the controls **must** be checked. Refer to the fan clutch manufacturer's service manual.

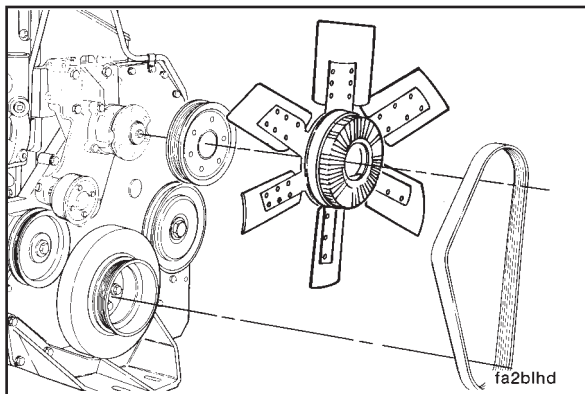


If a fan speed measuring device is **not** available and the complaint is overheating, remove the viscous fan hub bi-metal strip and the control pin. This will cause the fan hub to operate all the time.



If the overheating complaint does **not** occur with the control pin removed, install the control pin and take the fan hub to an authorized fan hub dealer for repair or replacement.



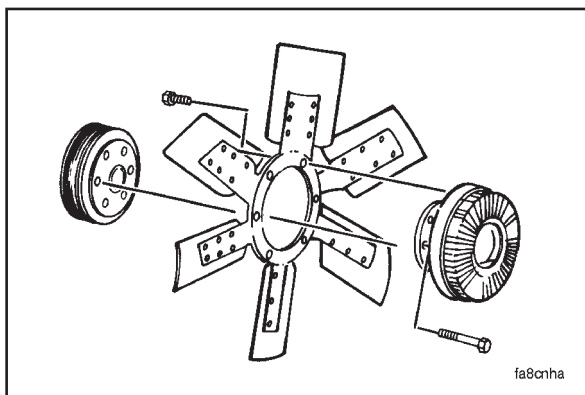


Remove (008-028-002)

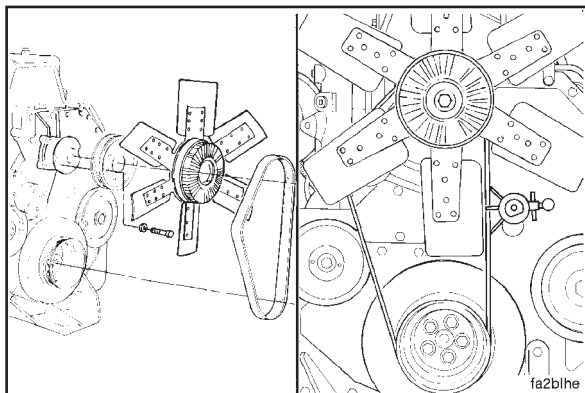
Remove the fan drive belt. Refer to Procedure 008-002-002.



Remove the fan and fan clutch assembly.



Remove the nuts, washers and fan.



Install (008-028-026)

Install the fan on the fan clutch assembly.



Tighten the mounting nuts to the manufacturer's torque specifications.



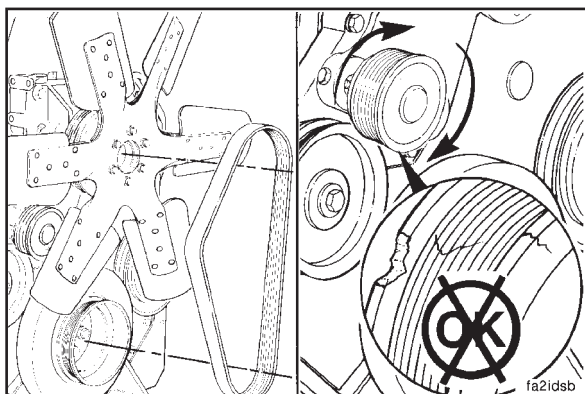
Install the fan clutch and fan assembly on the engine.



Tighten the capscrews.

Torque Value: 68 N•m [50 ft-lb]

Install, adjust, and tighten the fan drive belt. Refer to Procedure 008-002-026.



Fan Drive Idler Pulley Assembly (008-030)



Initial Check (008-030-001)

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



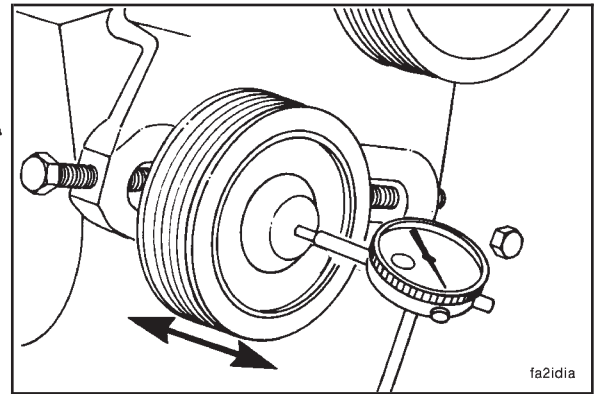
Visually inspect the idler pulley for:

- Freedom of rotation
- Cracked, chipped or broken pulley grooves

Measure the idler pulley end clearance.

Idler Pulley End Clearance		
mm		in
0.025	MIN	0.0010
0.250	MAX	0.0100

Replace or rebuild the idler pulley if the end clearance is **not** within these specifications. Refer to M11 Shop Manual, Bulletin No. 3666075, for rebuilding procedures..



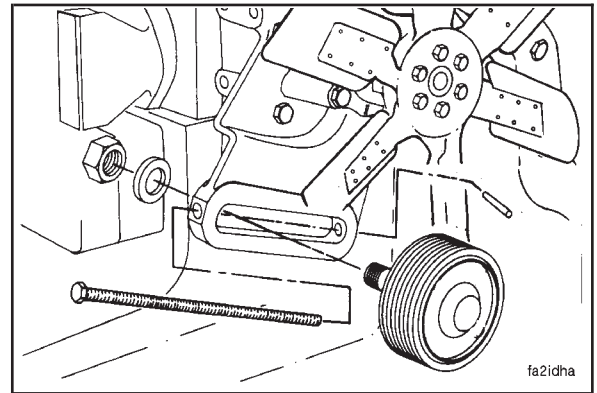
Remove (008-030-002)

Remove the roll pin and washer from the idler pulley adjusting screw.

Remove the locknut and washer from the back of the idler pulley shaft.

Remove the adjusting screw.

Remove the fan idler pulley from the fan hub support bracket.

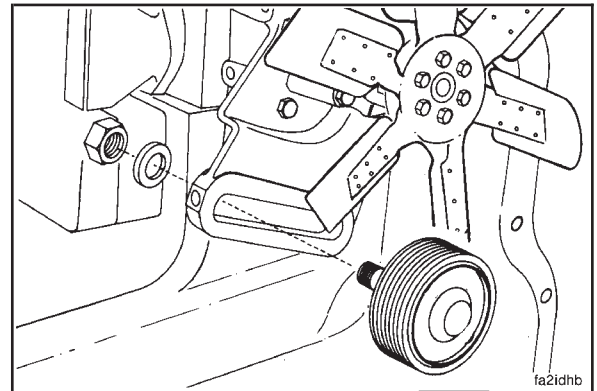


Install (008-030-026)

NOTE: Do not tighten the locknut until the fan drive belt has been installed and adjusted.

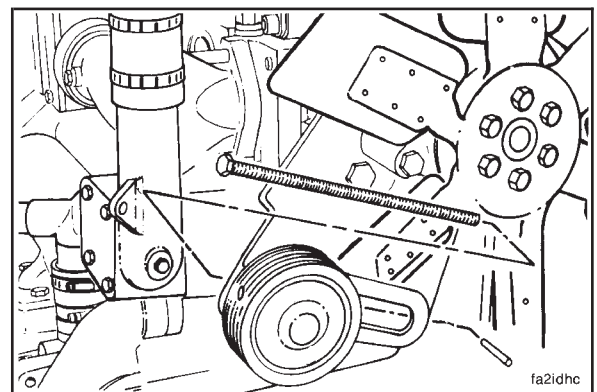
Install the idler pulley in the fan hub support bracket.

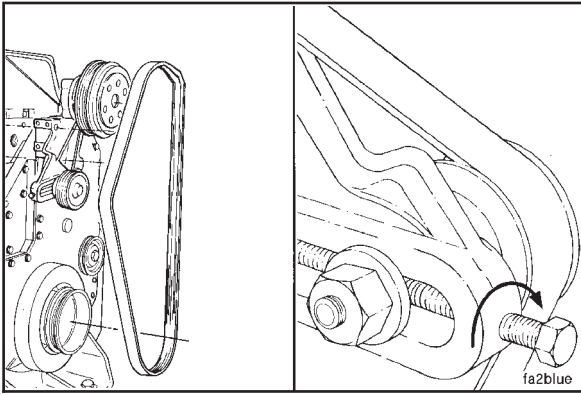
Install the washer and locknut on the idler pulley shaft.



Install the adjusting screw in the idler pulley shaft.

Turn the adjusting screw in far enough to install the washer and roll pin in the shaft at the bottom of the fan hub support bracket.





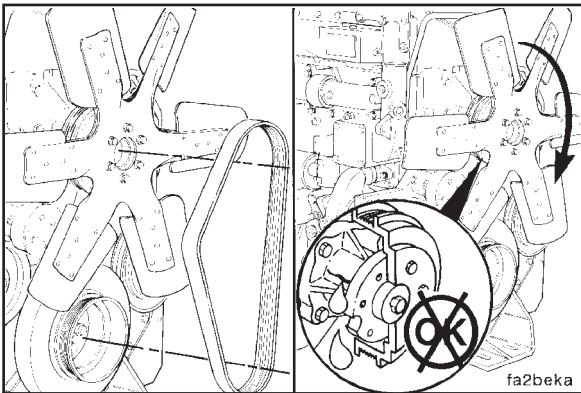
Install and adjust the fan drive belt. Refer to Procedure 008-002-026.

Tighten the idler pulley shaft locknut.



Torque Value: 190 N•m [140 ft-lb]

Check the belt tension again after the locknut is tightened.



Fan Hub, Belt Driven (008-036)

Initial Check (008-036-001)

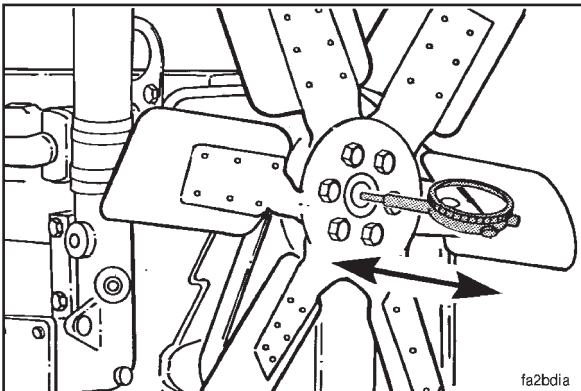


Remove the fan drive belt. Refer to Procedure 008-002-002.



Visually inspect the fan hub for:

- Freedom of rotation
- Cracks
- Grease seal leakage

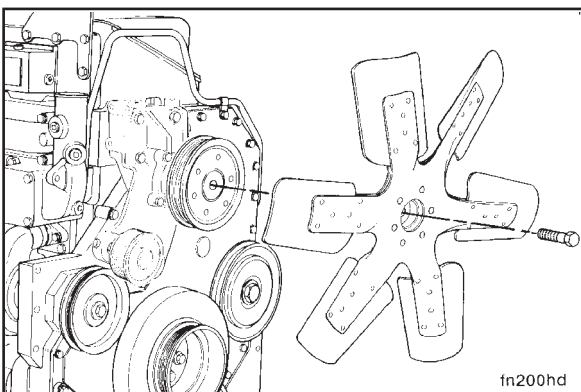


Measure the fan hub end clearance.



Fan Hub End Clearance		
mm		in
0.08	MIN	0.003
0.41	MAX	0.016

Replace or rebuild the fan hub if the end clearance does **not** meet these specifications. Refer to the M11 Shop Manual, Bulletin No. 3666075, for rebuilding the fan hub.

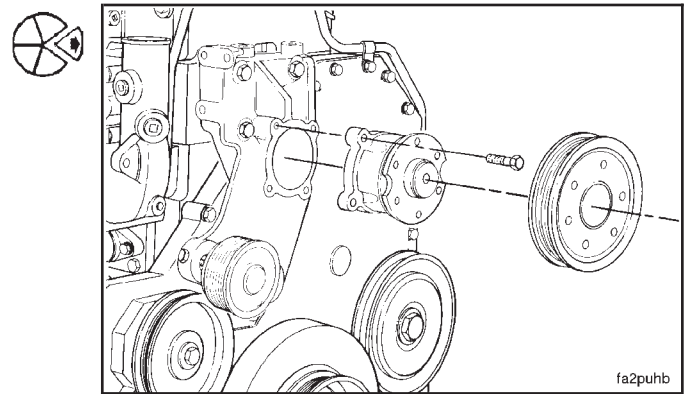


Remove (008-036-002)

Remove the fan and clutch assembly. Refer to Procedure 008-040-002.

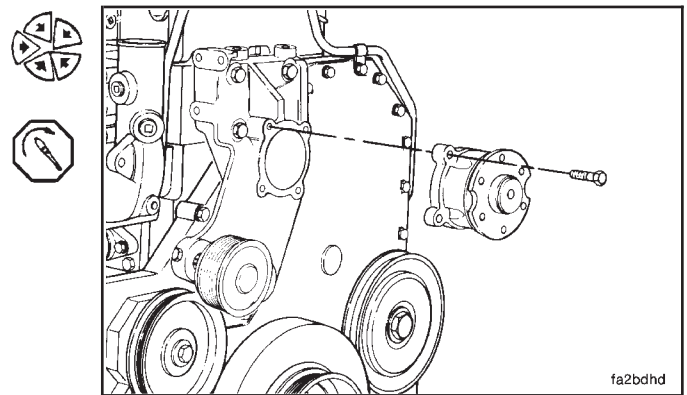


Remove the fan drive pulley.
Remove the four capscrews and the fan hub.

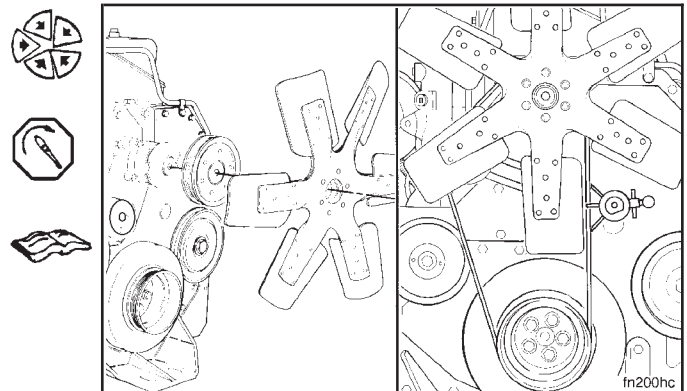


Install (008-036-026)

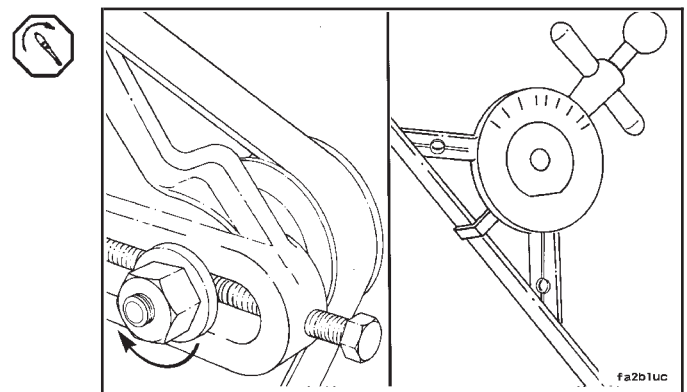
Install the new fan hub and four capscrews.
Torque Value: 47 N•m [35 ft-lb]

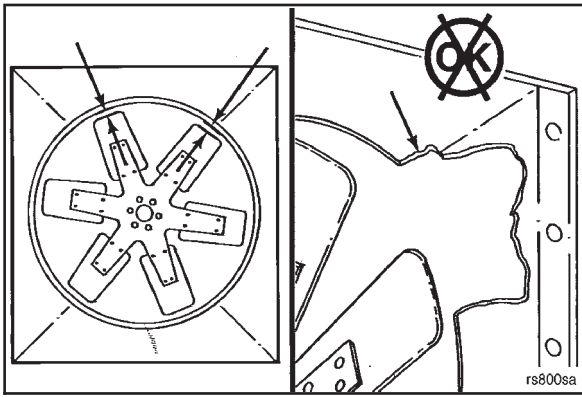


Install the fan drive pulley.
Install the fan and clutch assembly. Refer to Procedure 008-040-026.
Install and tighten the mounting capscrews.
Torque Value: 68 N•m [50 ft-lb]
Install, adjust and tighten the fan drive belt. Refer to Procedure 008-002-026.



Tighten the fan idler pulley shaft locknut.
Torque Value: 190 N•m [140 ft-lb]
Check the belt tension again after the locknut is tightened.





Fan Shroud Assembly (008-038)

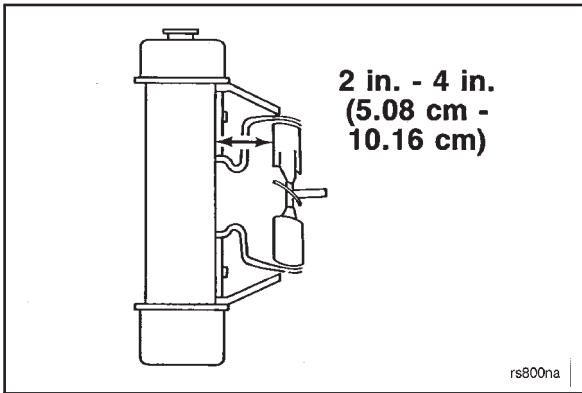
Initial Check (008-038-001)



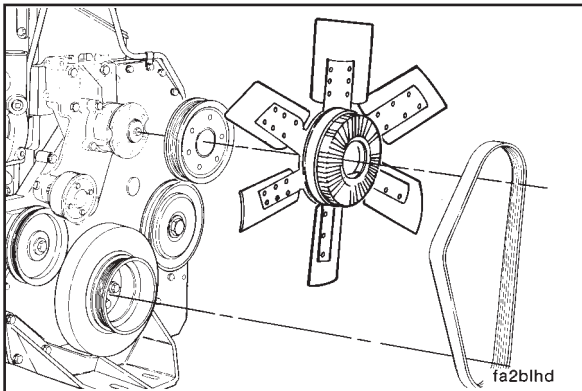
CAUTION

The fan shroud must be installed correctly, be in good condition, and the shroud to fan clearance within the manufacturer's specifications to insure proper air flow through the radiator to provide adequate engine cooling.

Visually inspect the fan shroud for proper fan clearance, cracks, air leaks or damage. Replace if necessary. Refer to the manufacturer's instructions.



Cummins Engine Company, Inc. recommends fan clearance be 5.08 to 10.16 cm [2 to 4 in.] from the radiator core. Refer to the equipment manufacturer for alternative positions.



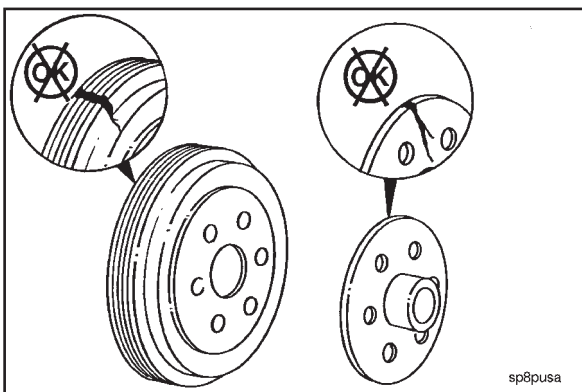
Fan Spacer and Pulley (008-039)

Remove (008-039-002)



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

Remove the fan and fan clutch assembly.



Inspect for Reuse (008-039-007)



Visually inspect the fan spacer and pulley, if used, for cracks or damage. Replace if necessary.

Install (008-039-026)

Install the fan on the fan clutch assembly.

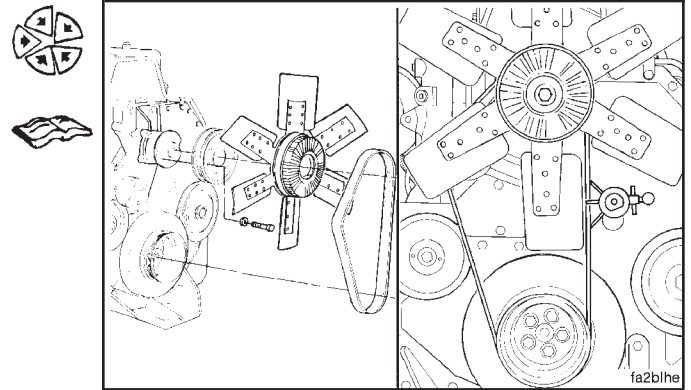
Tighten the mounting nuts to the manufacturer's specifications.

Install the fan clutch and fan assembly on the engine.

Tighten the capscrews.

Torque Value: 68 N•m [50 ft-lb]

Install, adjust, and tighten the fan drive belt. Refer to Procedure 008-002-026.

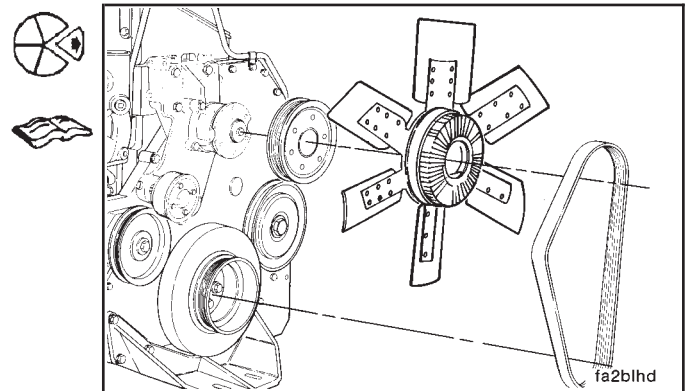


Fan, Cooling (008-040)

Remove (008-040-002)

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

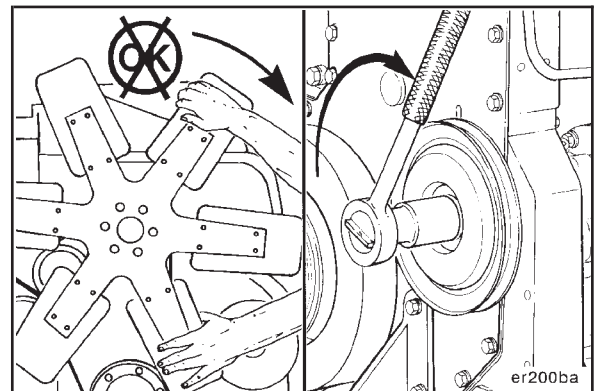
Remove the fan and fan clutch assembly.



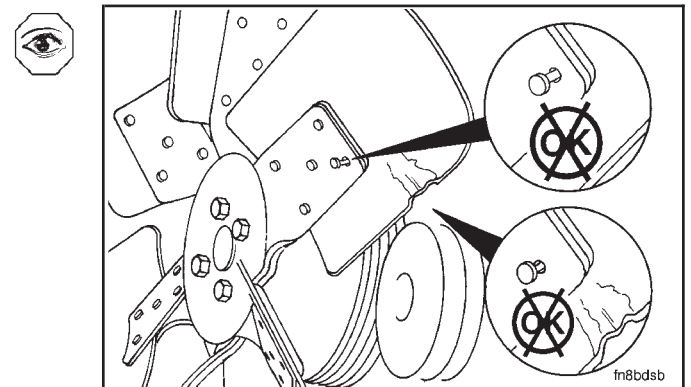
Inspect for Reuse (008-040-007)

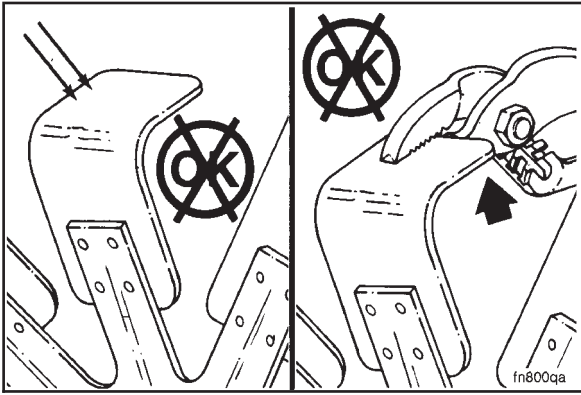


Do not rotate the engine by pulling or prying on the fan. The fan blade(s) can be damaged and cause the fan to fail and cause serious personal injury or property damage. Use the accessory drive shaft to rotate the crankshaft.



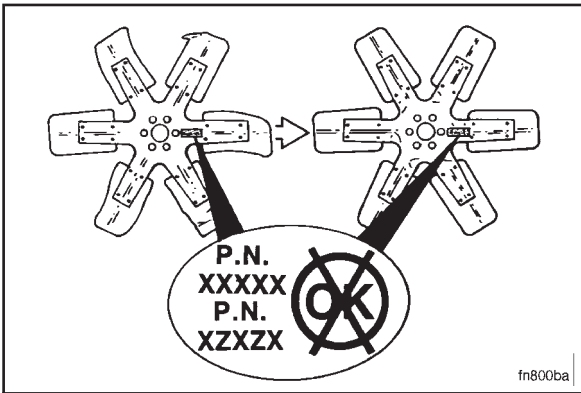
A visual inspection of the cooling fan is required daily. Check for cracks, loose rivets, and bent or loose blades. Check the fan to make sure it is securely mounted. Tighten the capscrews if necessary.



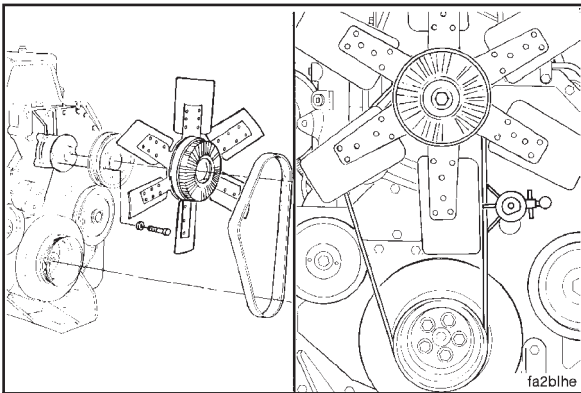


▲ WARNING ▲

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 serious personal injury or property damage.



Replace any original equipment fan that is damaged with a fan of the identical part number. Cummins Engine Company, Inc. **must** approve any other fan changes.



Install (008-040-026)

Install the fan on the fan clutch assembly.



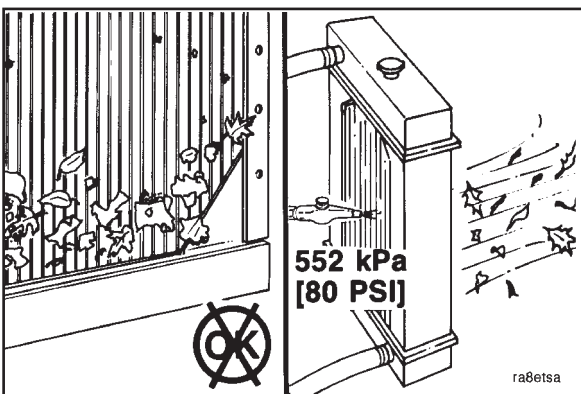
Tighten the mounting nuts to the manufacturer's specifications.

Install the fan clutch and fan assembly on the engine.

Tighten the capscrews.

Torque Value: 68 N•m [50 ft-lb]

Install, adjust, and tighten the fan drive belt. Refer to Procedure 008-002-026.



Radiator (008-042)

Initial Check (008-042-001)



▲ CAUTION ▲

Wear appropriate eye and face protection when using compressed air. Improper use can cause bodily injury from flying debris and dirt.

Visually inspect for plugged radiator fins.

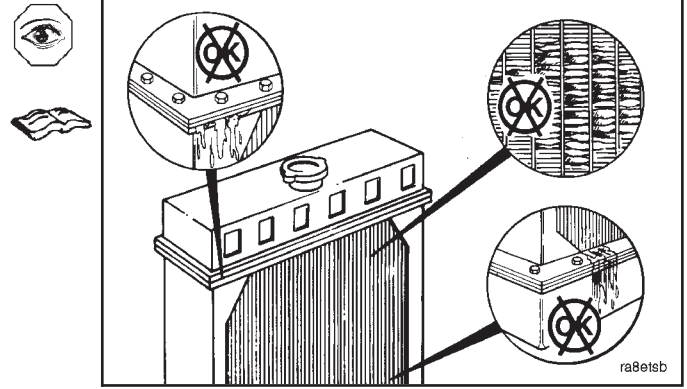
Use compressed air to blow out the dirt and debris.

Air Pressure: 552 kPa [80 psi]

Visually inspect for bent or broken fins.

Visually inspect for radiator core and gasket leaks.

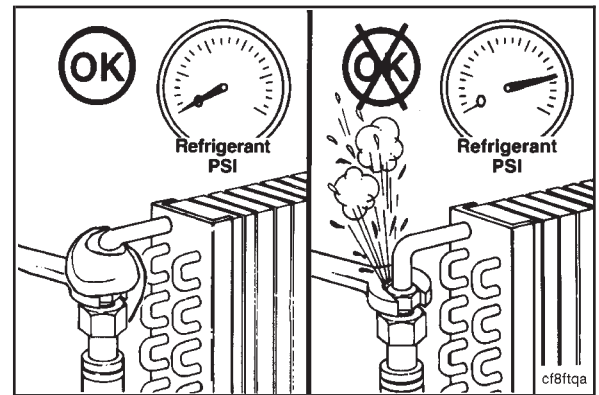
If the radiator **must** be replaced, refer to the manufacturer's replacement procedures.



⚠ WARNING ⚠

If a liquid refrigerant system must be removed before removing the radiator, wear eye and face protection. Wrap a cloth around the fittings before removal. Liquid refrigerant can cause serious eye and skin injury.

For environmental protection, federal regulations require that Freon be recycled, and **not** vented into the atmosphere.

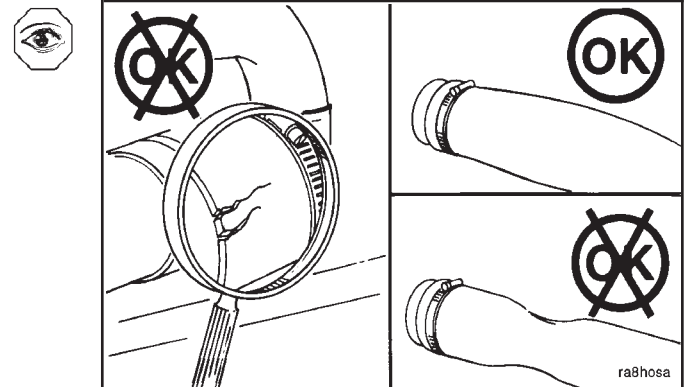


Radiator Hoses (008-045)

Inspect for Reuse (008-045-007)

Inspect all hoses for cracks, cuts or collapsing.

NOTE: The silicone engine coolant hose will exhibit swelling due to the elasticity of the hose.



Radiator Pressure Cap (008-047)

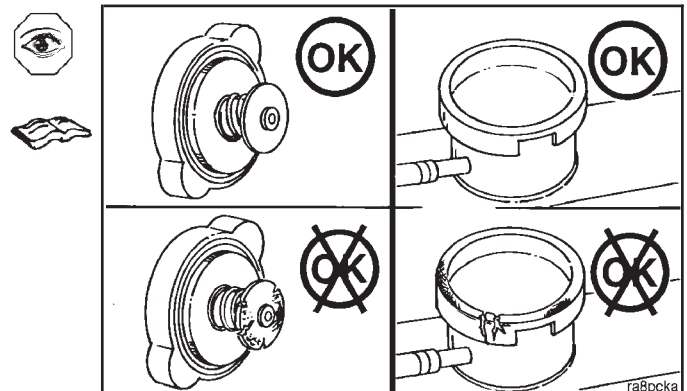
Inspect for Reuse (008-047-007)

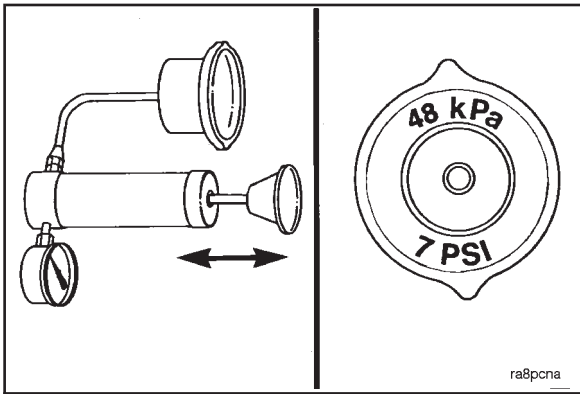
Be sure the correct radiator cap is being used. Refer to "Cooling System-Specifications".

Visually inspect the rubber seal of the pressure cap for damage.

Visually inspect the radiator fill neck for cracks or other damage.

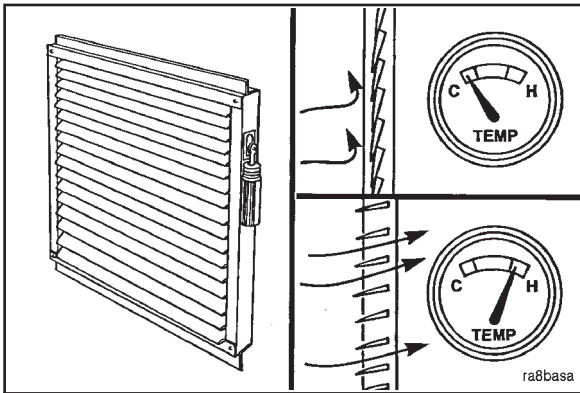
Refer to the radiator manufacturer for instructions if the fill neck is damaged.





Pressure test the radiator cap.

The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.



Radiator Shutter Assembly (008-049) Initial Check (008-049-001)

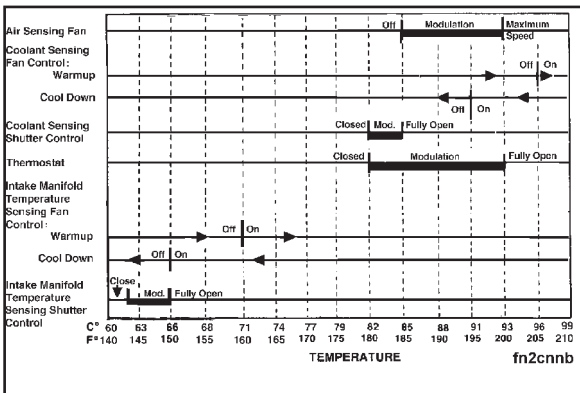


Check the shutters in the closed position to be sure they are completely closed.

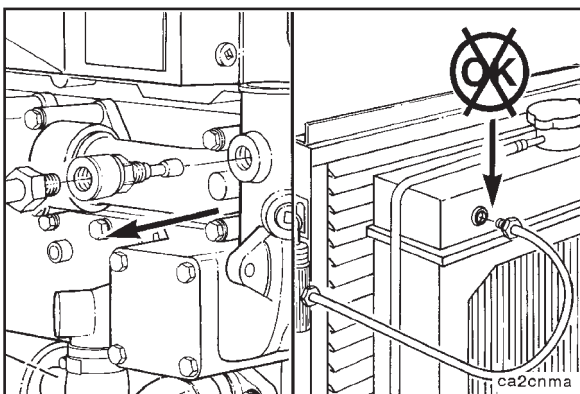
NOTE: If the shutters are **not** closed, refer to the manufacturer's instructions.

Be sure the shutters open completely at the desired temperature setting.

NOTE: If the shutters are **not** open, refer to the manufacturer's instructions.



Shutters and thermatic fans **must** be set to operate in the same temperature range as the thermostat with which they are used. Refer to the Thermal Control Settings chart at the front of this section.



Install the shutter temperature sensor in the thermostat housing.

Do **not** install the shutter temperature sensing unit in the radiator top (expansion) tank.

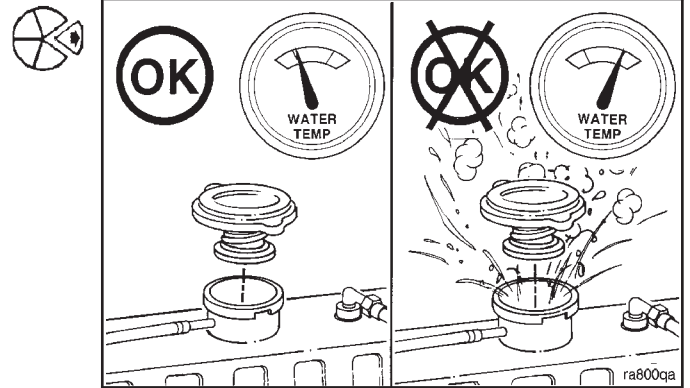
Water Pump (008-062)

Remove (008-062-002)

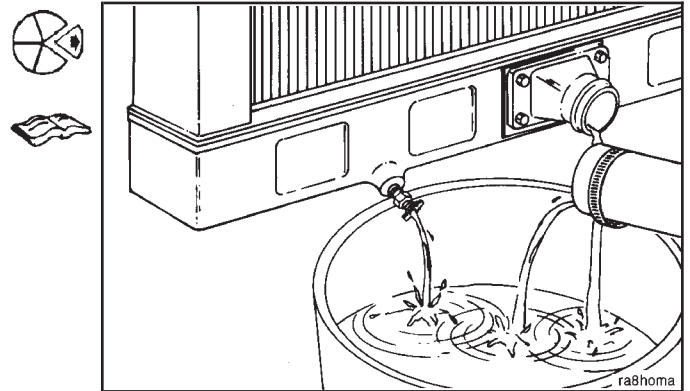


Do not remove the radiator cap from a hot engine. Wait until the temperature is below 50°C [120°F] before removing the coolant system pressure cap. Failure to do so can cause serious personal injury from heated coolant spray.

Remove the radiator cap after the engine is cool.



Drain the cooling system. Refer to Procedure 008-018-005.

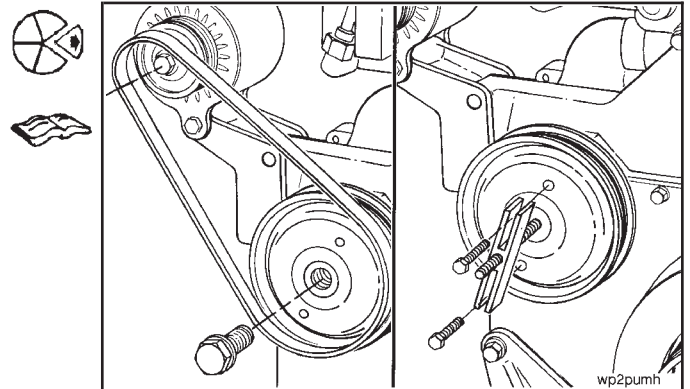


Remove the alternator drive belt. Refer to Procedure 013-005-002.

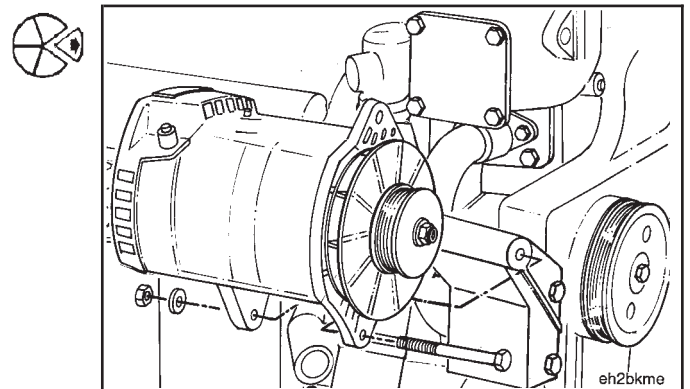
Remove the water pump pulley retaining capscrew.

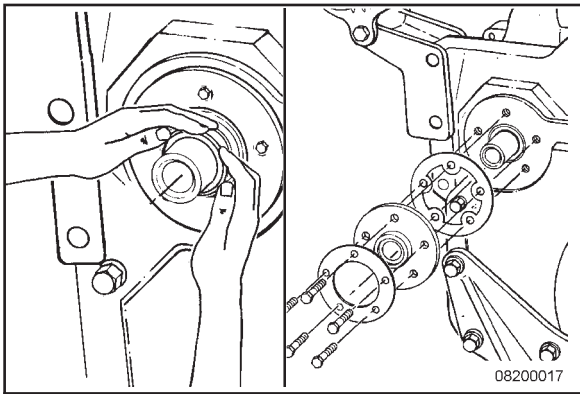
Use the standard pulley puller, Part No. ST-647, and two 5/16 X 18 X 2 capscrews to remove the pulley.

NOTE: Be sure the puller capscrews are threaded all the way through the puller before applying pressure to the puller screw.



Remove the alternator. Refer to Procedure 013-001-002.





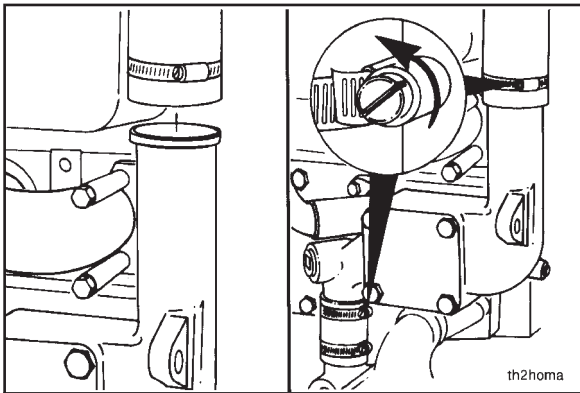
Remove the dust seal.

Remove the five water pump oil seal capscrews, clamping ring, oil seal and gasket.



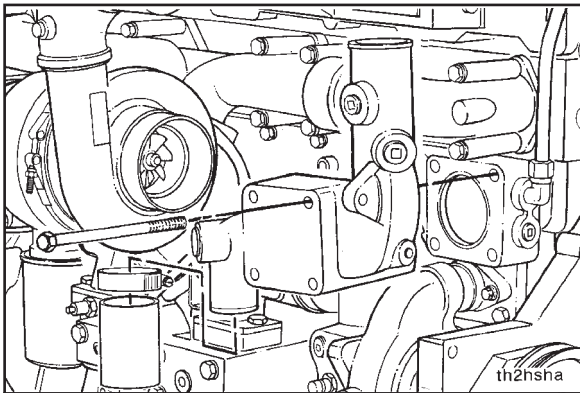
NOTE: Remove the dust seal as the seal carrier is removed or use a heel bar, or similar tool, to pry the dust seal away from the seal case. Then remove the dust seal by hand.

Discard the oil seal and dust seal.

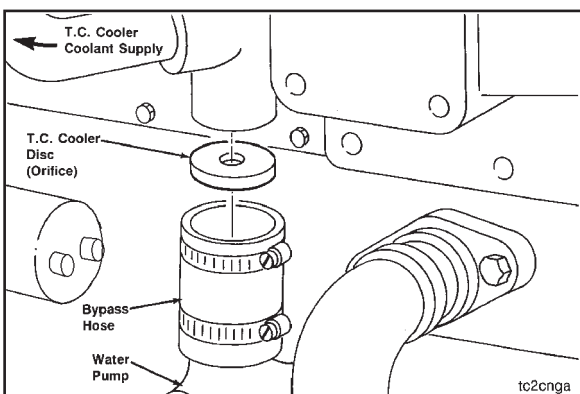


Remove the upper radiator hose from the thermostat housing.

Loosen the coolant bypass hose clamps.



Remove the four thermostat housing mounting capscrews and the thermostat housing.



The coolant flow to provide cooling to the torque converter (if equipped) is achieved in different manners.

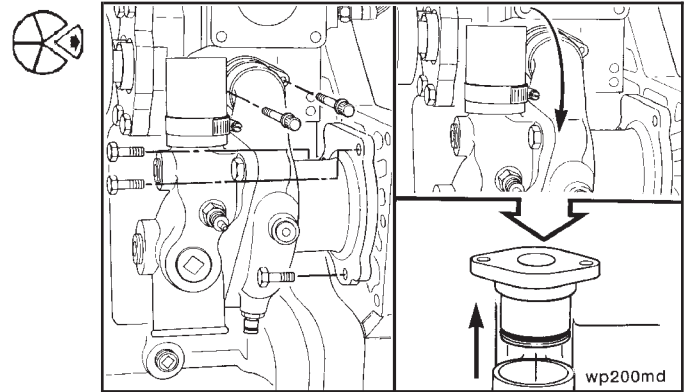
M11 engines use a torque converter cooler disc inside the coolant bypass hose to direct engine coolant to the inlet side of the torque converter cooler.

Remove the two water pump water transfer connection capscrews.

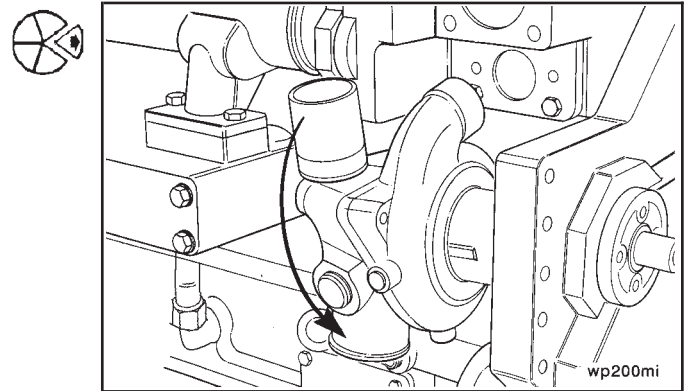
Remove the three water pump mounting capscrews.

Rotate the water pump outward so the water transfer connection can be removed from the water pump.

Remove the water transfer connection from the water pump.

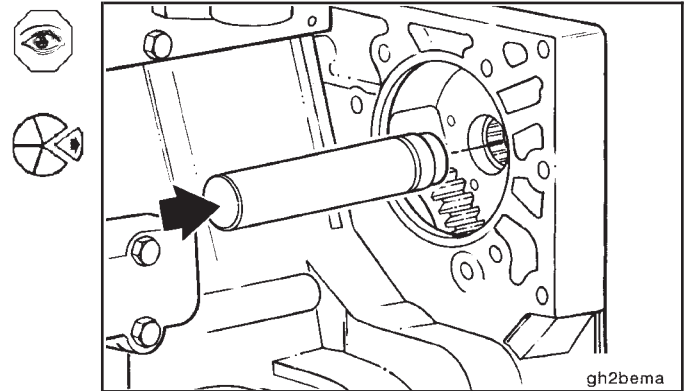


Remove the water pump. Twist the pump outward from the top and angle the rear of the pump downward as it is being removed to allow the pump to pass the thermostat housing support.



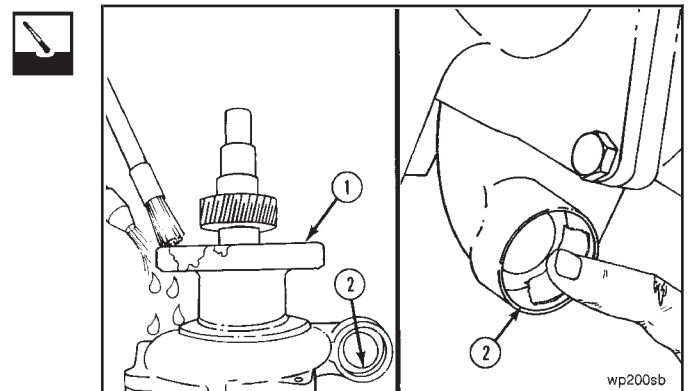
Visually check the needle bearing for damage and freedom of needle rotation. Replace the bearing if it is damaged or if it does **not** turn freely.

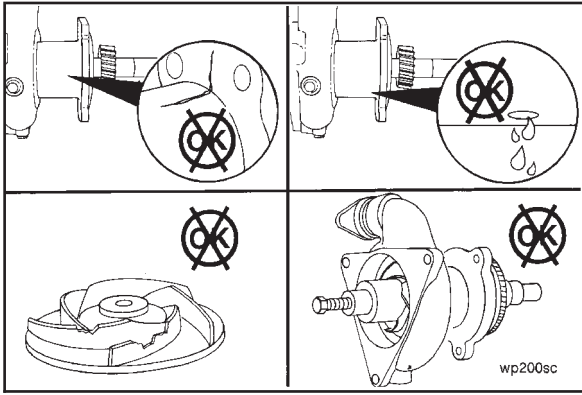
If the bearing is replaced, use bearing installation tool, Part No. 3824117, along with a cup plug driver to remove the needle bearing from the gear housing. Gently tap the bearing out from the rear side of the housing.



Clean (008-062-006)

Clean surfaces (1) and (2).





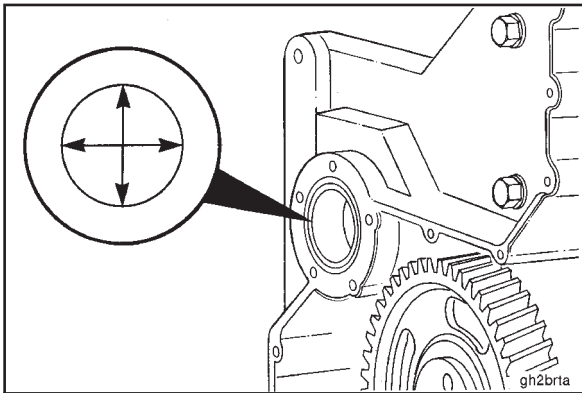
Inspect for Reuse (008-062-007)

Inspect the water pump housing for cracks.

Inspect the water pump weep hole for indication of leaks.

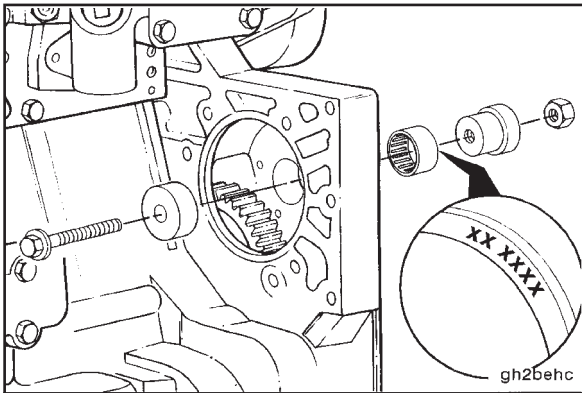
NOTE: A streak or chemical buildup at the weep hole is **not** justification for water pump replacement. If a steady flow of coolant or oil is observed, replace the water pump with a new or rebuilt unit.

Remove the water pump cover and visually inspect the water pump impeller for cracks or damage.



If the needle bearing was removed, measure the inside diameter of the gear housing needle bearing bore.

Needle Bearing Bore I. D. (Gear Housing)		
mm		in
36.967	MIN	1.4553
36.992	MAX	1.4564

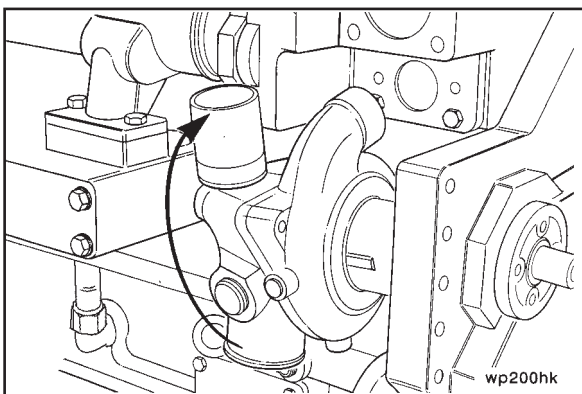


Install (008-062-026)

If the needle bearing was removed, use bearing installation tool, Part No. 3824117, to install a new needle bearing in the gear housing.

NOTE: The bearing **must** be installed with the part number side of the bearing against the installation tool to prevent damage to the bearing during the installation.

Install the bearing from the front side of the gear housing until the bearing is flush with the front edge of the housing bore.



Install the water pump cover. Use a new o-ring seal.

Torque Value: 47 N•m [35 ft-lb]

Install a new o-ring on the water pump mounting flange.

NOTE: The water pump **must** be twisted outward from the top until the transfer outlet clears the thermostat housing support during installation.

Install the water pump.

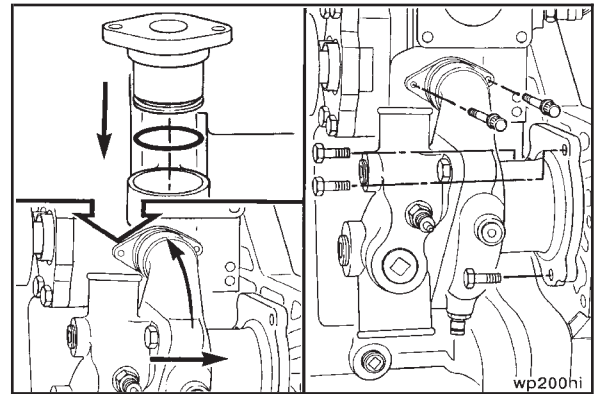
Install a new o-ring on the water pump water transfer tube.
Install the connection into the water pump.

Twist the water pump inward and install the three water pump mounting capscrews.

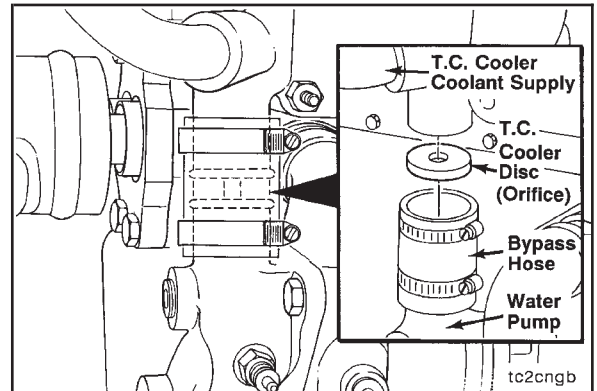
Torque Value: 47 N•m [35 ft-lb]

Install a new gasket on the water pump water transfer connection. Install and tighten the water transfer connection capscrews.

Torque Value: 25 N•m [18 ft-lb]

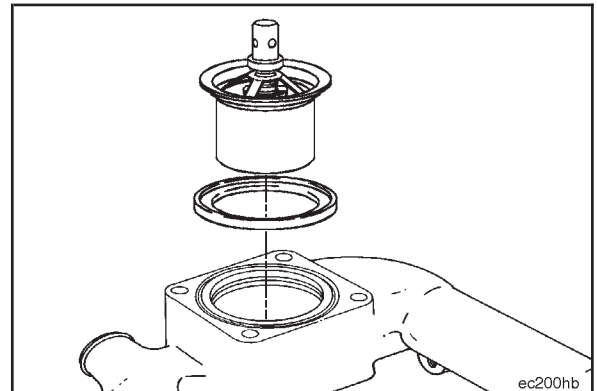


If the engine is equipped with a torque converter cooler, install the disc in the bypass hose before installing the thermostat housing.



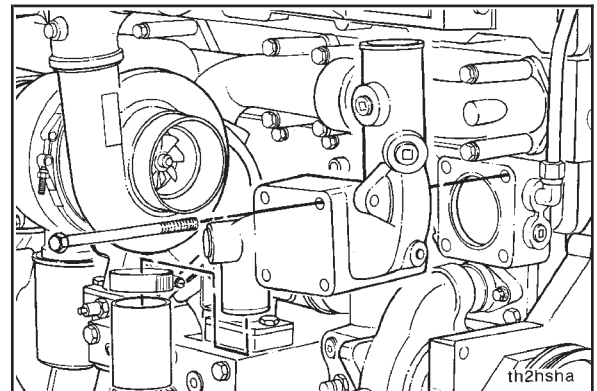
Install the thermostat in the housing.

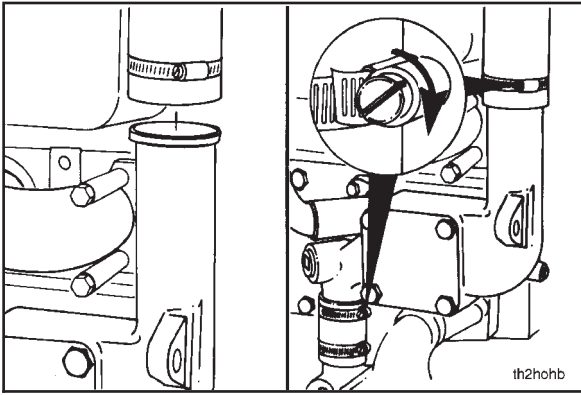
Install a new seal in the groove on the thermostat housing mounting surface.



Install the hose on the thermostat housing bypass outlet.
Install the thermostat housing and four mounting capscrews.

Torque Value: 54 N•m [40 ft-lb]





Equally space the bypass hose over the water pump connection and thermostat housing connection, and tighten the bypass hose clamps.

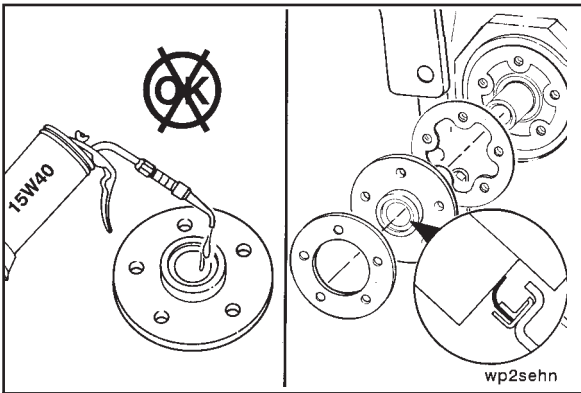


Torque Value: 3 N•m [30 in-lb]

Install the upper radiator hose. Refer to the manufacturer's specifications for the correct torque value.



Install the lower radiator hose. Refer to the manufacturer's specifications for the correct torque value.

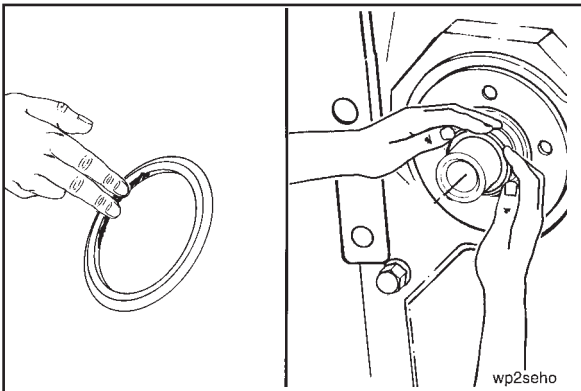


The oil seal **must** be installed with the lip of the seal and the shaft clean and dry. Do **not** lubricate. The yellow dust lip **must** be facing out.

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

The capscrew threads **must** be coated with thread sealant, Part No. 3823494, to prevent oil leakage.

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

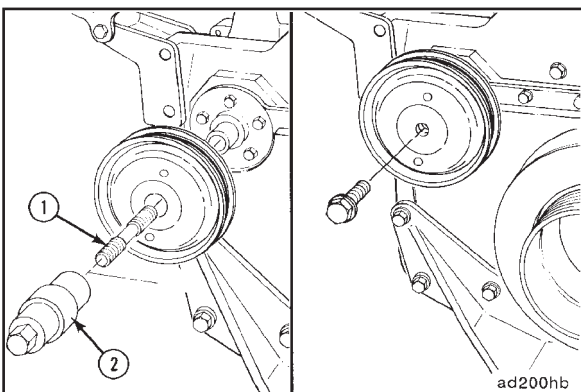


Place a light film of oil or antifreeze on the inside diameter of the oil seal dust seal.

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



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



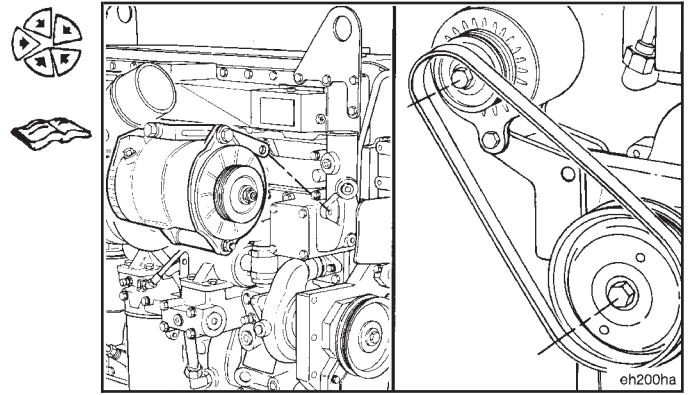
Use the Part No. 3377401 Pulley Pusher Adapter (1) and the Part No. 3376326 Pulley Pusher (2) to install the pulley.

Install the capscrew in the shaft.

Torque Value: 75 N•m [55 ft-lb]

Install the alternator. Refer to Procedure 013-001-026.

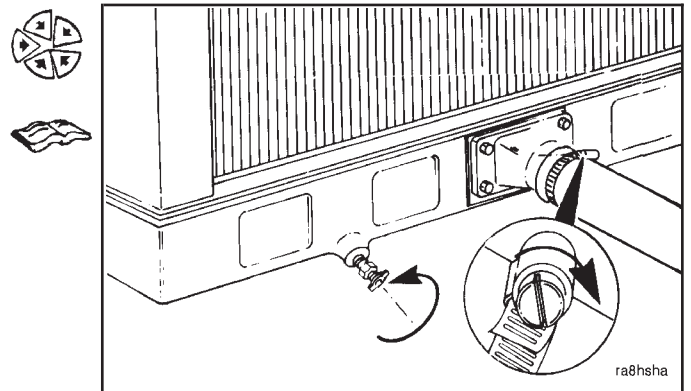
Install and adjust the alternator drive belt. Refer to Procedure 013-005-026.



Close the radiator draincock and install the lower radiator hose.

Tighten the hose clamp(s).

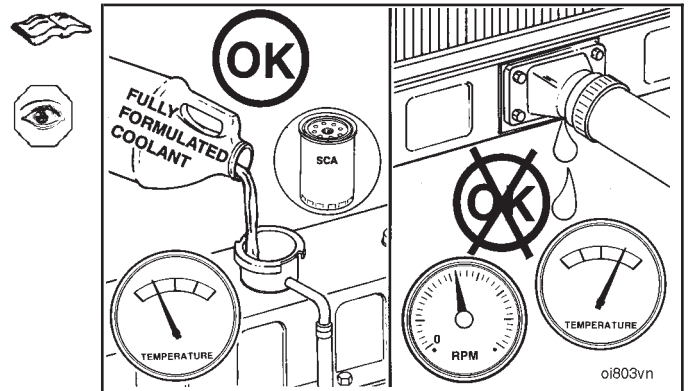
Refer to the manufacturer's specifications for the correct torque value.



The correct concentration of coolant additives **must** be used in the cooling system.

Fill the cooling system. Refer to Procedure 008-018-028.

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

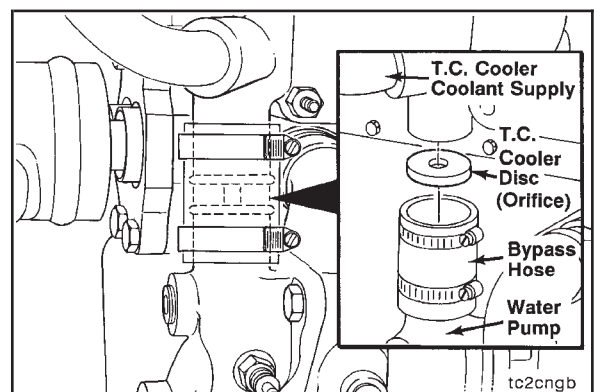


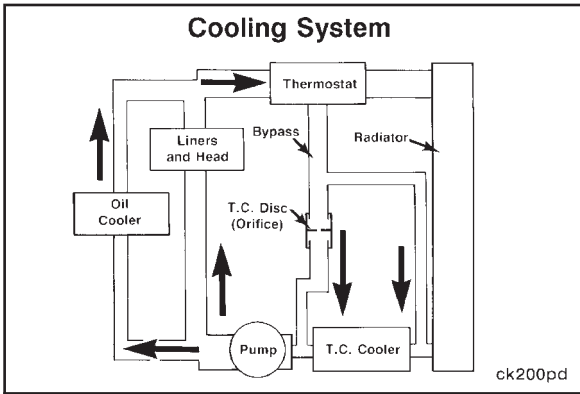
Torque Converter Cooler (008-065)

General Information

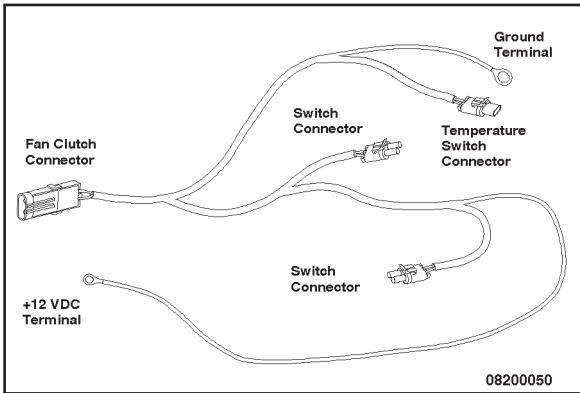
The coolant flow to provide torque converter cooling is achieved in different manners.

M11 engines use a torque converter cooler disc inside the coolant bypass hose to direct engine coolant to the inlet side of the torque converter cooler. The disc functions as follows:





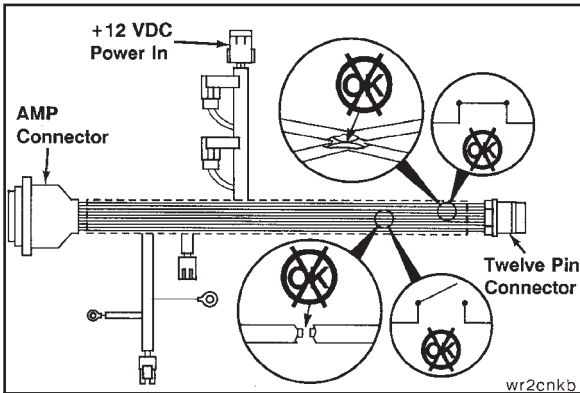
- Closed Thermostat: Coolant flows from the engine through the thermostat housing and down the bypass hose. The disc directs coolant to the inlet side of the torque converter cooler.
- Open Thermostat: Coolant flows from the engine through the thermostat to the radiator out from the radiator to the torque converter cooler to the water pump inlet. The disc prevents reverse flow around the torque converter cooler to the bypass hose and then to the water pump.



Wiring Harness, Cummins Electric Fan Clutch (008-069)

General Information

This procedure applies to engine using an electric fan clutch controlled by the ECM on CELECT™ or CELECT™ Plus systems and utilizing a Cummins electric fan clutch wiring harness. If the wiring harness is **not** a Cummins electric fan clutch wiring harness, refer to the OEM for the correct troubleshooting procedure.

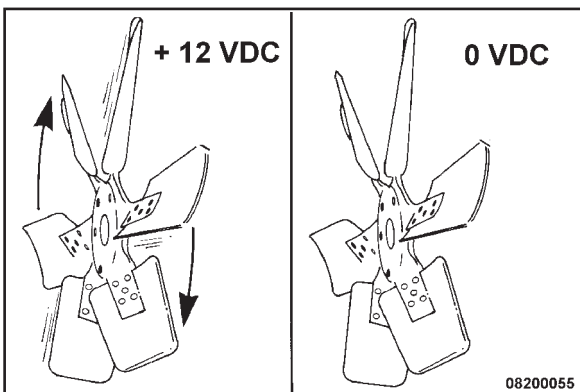


Initial Check (008-069-001)

Electrical Connections

To operate the fan with the CELECT™ or CELECT™ Plus system, the Cummins electromagnetic fan clutch relay **must** receive 0 VDC from the ECM to engage and 12 VDC from the ECM to disengage the fan clutch. To be sure correct electrical connections have been made, refer to the CELECT™ Plus Troubleshooting and Repair Manual, Bulletin No. 3666130.

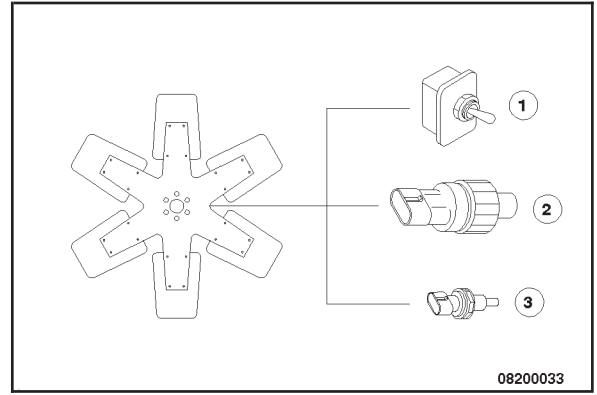
Visually inspect the wires and harness to be sure none are broken or shorted. Replace the harness or wires that are broken.



The fan clutch will engage when it receives 12 VDC from the fan clutch relay and disengage when it receives 0 VDC from the fan clutch relay.

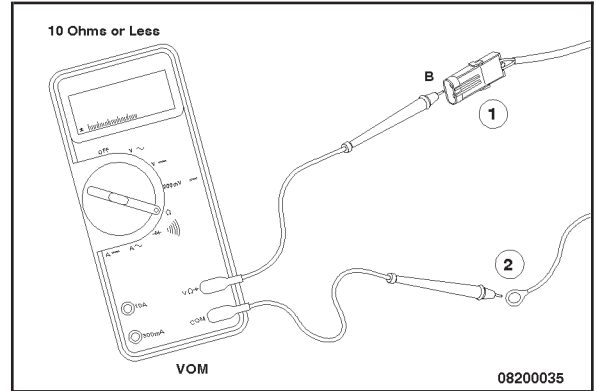
The 12 VDC is supplied from the vehicle electrical system to the fan by one of three possible controls:

- The manual fan ON/OFF switch (1) in the cab
- The Freon compressor pressure switch (2)
- The temperature switch (3) in the thermostat housing

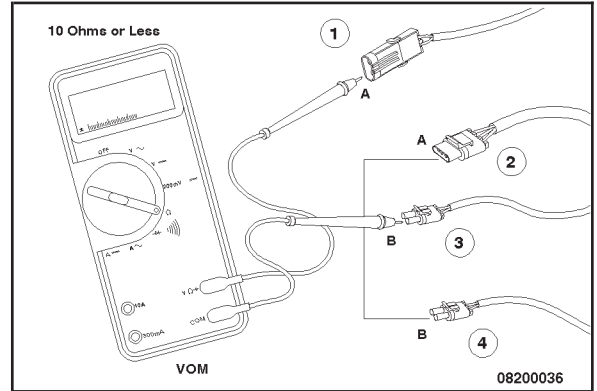


To check to be sure there are no open circuits, the continuity **must** be checked between the following pins of the wiring harness:

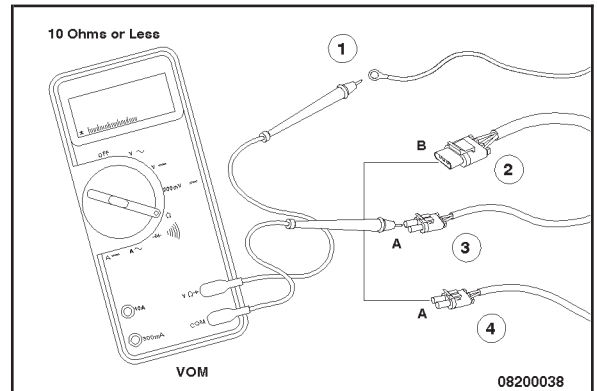
- Pin B of the fan clutch connector (1) and the ground terminal (2)



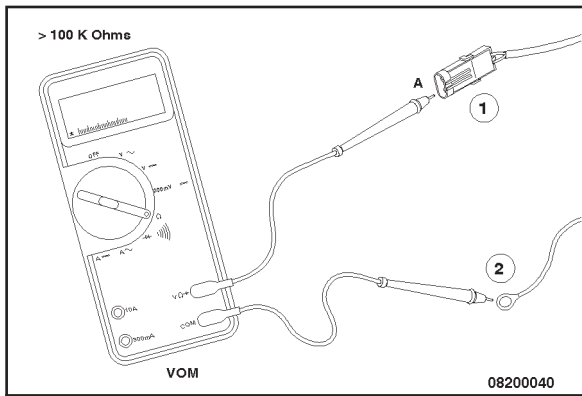
- Pin A of the fan clutch connector (1) and the following fan harness connectors:
 - pin A of the temperature switch connector (2)
 - pin B of the Freon compressor pressure switch connector (3)
 - pin B of the manual ON/OFF cab switch connector (4)



- The +12 VDC terminal (1) and the following fan harness connectors:
 - pin B of the temperature switch connector (2)
 - pin A of the Freon compressor pressure switch connector (3)
 - pin A of the manual ON/OFF cab switch connector (4)

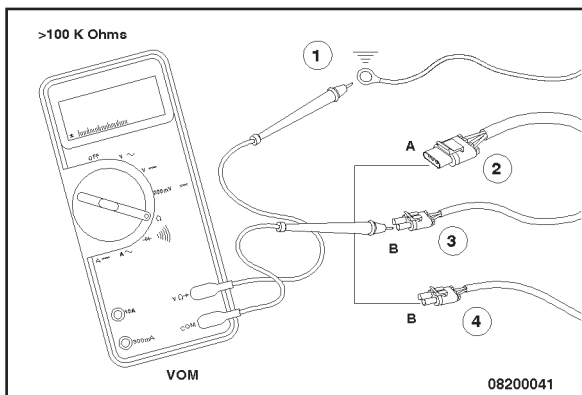


The VOM **must** read a closed circuit (10 ohms or less). Repair or replace the harness if more than 10 ohms is detected on any of the above checks.



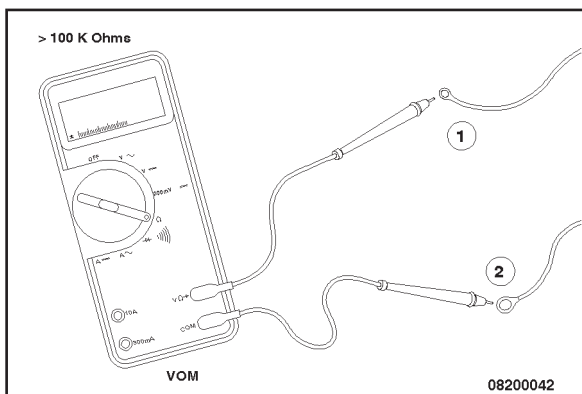
Check for short circuits in the harness. The resistance **must** be greater than 100K ohms for the following:

- Pin A of the fan clutch connector (1) to the ground terminal (2)

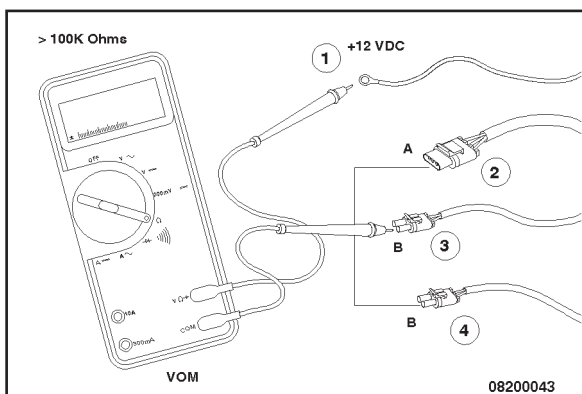


- The ground terminal (1) and the following fan harness connectors:

- pin A of the temperature switch connector (2)
- pin B of the Freon compressor pressure switch connector (3)
- pin B of the manual ON/OFF cab switch connector (4)



- The + 12 VDC terminal (1) to the ground terminal (2)

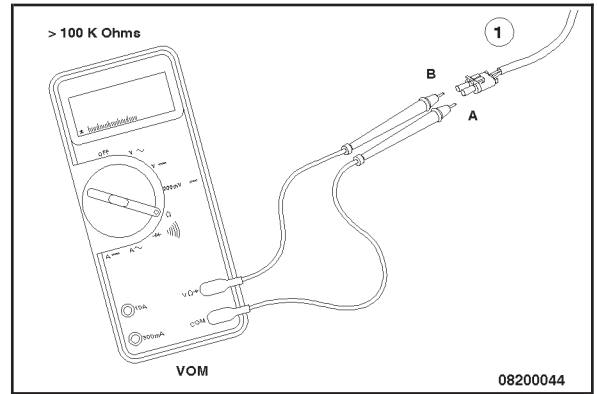


- The + 12 VDC supply (1) and the following fan harness connectors:

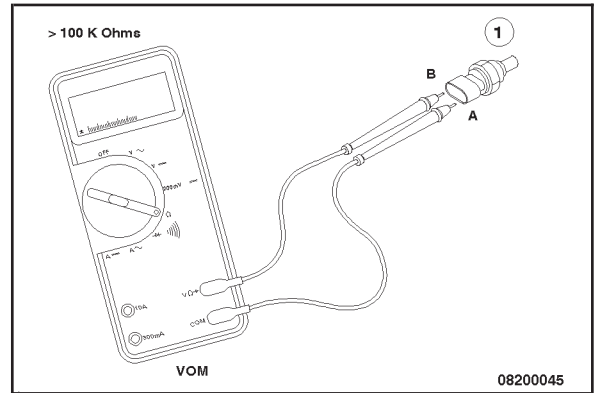
- pin A of the temperature switch connector (2)
- pin B of the Freon compressor pressure switch connector (3)
- pin B of the manual ON/OFF cab switch connector (4)

- Pin A of each of the three switch connectors (1) to pin B of each of the three switch connectors (1)

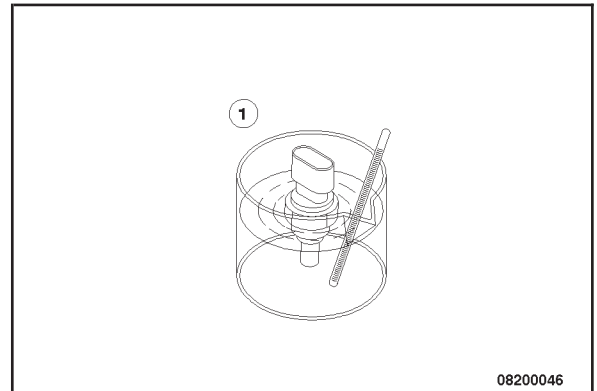
The harness **must** be repaired or replaced if any of the above resistances are less than 100K ohms.



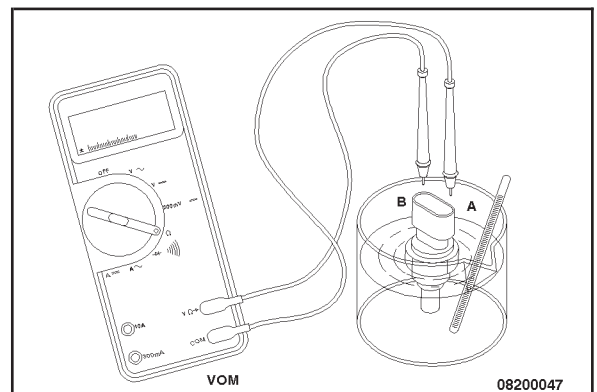
To check the temperature switch (1) for proper operation, check the continuity from pin A to pin B at room temperature (**must** be greater than 100K ohms). Replace the switch if the resistance is less than 100K ohms.

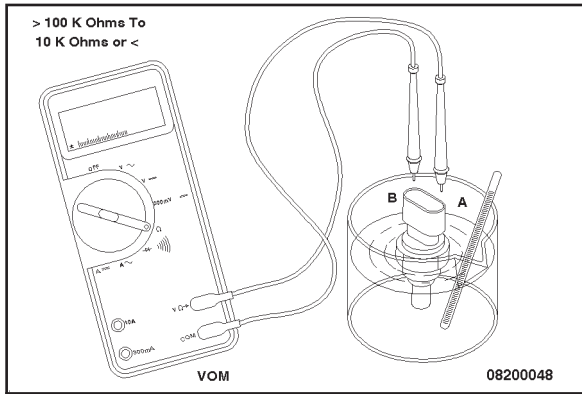


To check the temperature switch for operation at the “Fan ON” temperature, place the probe (1) in a container of water, along with a thermometer.



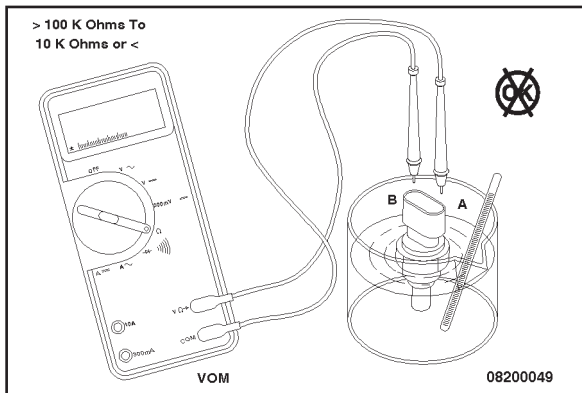
Place the VOM probes in pin A and pin B.





Heat the water.

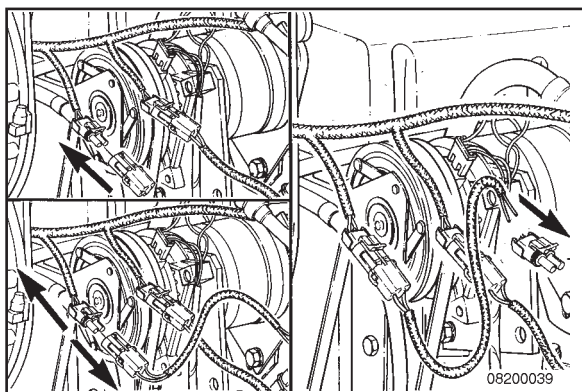
Note the temperature at which the resistance changes from 100K or greater ohms to 10 ohms or less.



If the switch does **not** close at the temperature required per the switch manufacturer, the switch **must** be replaced.



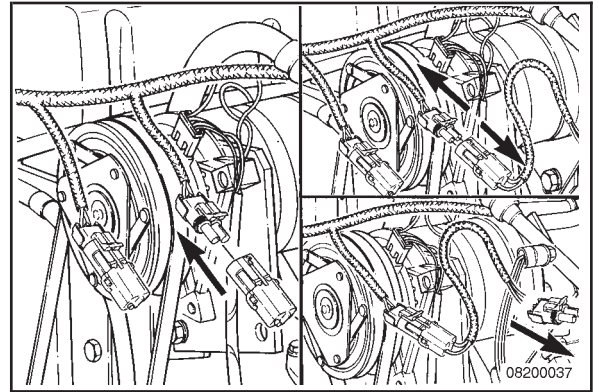
To check the Freon compressor pressure switch and the manual fan ON/OFF cab switch, refer to the manufacturer's recommendations.



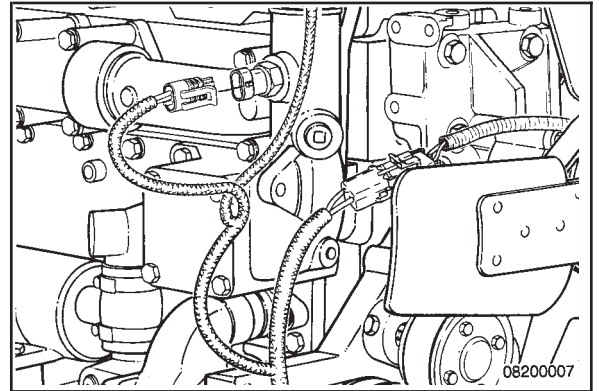
Remove (008-069-002)

Disconnect the operator controlled manual switch harness, if used, from the base harness.

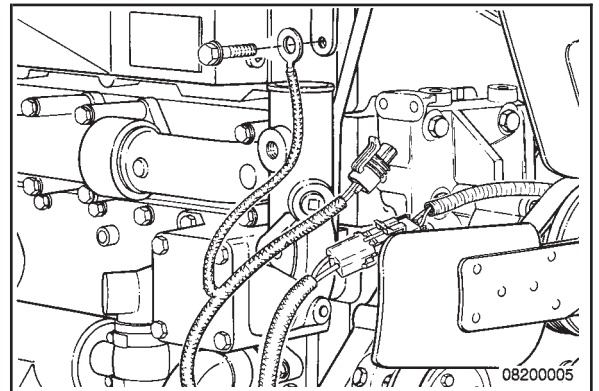
Remove the refrigerant pressure switch harness from the base harness.



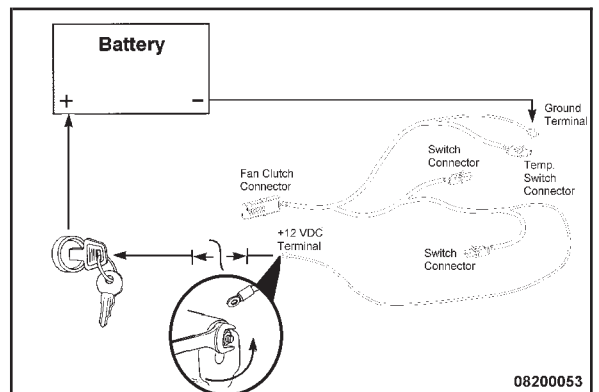
Disconnect the gray harness connector from the temperature switch in the thermostat housing.

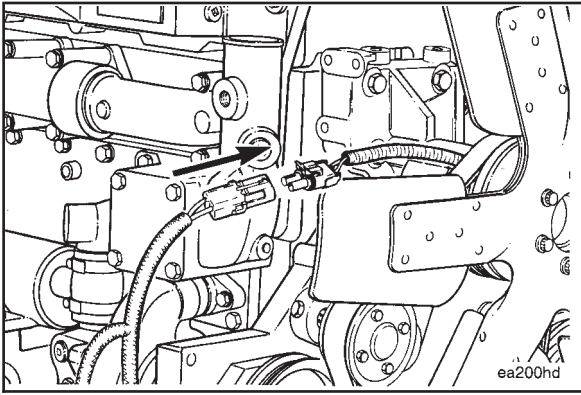


Disconnect the large ring terminal with the black wire from the chassis ground.

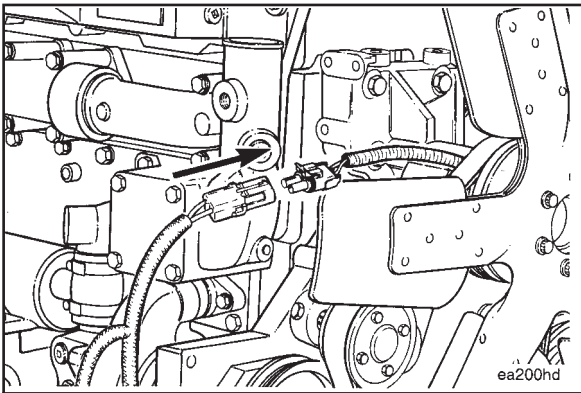


Disconnect the small ring terminal from the power source.



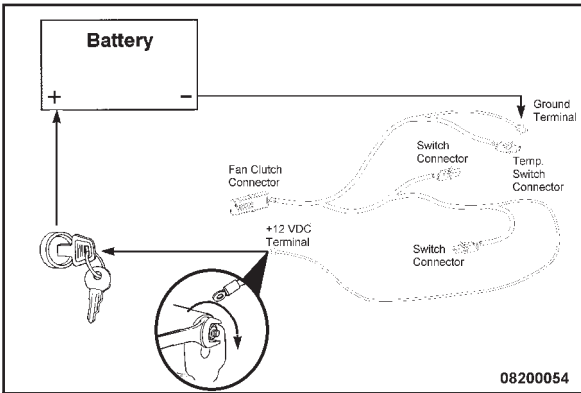


Disconnect the fan clutch connector on the base harness from the fan clutch.

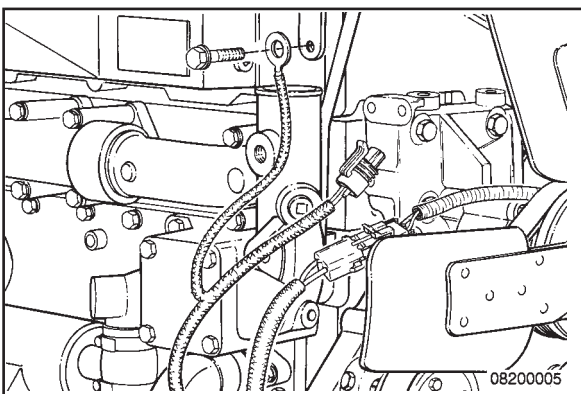


Install (008-069-026)

Connect the fan clutch connector on the base harness to the fan clutch.

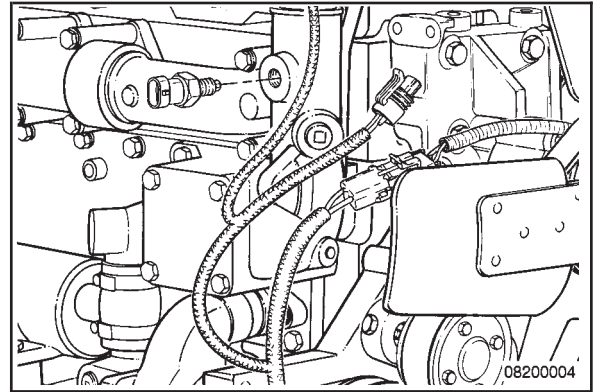


Connect the small ring terminal with the red wire to an ignition switch controlled, fused power source.

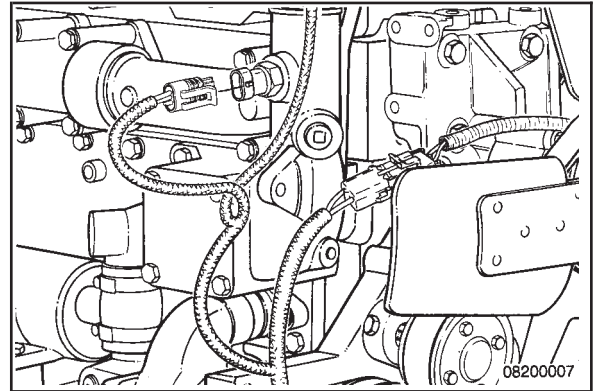


Connect the large ring terminal with the black wire to the chassis ground.

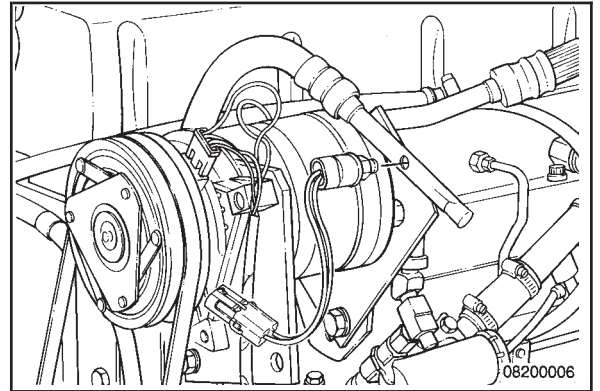
Install the coolant temperature switch in the thermostat housing if it was removed.



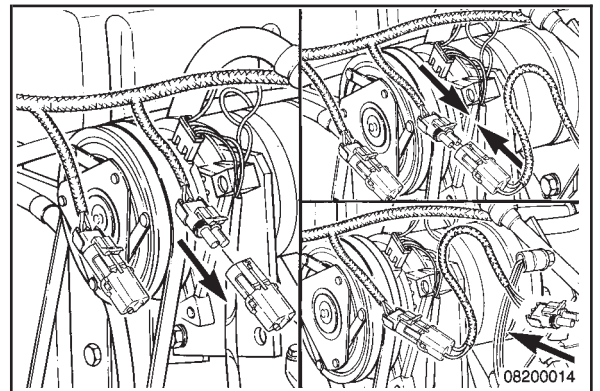
Connect the gray harness connector to the temperature switch in the thermostat housing.

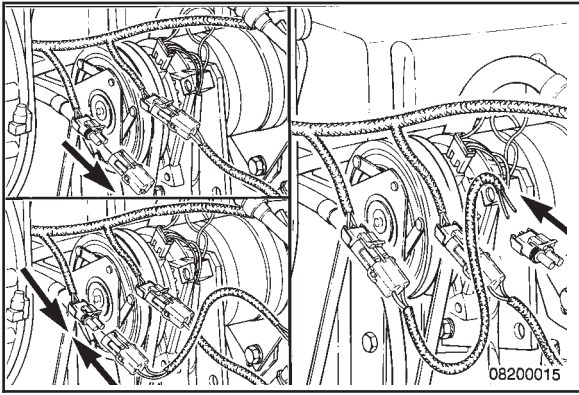


On air conditioned vehicles, install the appropriate refrigerant pressure switch into the compressor outlet side of the refrigerant circuit if it was removed.

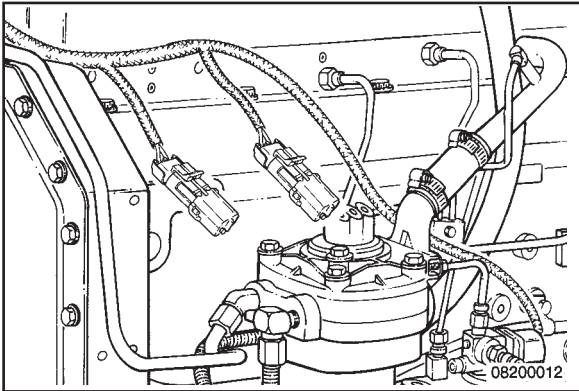


Connect the switch harness to the base harness and to the refrigerant pressure switch.





Connect the operator controlled manual switch harness to the base harness.



Leave the base harness switch connector sealing cap(s) in place if a refrigerant pressure switch or an operator controlled manual switch is **not** used.

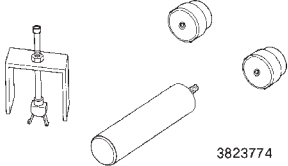
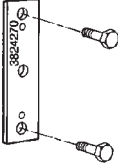
Section 9 - Drive Units - Group 09

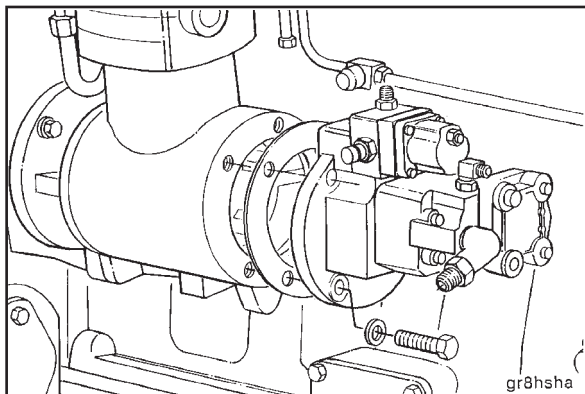
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Service Tools Drive Units

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

Tool No.	Tool Description	Tool Illustration
3823774	<p>Needle Bearing Kit</p> <p>Used to remove and install needle bearings in the hydraulic pump adapter. Use mandrel, Part No. 3823776, to install hydraulic pump needle bearings.</p>	 <p style="text-align: right;">3823774</p>
3824270	<p>Engine Baring Tool</p> <p>Used to fasten a slide hammer to the hydraulic drive adapter for removal.</p>	 <p style="text-align: right;">3824270</p>



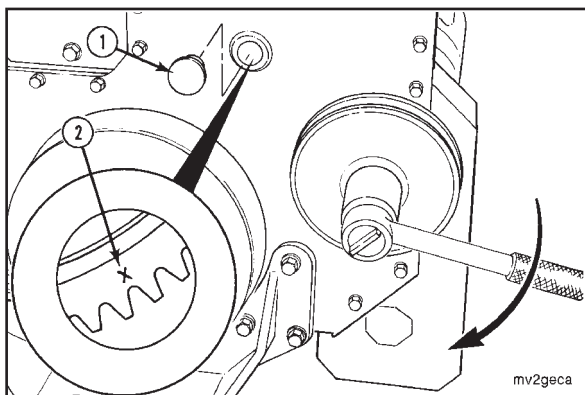
Accessory Drive (009-001)

Remove (009-001-002)



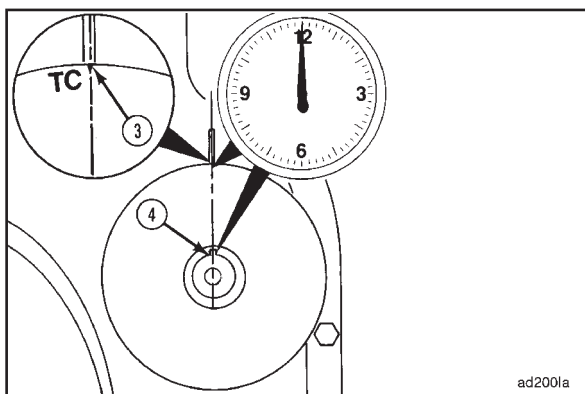
Remove the fuel pump. Refer to Procedure 005-016-002.

Remove the air compressor, if equipped. Refer to Procedure 012-005-002.

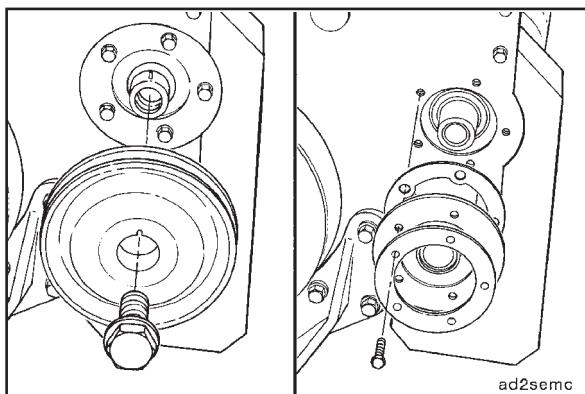


To mark the accessory drive pulley position:

- Remove the inspection hole plug (1) in the gear cover.
- Use the accessory drive shaft to rotate the engine until the camshaft gear timing mark (2) is visible through the inspection hole.



When the timing mark is visible through the inspection hole, cylinders number one and six are at top dead center. The accessory drive pulley "T-C" mark (3) and keyway (4) are at the 12 o'clock location.



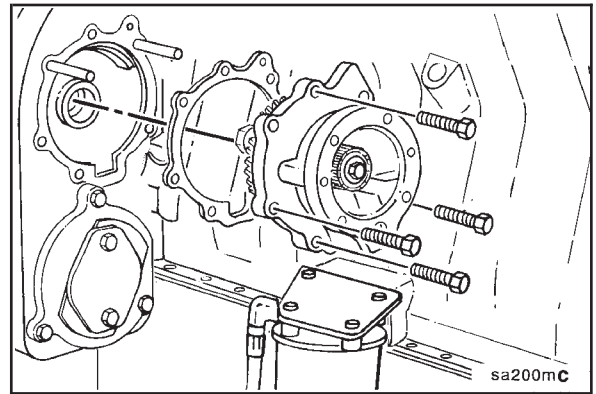
Remove the pulley retainer capscrew.

Remove the accessory drive pulley.

NOTE: This is a slip fit pulley and does **not** require the use of a puller.

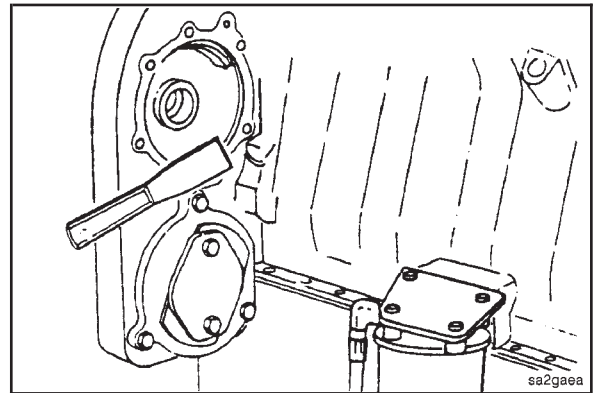
Remove the five seal retaining capscrews, clamping ring and accessory oil drive seal. Refer to Procedure 001-003-002.

Remove the six capscrews and the accessory drive assembly.

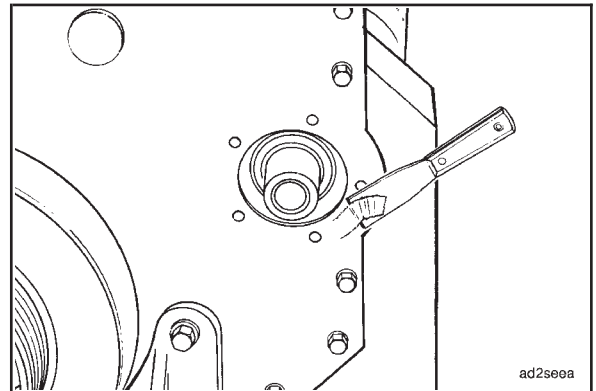


Clean (009-001-006)

Clean the accessory drive to gear housing gasket surface.



Clean the accessory drive oil seal surface on the front of the gear cover.



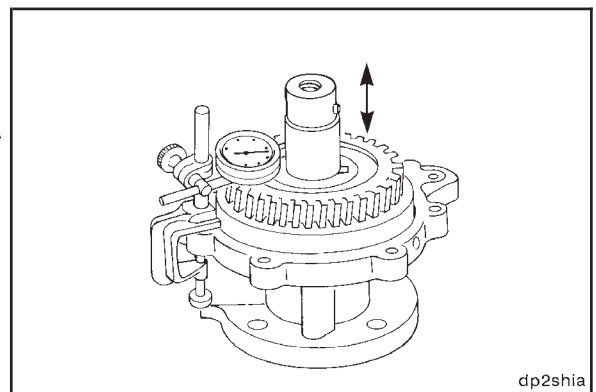
Inspect for Reuse (009-001-007)

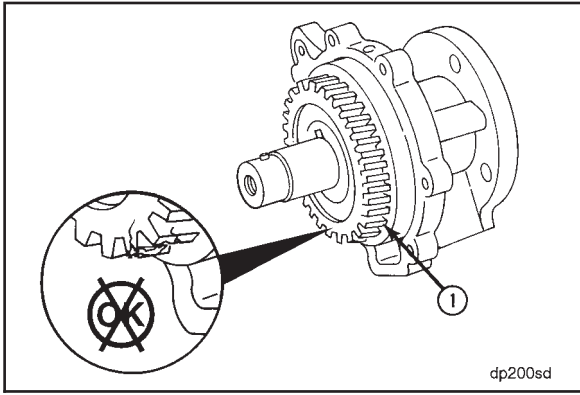
Measure the drive shaft end clearance.



Drive Shaft End Clearance		
mm		in
0.10	MIN	0.004
0.30	MAX	0.012

If the shaft end clearance does **not** meet these specifications, rebuild or replace the drive unit. Refer to the M11 Shop Manual, Bulletin No. 3666075.



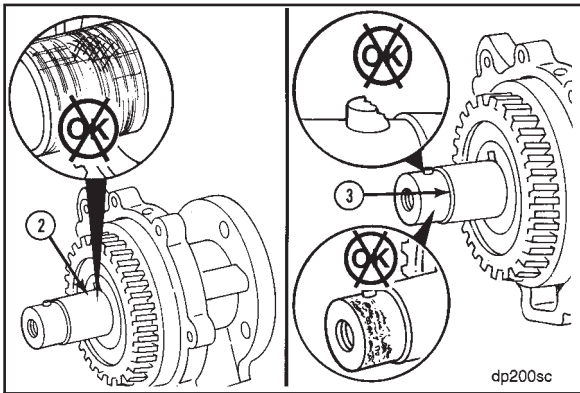


Visually inspect the housing for cracks and non-uniform front and rear gasket sealing surfaces.

Replace the housing or the drive unit if cracks are found or the gasket sealing surfaces **cannot** be made uniform using Scotch-Brite® 7448 or its equivalent.

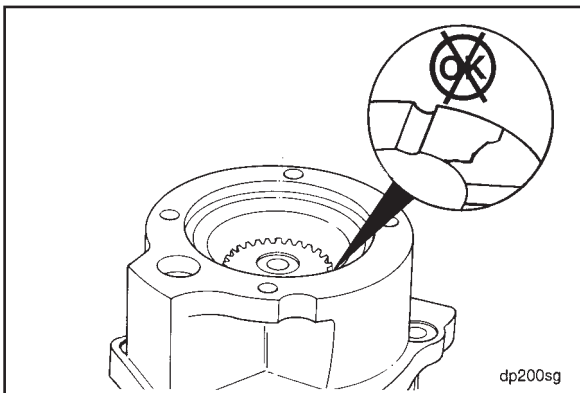
Visually inspect the drive gear (1) for cracked or severely worn teeth.

Replace the drive gear or the drive unit if the drive gear is cracked or abnormally worn teeth are found.



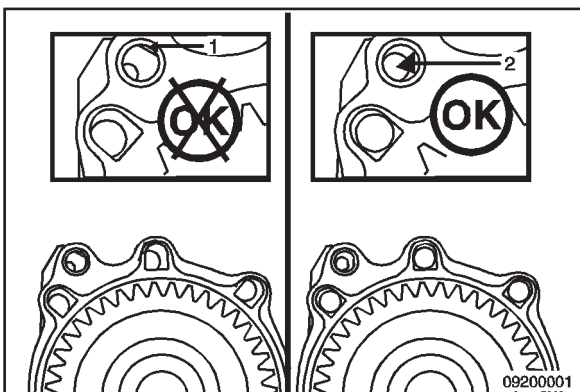
Visually inspect the shaft surface (2). Pay special attention to the pulley hub to shaft shoulder contact area (3). Replace the shaft if scratches, scoring, or fretting is found.

Inspect the dowel pin for damage. Replace if required.



Visually inspect the rear thrust washer for cracks.

Replace the washer if cracks are found. Refer to the M11 Shop Manual, Bulletin No. 3666075.



Install (009-001-026)

CAUTION

Care must be used when installing the accessory drive gasket. If the gasket is twisted during the installation of the accessory drive, a leak path (1) will exist between the gasket and the oil passage port at point (2).

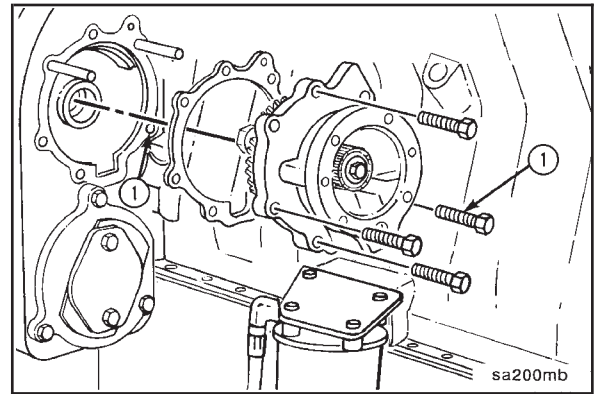
Use a small amount of grease or sealant to hold the gasket in place during installation. Use care **not** to block the oil passage.

The accessory drive shaft dowel pin **must** be at the 12 o'clock location when the accessory drive is installed. Make sure the camshaft gear timing mark "X" is visible through the inspection hole in the front of the gear cover.

Use a new gasket to install the accessory drive assembly. Install the six capscrews and tighten.

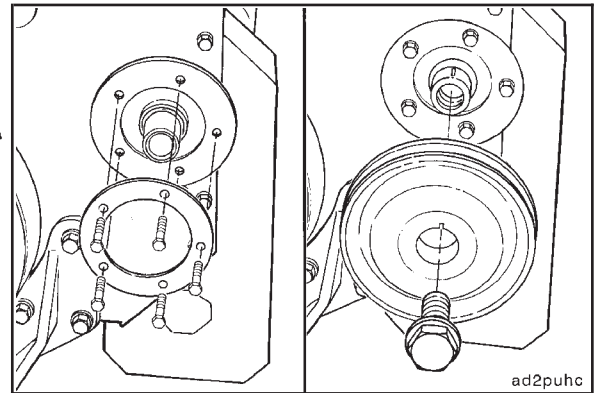
Torque Value: 47 N•m [35 ft-lb]

NOTE: The capscrew (1) located in the lower corner nearest the cylinder block **must** be installed with a new copper sealing washer, Part No. 3882885, and thread sealant, Part No. 3823494, applied to the threads.



Install the accessory drive oil seal. Refer to Procedure 001-003-026.

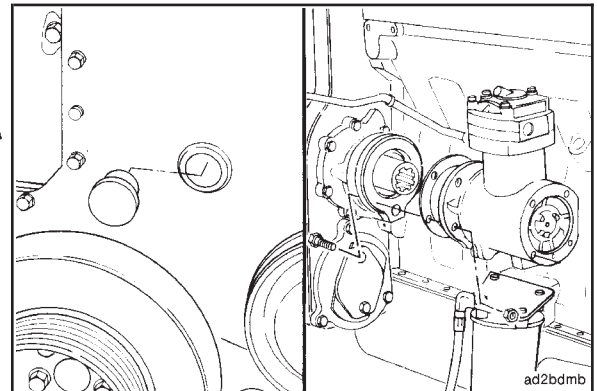
Install the accessory drive pulley. Refer to Procedure 009-004-026.



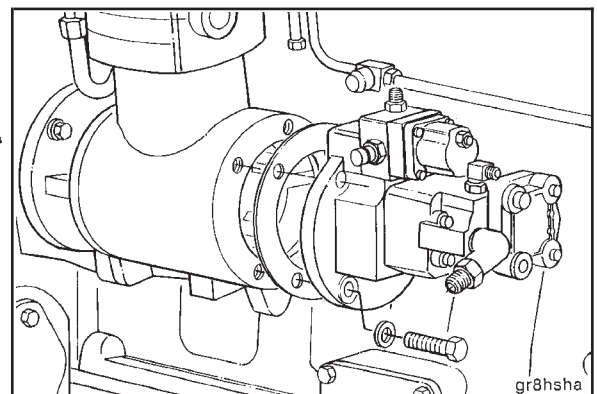
Install the inspection hole plug in the gear cover.

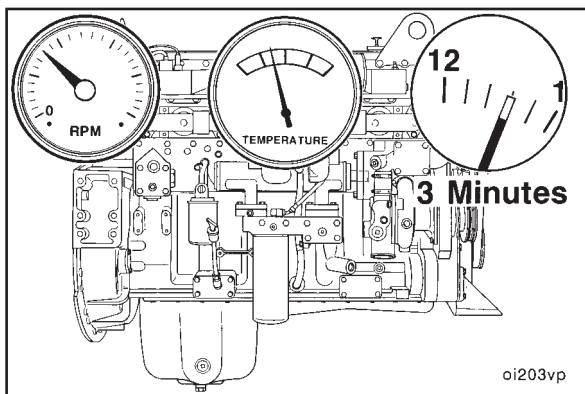
NOTE: The air compressor **must** be timed to the accessory drive.

Install the air compressor, if equipped. Refer to Procedure 012-014-026.

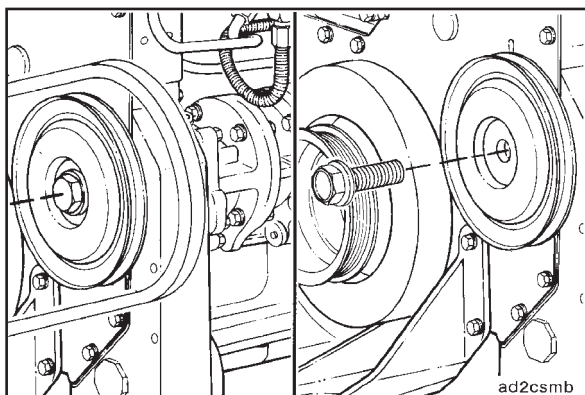


Install the fuel pump. Refer to Procedure 005-016-026.





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

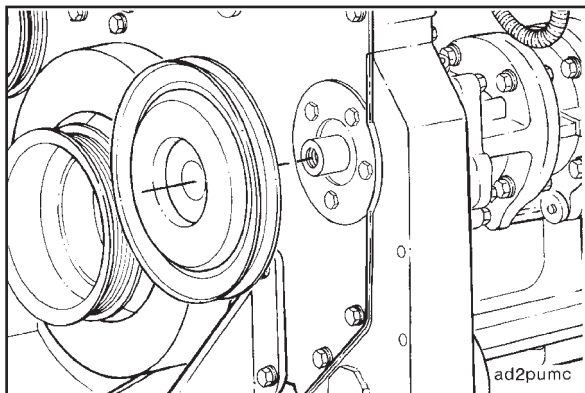


Accessory Drive Pulley (009-004) Remove (009-004-002)



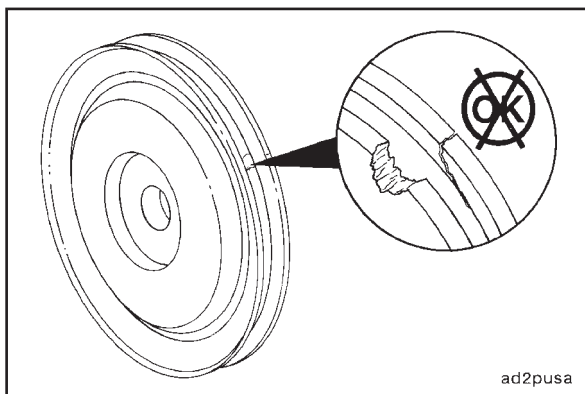
Remove the Freon compressor drive belt, if equipped. Refer to the manufacturer's instructions.

Remove the accessory drive pulley retaining capscrew.



NOTE: The accessory drive pulley is slip fit, and does **not** require a puller to be removed from the engine.

Remove the accessory drive pulley.



Inspect for Reuse (009-004-007)

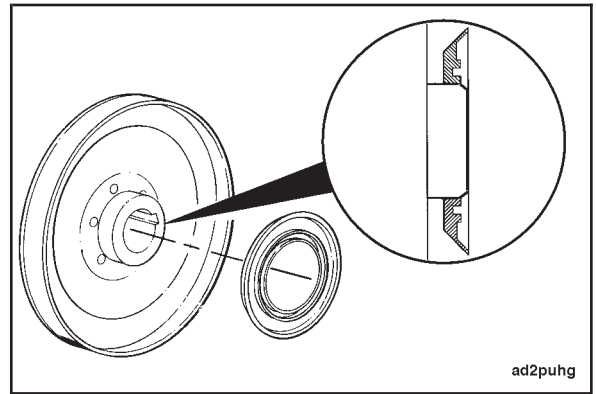
Visually inspect the pulley for nicks, cracks or other damage.

Install (009-004-026)

NOTE: Accessory drive seal dust seals are currently only to be installed on single v-groove stamped steel accessory drive pulleys. The dust seal is **not** compatible with other pulleys.

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

Install the dust seal onto the accessory drive pulley hub so that the larger outside diameter of the dust seal is facing away from the pulley. Push the dust seal onto the hub until the inside diameter of the dust seal is flush with the pulley hub end.



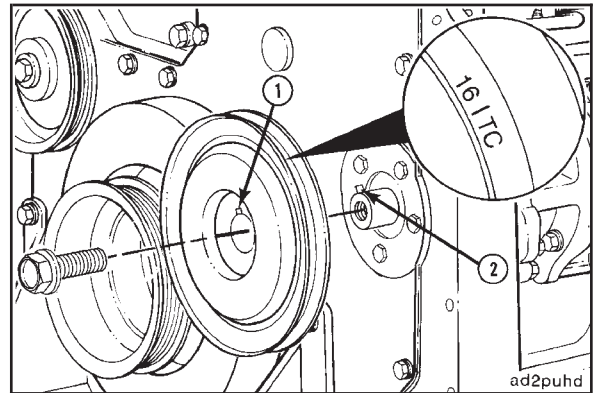
⚠ CAUTION ⚠

To prevent dowel pin damage, the slot (1) in the pulley must align with the dowel pin (2) in the shaft.

The timing marks on the pulley **must** be facing away from the engine.

This is a slip fit pulley and does **not** require the use of an installation tool.

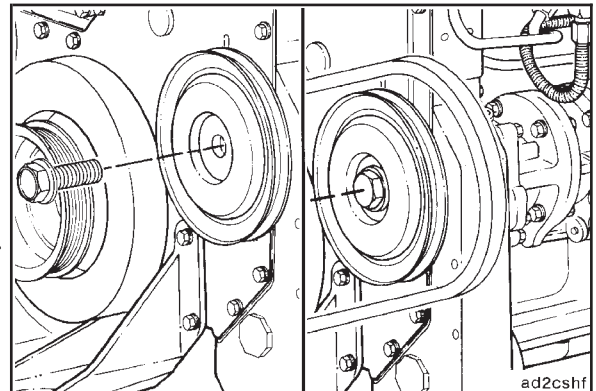
Install the pulley on the shaft by hand.



Install the M20-2.50 x 45 pulley retaining capscrew.

Torque Value: 542 N•m [400 ft-lb]

Install and adjust the freon compressor drive belt, if equipped. Refer to the manufacturer's specifications.



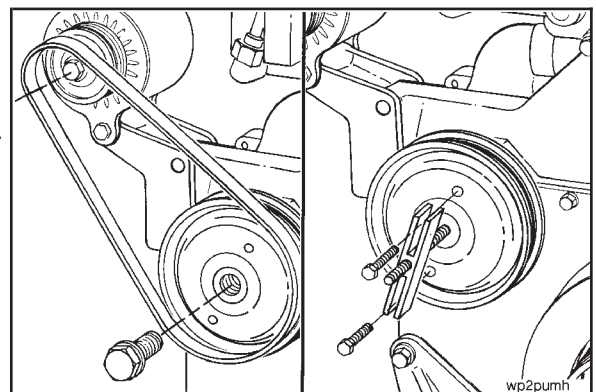
Alternator Drive Pulley (009-010)

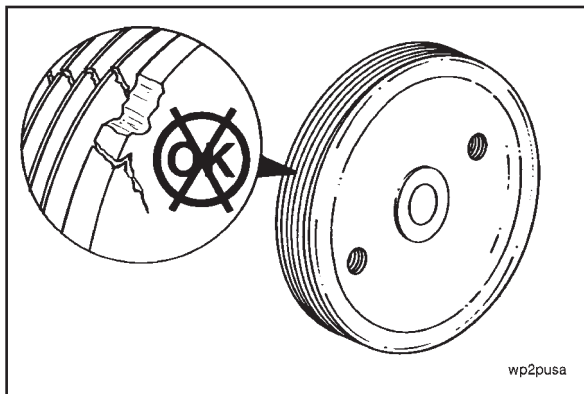
Remove (009-010-002)

Remove the alternator drive belt. Refer to Procedure 013-005-002.

Remove the pulley retainer capscrew.

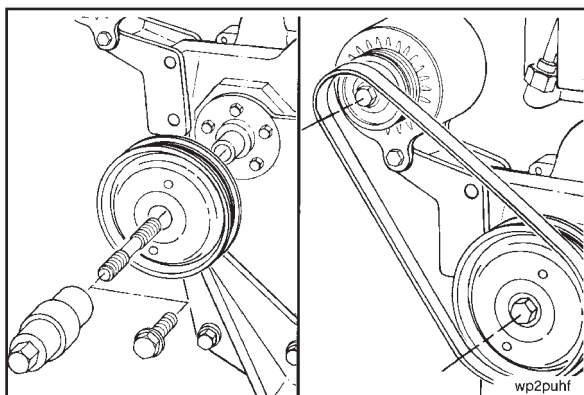
Use pulley puller, Part No. ST-647, and two 5/16 x 18 x 2 capscrews to remove the pulley.





Inspect for Reuse (009-010-007)

Visually inspect the pulley for nicks, cracks, excessive wear in the belt grooves or other damage.



Install (009-010-026)

The pulley **must** be installed with the deep dished side of the pulley facing away from the engine.



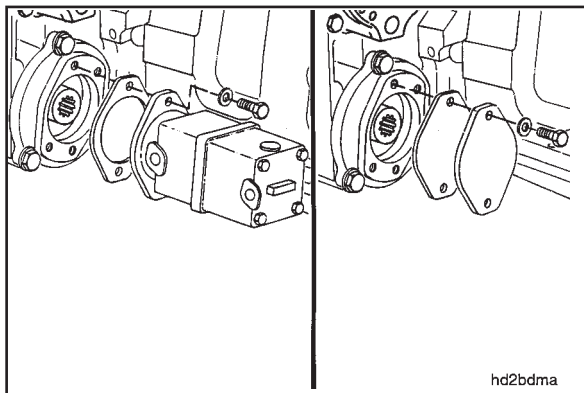
Use pulley installation tool, Part No. 3376326, and pulley pusher adapter, Part No. 3377401, to install the alternator drive pulley.



Install and tighten the retaining cap screw.

Torque Value: 75 N•m [55 ft-lb]

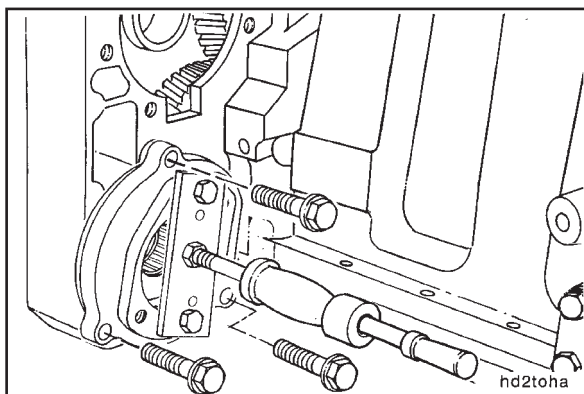
Install and adjust the alternator drive belt. Refer to Procedure 013-005-026.



Hydraulic Pump Drive (009-016)

Remove (009-016-002)

Remove the two mounting cap screws and the hydraulic pump, if equipped, or the cover plate.



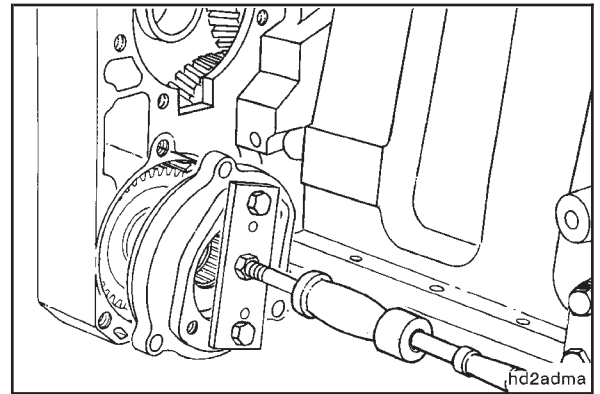
Remove the three pump drive mounting cap screws.

Install a slide hammer and the engine barring tool, Part No. 3824270, to the hydraulic drive adapter. Use two M10-1.50 x 30 cap screws, Part No. 3335003, for SAE 'A' drives, or two M12-1.75 x 40 cap screws, Part No. 3018671, for SAE 'B' drives.

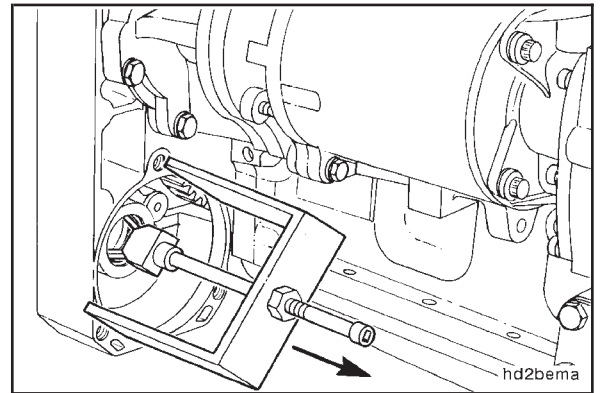
⚠ CAUTION ⚠

Do not allow the hydraulic drive gear to slide out of the adapter or the gear housing during removal. Damage to the gear will result.

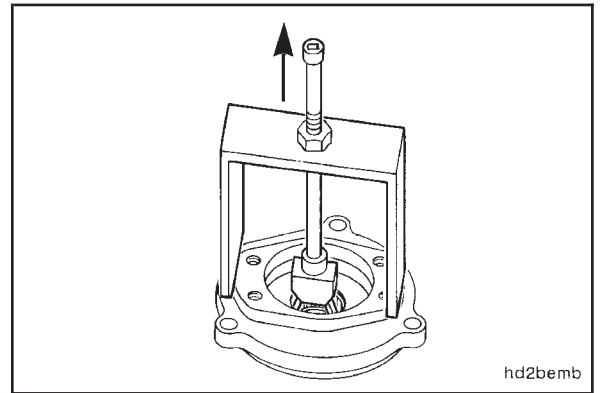
Remove the hydraulic drive adapter, o-ring and hydraulic drive gear.



Use bearing puller kit, Part No. 3823774, to remove the needle bearing from the gear housing.

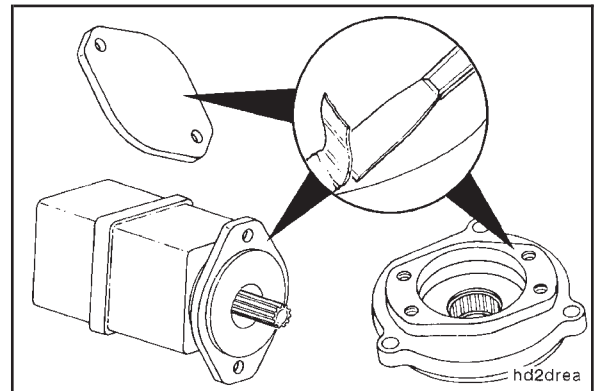


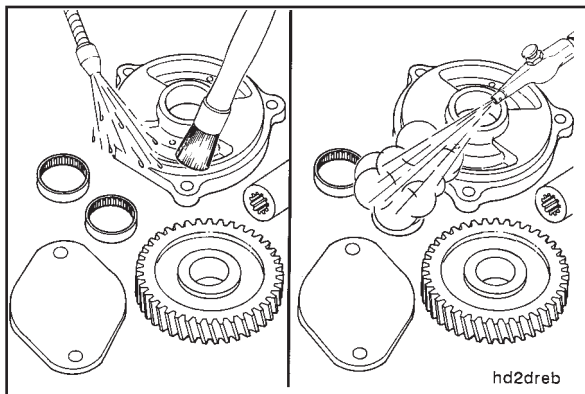
Remove the needle bearing from the hydraulic pump adapter.



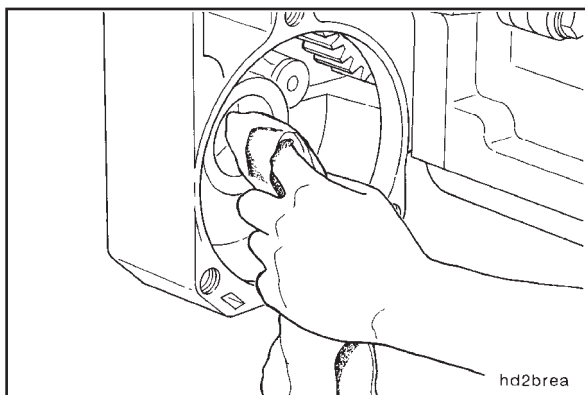
Clean (009-016-006)

Remove the gasket material from the hydraulic pump adapter and hydraulic pump, if equipped, or cover plate surface.

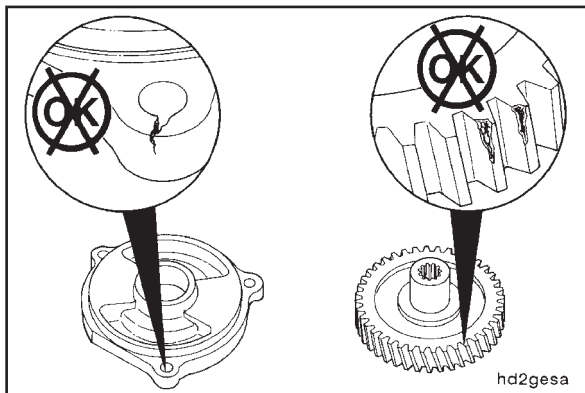




Clean the hydraulic pump adapter, cover plate, gear and needle bearings with solvent. Dry with compressed air.

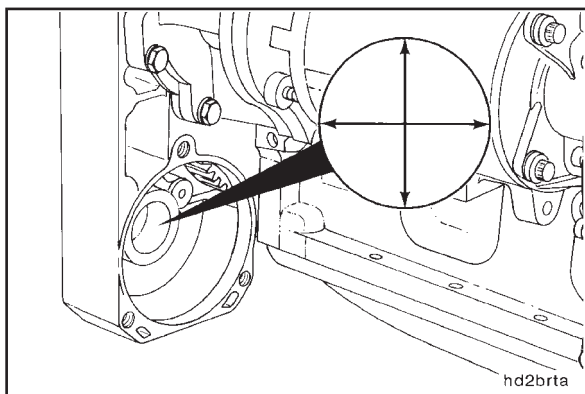


Clean the needle bearing bore in the gear housing with solvent and dry with a clean cloth.



Inspect for Reuse (009-016-007)

Visually inspect the components for damage.



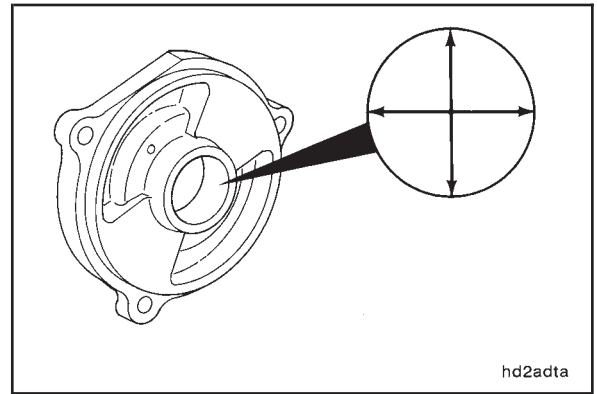
Measure the inside diameter of the needle bearing bore in the gear housing.

Needle Bearing Bore I.D. (Gear Housing)		
mm		in
41.967	MIN	1.6522
41.992	MAX	1.6532

Measure the inside diameter of the needle bearing bore in the hydraulic pump drive adapter.



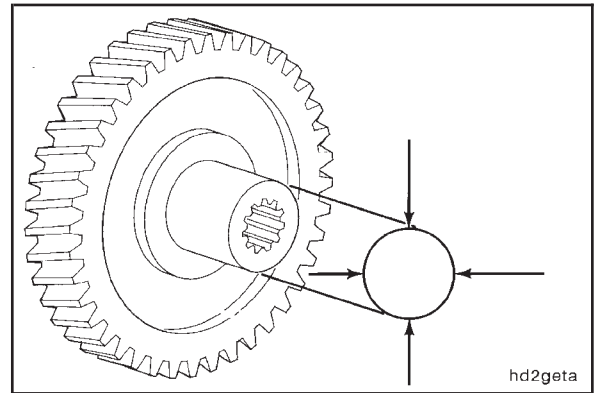
Needle Bearing Bore I.D. (Hydraulic Pump Drive Adapter)		
mm		in
41.967	MIN	1.6522
41.992	MAX	1.6532



Measure the hydraulic drive shaft outside diameter.



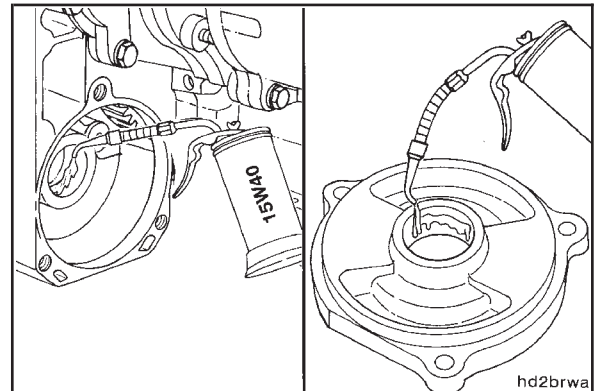
Hydraulic Drive Shaft O.D.		
mm		in
34.984	MIN	1.3773
35.000	MAX	1.3780



Install (009-016-026)

Use clean 15W-40 oil to lubricate the outside diameter of the needle bearings.

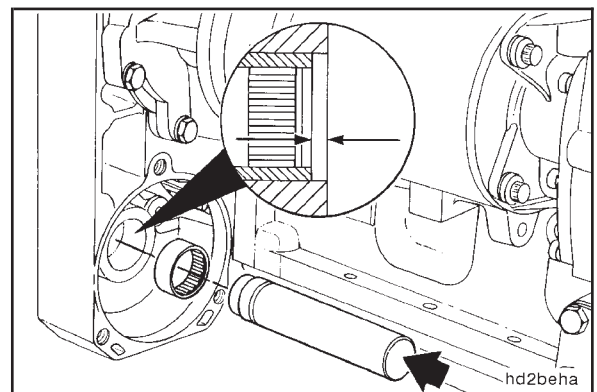
Use clean 15W-40 oil to lubricate the needle bearing bores in the gear housing and the hydraulic pump drive adapter.

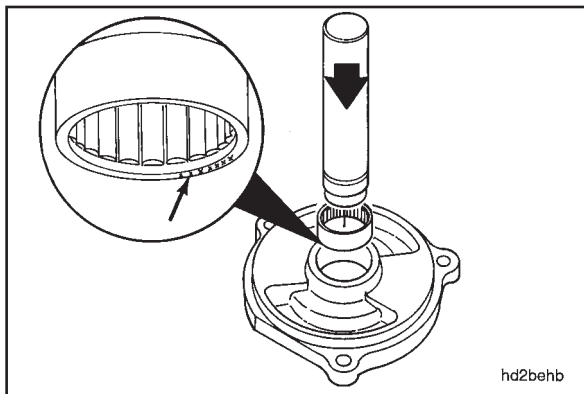


Use bearing installation tool, Part No. 3823776 included in bearing puller kit, Part No. 3823774, to install the needle bearings in the gear housing.

Tap the bearing gently until it comes in contact with the shoulder in the housing.

The bearing **must** be 0.25 to 0.76 [0.010 to 0.030 in] past the outside edge of the gear housing bore surface.

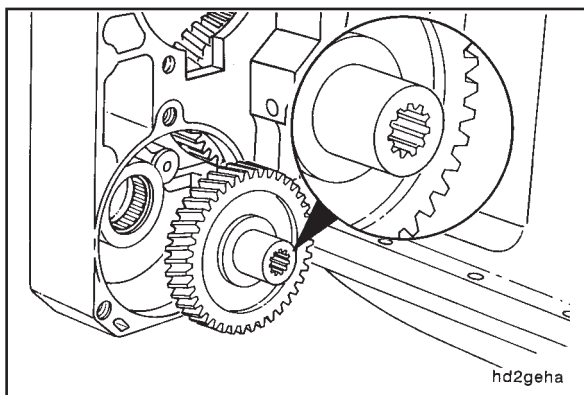




Install the needle bearing in the hydraulic pump drive adapter from the inside end (the end that will be closest to the hydraulic drive gear).



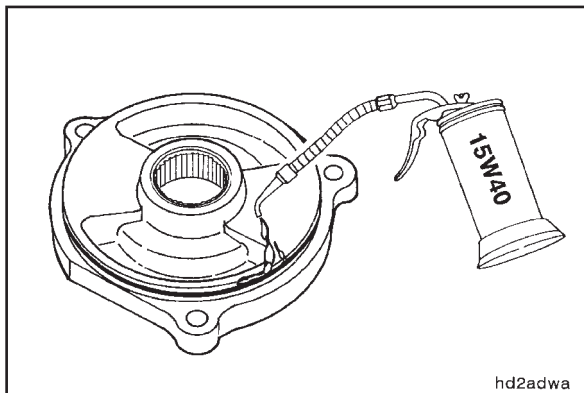
The bearing **must** be centered between the front and rear surfaces.



Use Lubriplate™ 105, or equivalent, to lubricate the needle bearing in the gear housing and the outside of the hydraulic drive shaft.



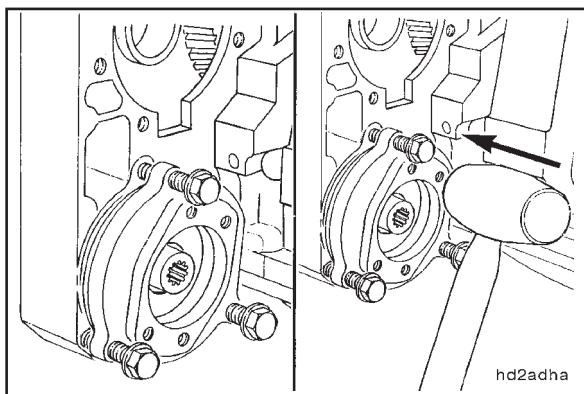
Install the shaft and gear assembly so the internal splines of the shaft are facing away from the gear housing and toward the rear of the engine.



Install a new o-ring on the hydraulic drive adapter. Lubricate the o-ring with clean 15W-40 oil.



Lubricate the hydraulic drive adapter needle bearing and bore with Lubriplate™ 105, or equivalent.



Install the hydraulic drive adapter over the shaft and gear assembly.



Start the three mounting capscrews by hand to align the hydraulic drive adapter with the gear housing.

Using a rubber hammer, tap around the outside diameter of the adapter to install the adapter.

NOTE: Use care **not** to damage the o-ring during installation.

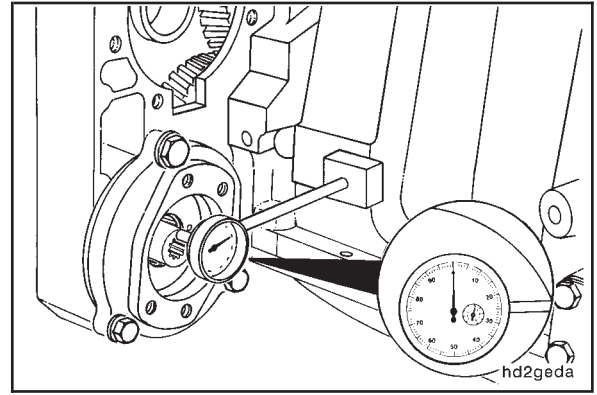
Tighten the mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]

Measure the drive shaft end clearance.

Use dial indicator assembly, Part No. 3376050, with extension, Part No. ST-537-4, and a magnetic base, Part No. 3377399.

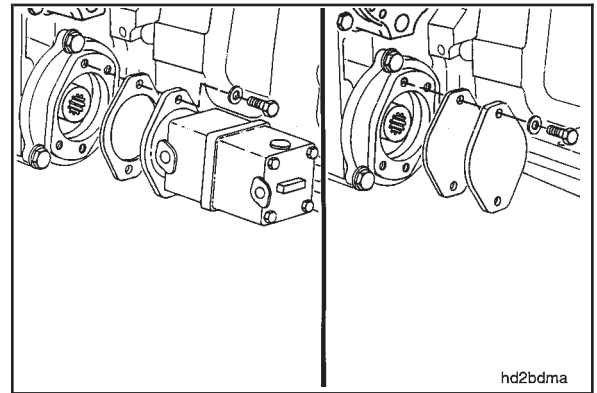
Hydraulic Pump Drive Shaft End Clearance		
mm		in
0.076	MIN	0.003
0.635	MAX	0.025



Use a new gasket and install the hydraulic pump, if equipped, or the cover plate.

Install the two mounting capscrews and tighten.

Torque Value: 27 N•m [20 ft-lb]



Section 10 - Air Intake System - Group 10

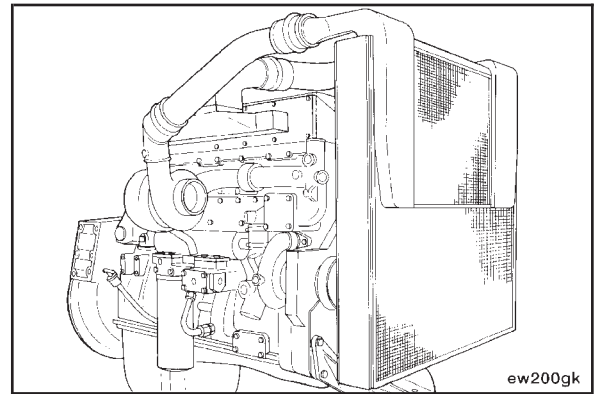
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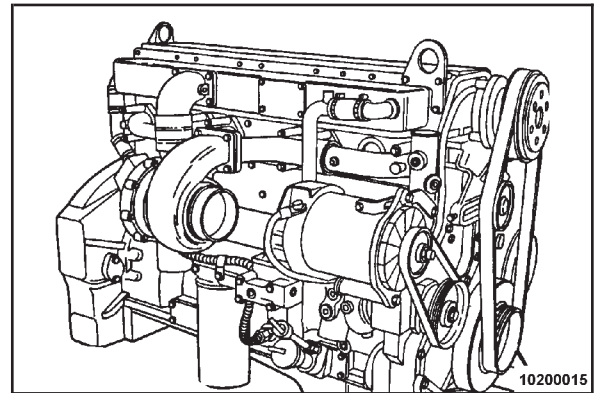
Air Intake System - General Information

General Information

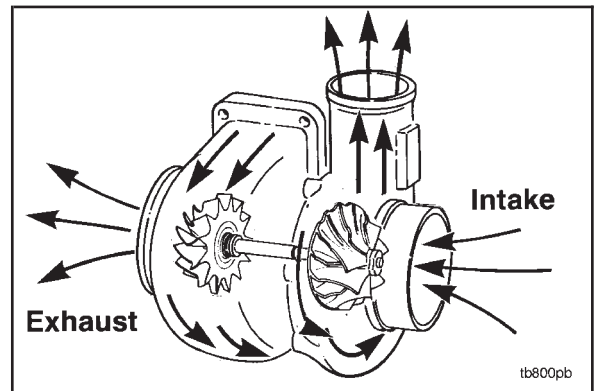
The Combustion Air System on CELECT™ and CELECT™ Plus engines consists of intake air piping, turbocharger, charge air piping, charge air cooler and exhaust gas piping.



On STC engines, the Combustion Air System consists of intake air piping, turbocharger, aftercooler connection and aftercooler, and exhaust gas piping.

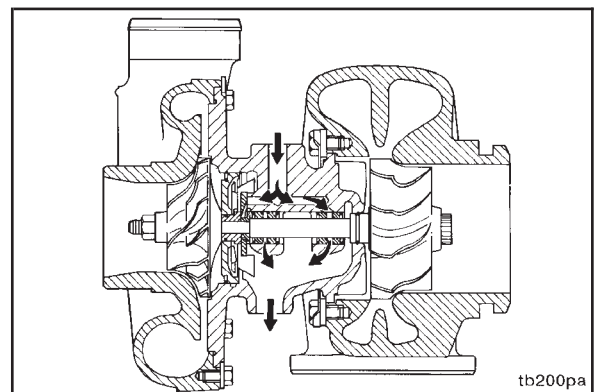


The turbocharger uses exhaust gas energy to turn the turbine wheel. The turbine wheel drives the compressor impeller which provides pressurized air to the engine for combustion. The additional air provided by the turbocharger allows more fuel to be injected to increase the power output from the engine.



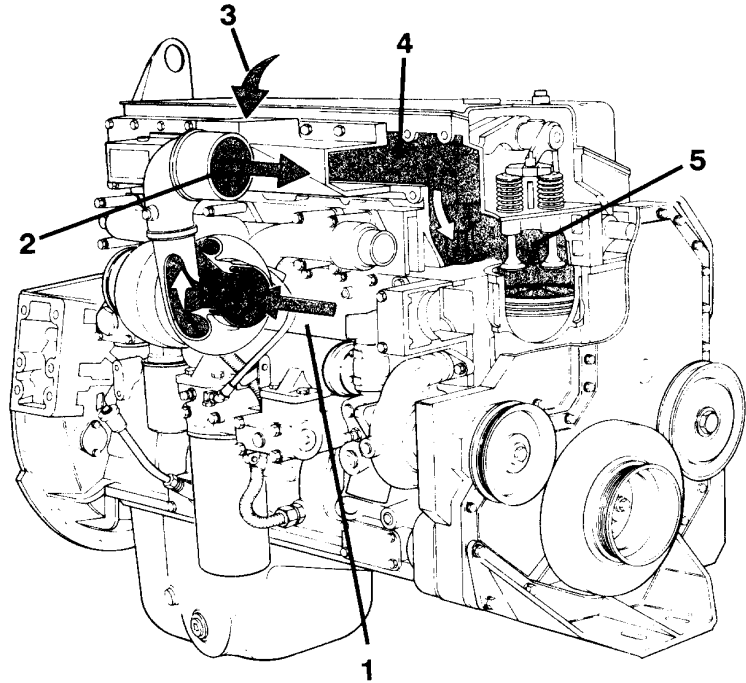
The turbine and compressor wheels, and the shaft are supported by two rotating bearings in the bearing housing. Passages in the bearing housing direct filtered, pressurized engine oil to the shaft bearings and thrust bearings. The oil is used to lubricate and cool the rotating components to provide for smooth operation. The oil then drains from the bearing housing to the engine sump through the oil drain line. A restricted oil drain line can cause the turbocharger bearing housing to be pressurized, causing oil to leak past the seal rings.

NOTE: An adequate supply of good, filtered oil is very important to the life of the turbocharger.



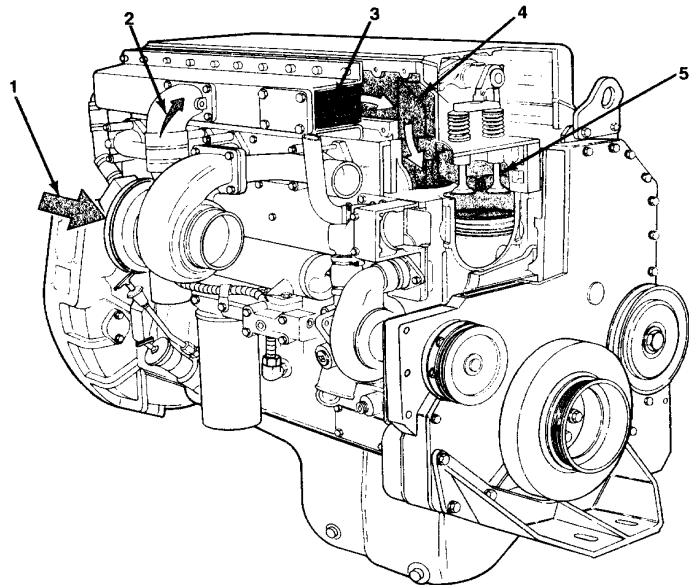
Flow Diagram, Air Intake System

1. Filtered Intake Air to Turbocharger
2. Turbocharger Air to Charge Air Cooler
3. Charge Air Cooler Intake Air to Intake Manifold
4. Intake Manifold
5. Intake Valve Ports



Intake System

1. Filtered Intake Air to Turbocharger
2. Turbocharger Air to Aftercooler
3. Aftercooler
4. Intake Manifold
5. Intake Valve Ports



Specifications

Air Intake System

Maximum Intake Restriction

Clean Air Filter Element	254 mm H ₂ O [10.0 in H ₂ O]
Dirty Air Filter Element	635 mm H ₂ O [25.0 in H ₂ O]

Maximum Temperature Rise Between Ambient Air and Engine Inlet Air:

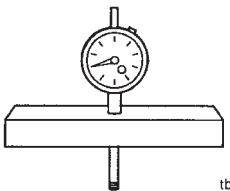
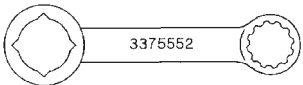

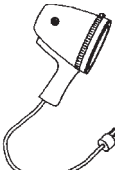
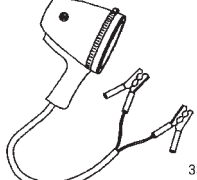
(Ambient (Above 0° [32°F])	17°C [30°F]
----------------------------------	-------------

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

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

Service Tools Air Intake System

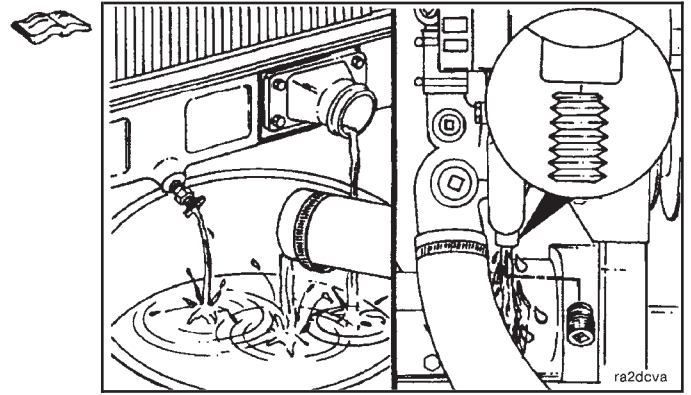
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-537	Dial Depth Gauge Measure turbocharger axial motion.	 <small>tb8togf</small>
3375552	Torque Wrench Adapter Torque compressor housing capscrews.	 <small>3375552</small>
3376891	Fluorescent Tracer Add to oil. Use with blacklight to find oil leaks.	 <small>3376891</small>
3377253	Black Light (AC) Inspect for oil or fuel leak.	 <small>3377253</small>
3377394	Black Light (DC) Inspect for oil or fuel leak.	 <small>3377394</small>

Aftercooler (010-001)

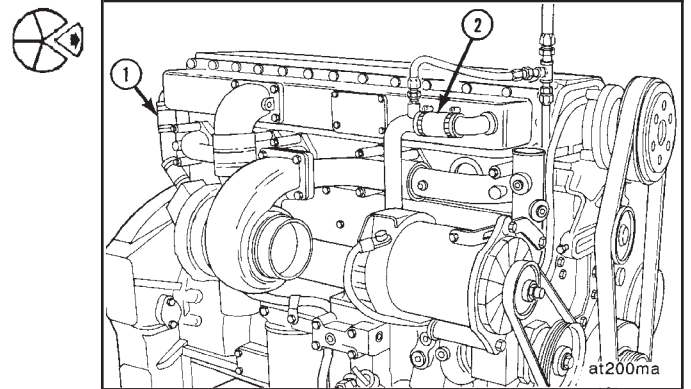
Remove (010-001-002)

Drain the cooling system. Refer to Procedure 008-018-005.



Loosen the hose clamps (1) and (2).

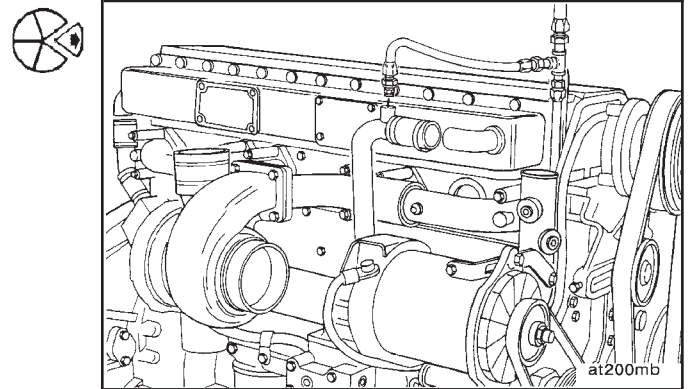
Remove the water inlet and outlet hoses from the aftercooler.



Remove the vent line connection.

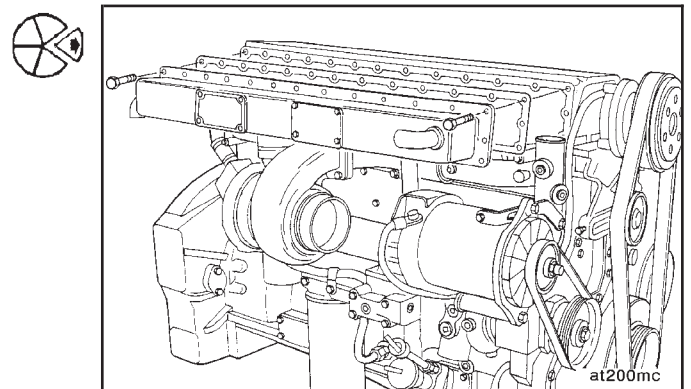
Loosen the top turbocharger air inlet air connection hose clamp.

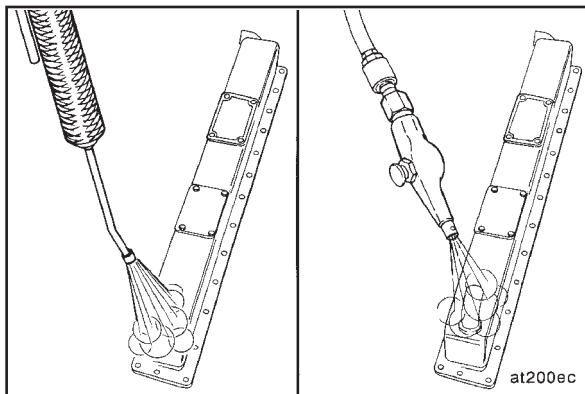
Remove the four capscrews and the air inlet connection elbow.



Remove the mounting capscrews.

Remove the aftercooler and gasket.



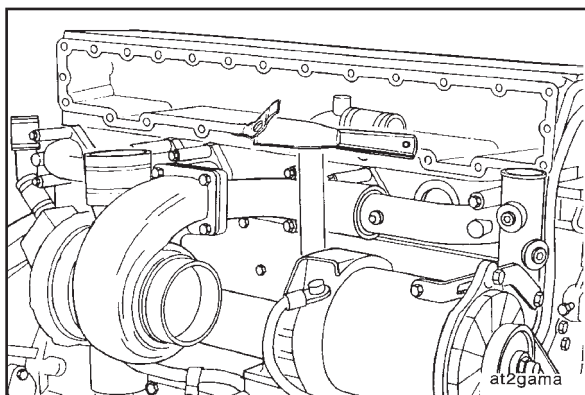


Clean (010-001-006)

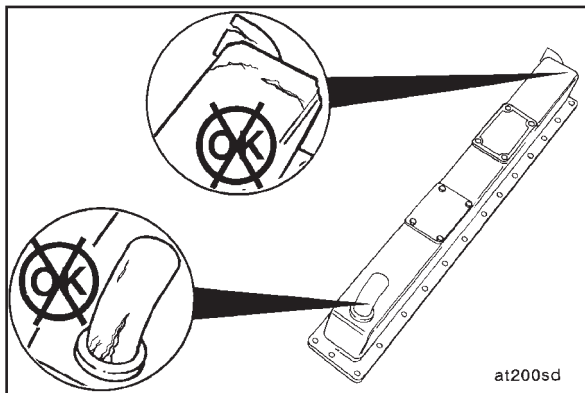
WARNING

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

Use steam to clean the aftercooler. Dry with compressed air.



Clean the gasket material from the rocker lever housing with a gasket scraper.

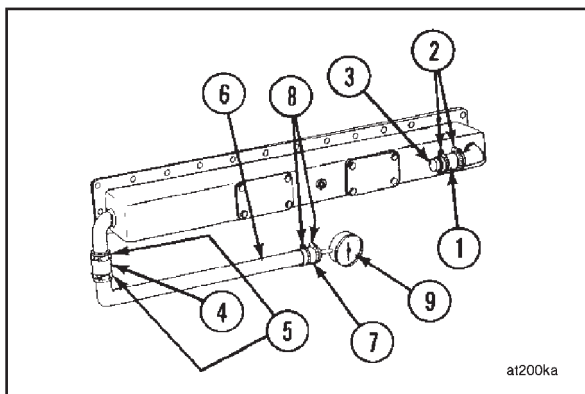


Inspect for Reuse (010-001-007)

Visually inspect the aftercooler for cracks or damage.



Pressure test the aftercooler. Refer to Procedure 010-001-013.



Pressure Test (010-001-013)

With the aftercooler removed from the engine, install hose (1), hose clamps (2), and solid pipe plug (3) on the water outlet pipe.

Install hose (4), hose clamps (5), and the water inlet supply tube (6) on the water inlet pipe.

Install hose (7), hose clamps (8), and air pressure gauge (9).

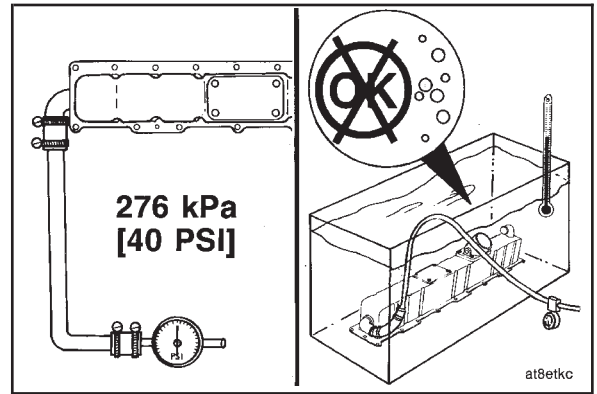
Connect the pressure gauge to a regulated air supply and apply air pressure.

Air Pressure 276 kPa [40 psi]

Submerge the aftercooler in a tank of heated water.

Temperature 82 °C [180 °F]

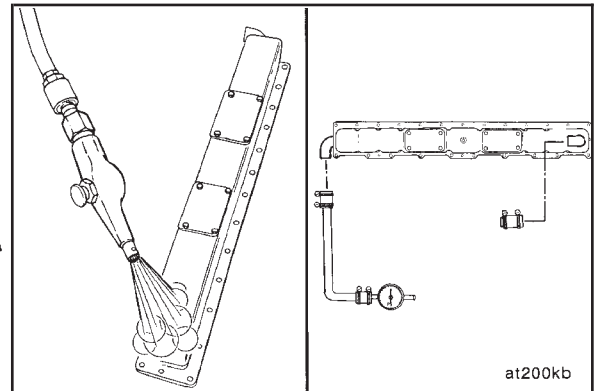
If air bubbles appear, the core is damaged and the aftercooler **must** be replaced.



Remove the aftercooler from the water tank and dry with compressed air.

Remove the test equipment.

Install the aftercooler. Refer to Procedure 010-001-026.

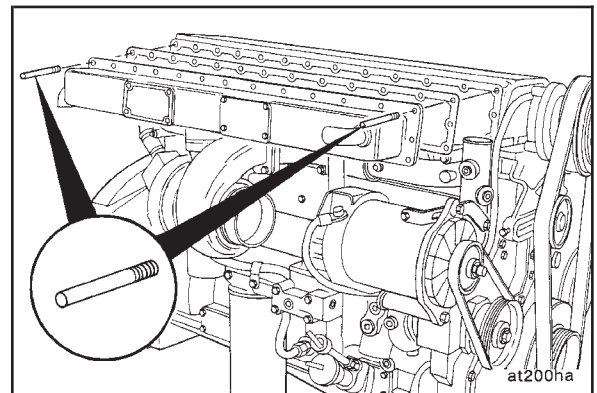


Install (010-001-026)

Install two guide studs in the rocker lever housing.

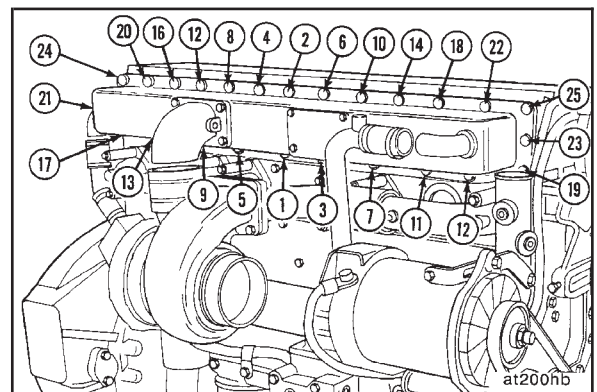
Install a new gasket on the two guide studs.

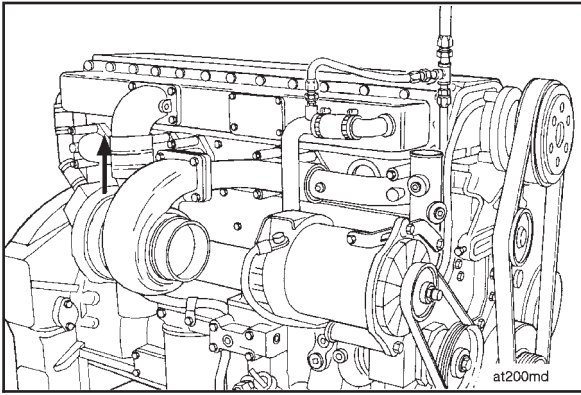
Install the aftercooler.



Install and tighten the capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]





NOTE: Be sure the air inlet hose is install on either the turbocharger compressor outlet or the air connection inlet before installing the air inlet connection to the aftercooler.



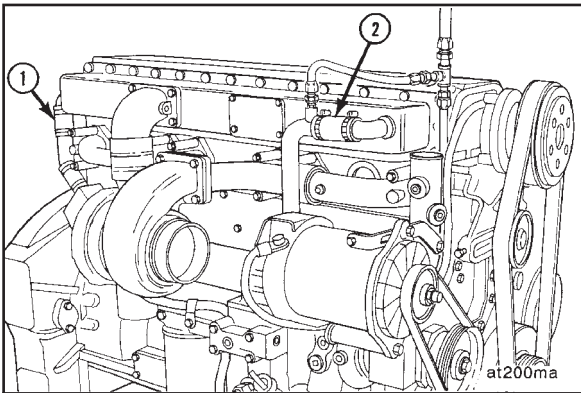
Install a new gasket and the air inlet connection elbow.

Torque Value: 41 N•m [30 ft-lb]

Install the air inlet hose an equal distance over the turbocharger compressor outlet and the aftercooler air inlet.

Tighten the hose clamp.

Torque Value: 8 N•m [72 in-lb]



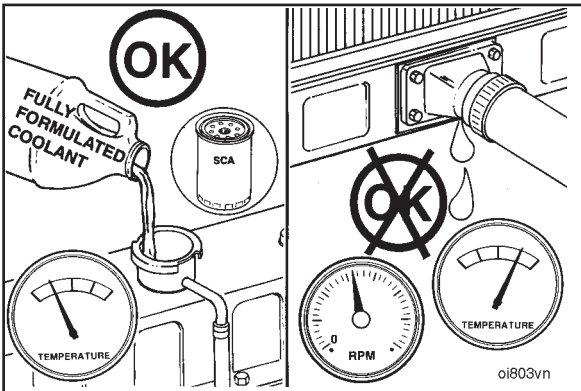
Install the inlet and outlet water hoses.

Tighten the hose clamps.

Torque Value: 3 N•m [30 in-lb]



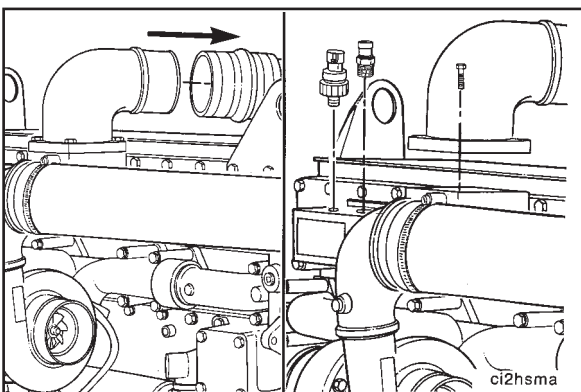
Install the vent line.



Fill the cooling system. Refer to Procedure 008-018-028.



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



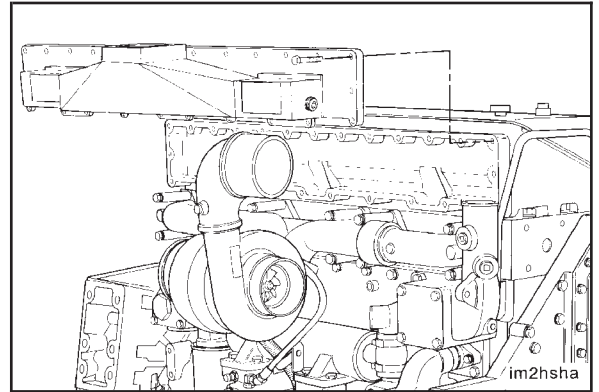
Air Intake Manifold (010-023)

Remove (010-023-002)

Disconnect the air pipe from the charge air cooler to the inlet air connection.

Remove the inlet air connection and the sensors from the air manifold.

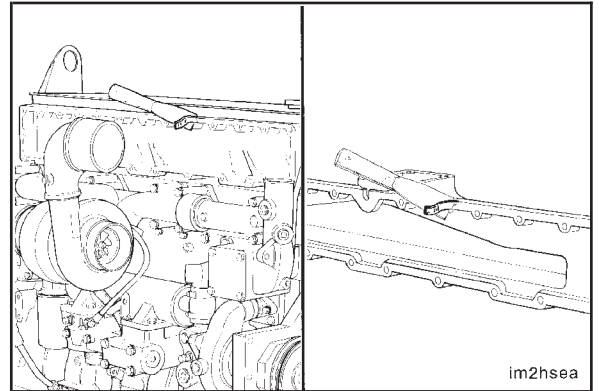
Remove the mounting capscrews and the intake manifold.



Clean (010-023-006)

Clean the intake manifold to rocker housing surface.

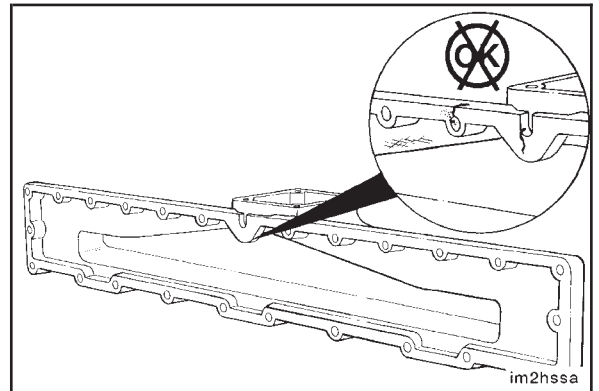
Clean the intake manifold gasket surface.



Inspect for Reuse (010-023-007)

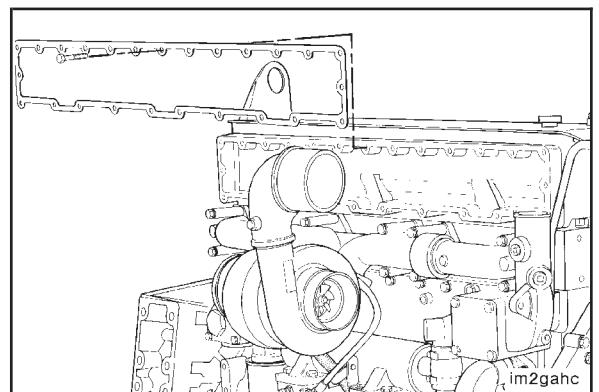
Visually inspect the intake manifold for cracks or other damage.

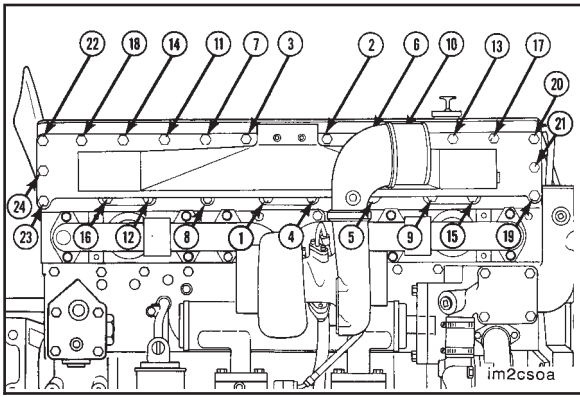
NOTE: When inspecting the intake manifold for oil or debris from an air system failure, also inspect the intake ports in the rocker housing and cylinder head for oil and debris.



Install (010-023-026)

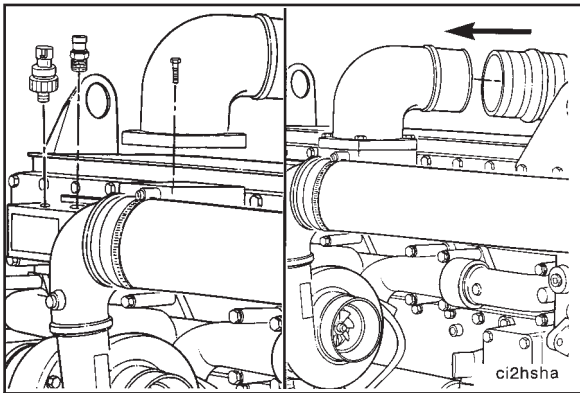
Install two guide pins in the rocker lever housing before installing a new gasket.





Install the intake manifold and capscrews.
Tighten the capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]



Use a new gasket and install the inlet air connection.

Torque Value: 41 N•m [30 ft-lb]

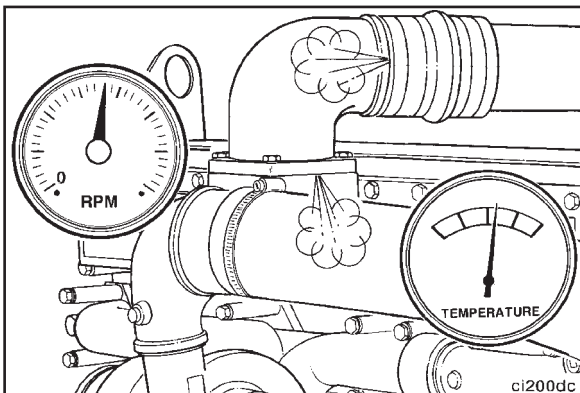
Install the sensors.



Install the air pipe from the charge air cooler to the intake connection. Tighten the clamps.



Refer to the manufacturer's specification for the correct torque value.



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

Air Leaks, Air Intake and Exhaust Systems (010-024)

Maintenance Check (010-024-008)



Engine intake air must be filtered to prevent dirt and debris from entering the engine. If intake air piping is damaged or loose, unfiltered air will enter the engine and cause premature wear.

Inspect the intake air piping for cracked hoses, damage, or loose clamps.

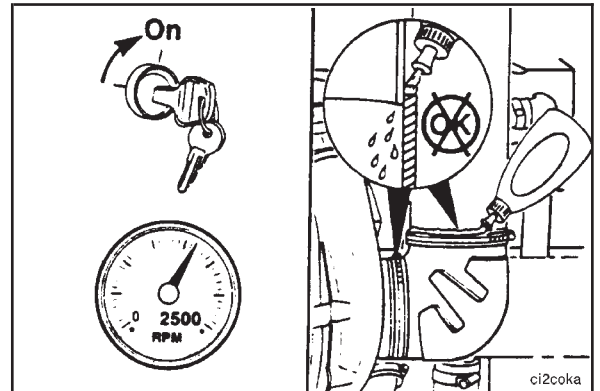
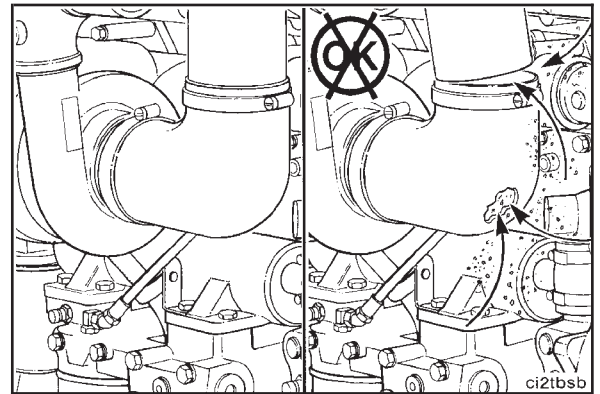
Replace damaged pipes and tighten loose clamps as necessary to make sure the air intake system does **not** leak.

Torque Value: 8 N•m [72 in-lb]

Check for corrosion of the intake system piping under the clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system. Disassemble and clean as required.

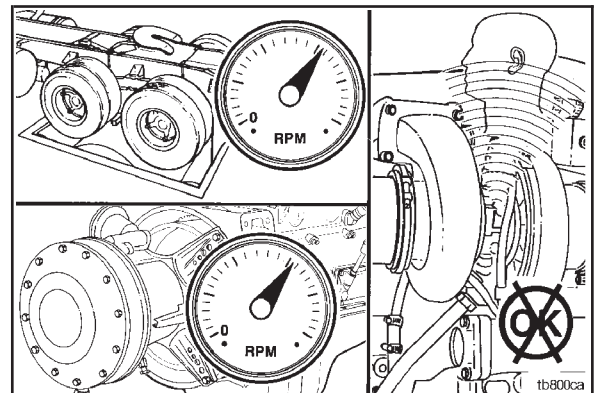
Operate the engine at high idle and use a solution of soapy water to spot intake air leaks.

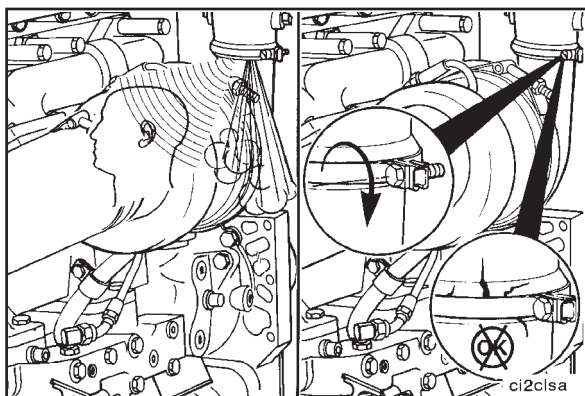
If an air leak exists, the soap bubbles will be drawn in with the air.



Operate the engine at full throttle and rated rpm with maximum load.

Listen for a high-pitched whistling noise from the turbocharger, nearby piping and connections.



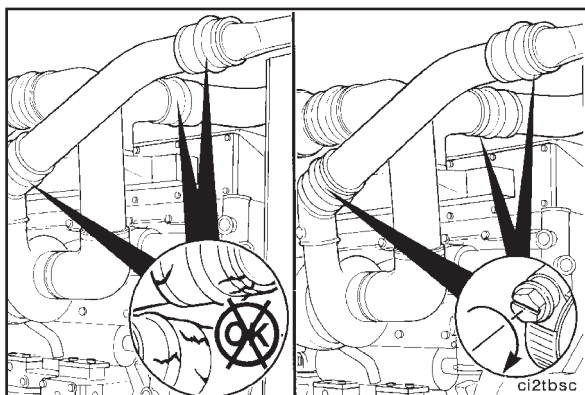


The noise can be caused by an air leak from the:

- turbocharger to discharge elbow connection

Inspect for damage. Tighten loose clamps.

Torque Value: 8 N•m [72 in-lb]

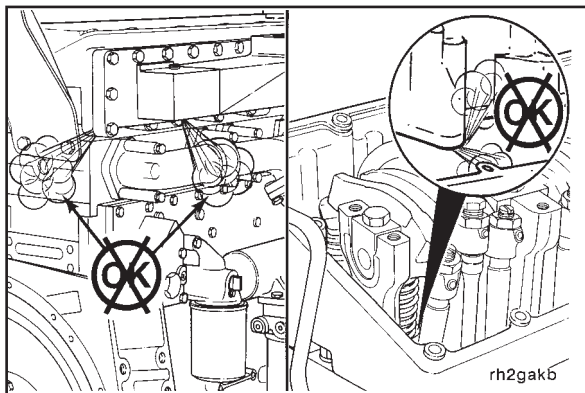


- any charge air cooler tubing or connecting hoses

Inspect the hose and tubing for damage.

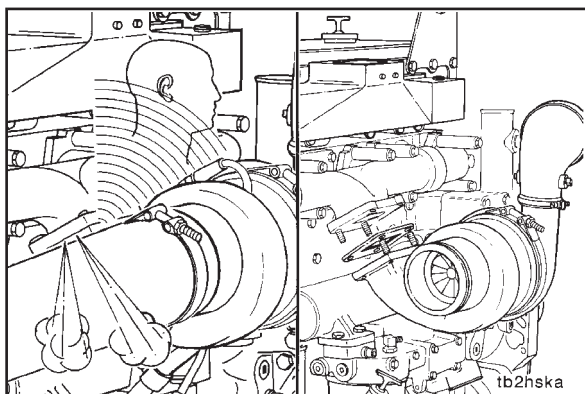
Tighten the hose clamps.

Refer to the manufacturer's specifications for the correct torque value.



- rocker housing and intake manifold gaskets

Inspect the intake manifold and rocker housing to cylinder head gasket joint. Replace the gasket if leaks are found. Refer to Procedure 003-013.



- turbocharger to exhaust manifold mounting gasket

Replace the gasket. Refer to Procedure 010-033 for turbocharger removal and installation.

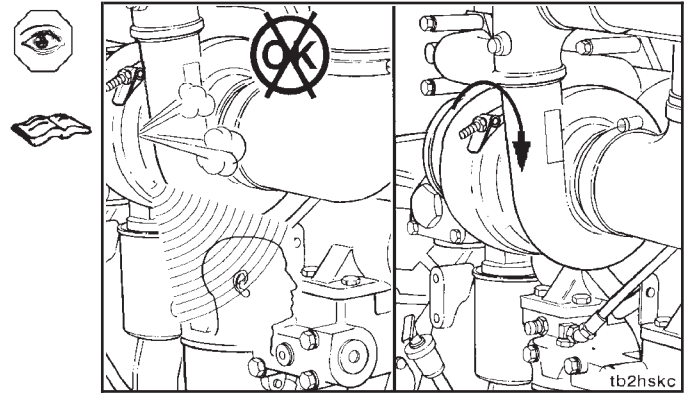


- turbine housing sealing surface exhaust leak

Tighten the turbine housing capscrews or v-band clamps.

Torque Value:

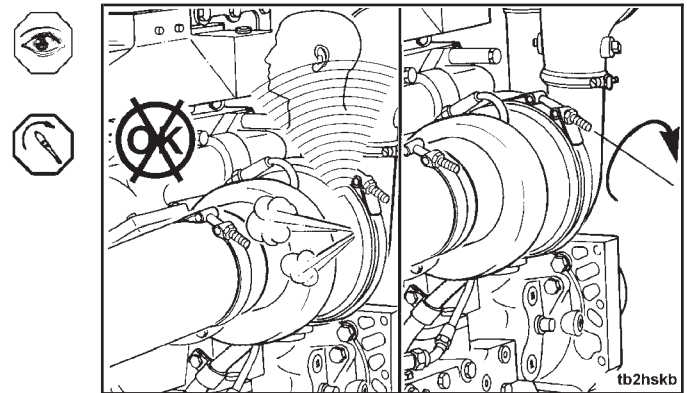
Capscrews	14 N•m	[120 in-lb]
V-band	9 N•m	[75 in-lb]



- compressor housing sealing surface air leak

Tighten the compressor housing v-band clamp nut.

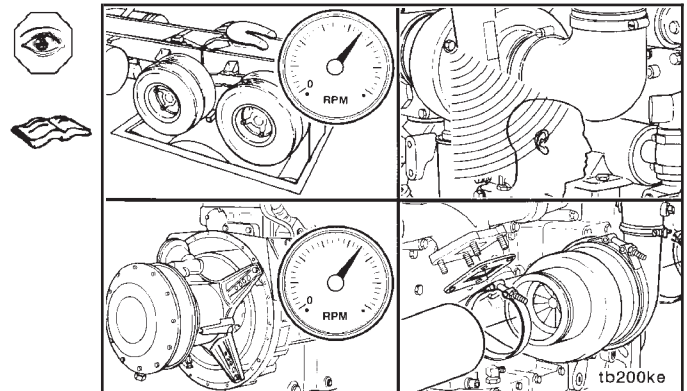
Torque Value: 9 N•m [75 in-lb]



Operate the engine at full throttle and rated RPM with maximum load.

Listen again for leaks.

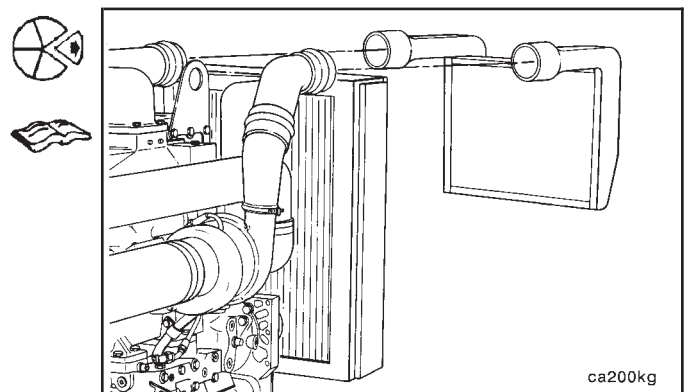
Replace the turbocharger if the air piping is **not** damaged and the noise can still be heard. Refer to Procedure 010-033.

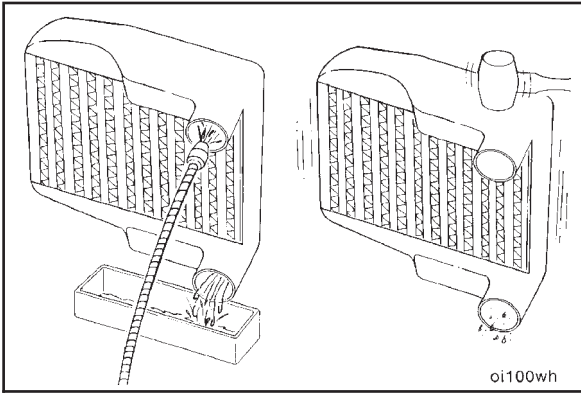


**Charge Air Cooler (CAC) (010-027)
Clean (010-027-006)**

If the engine experiences a turbocharger failure or any other occasion where oil or debris is put into the CAC, the CAC **must** be cleaned.

Remove the CAC piping and CAC from the vehicle. Refer to the manufacturer's instructions.





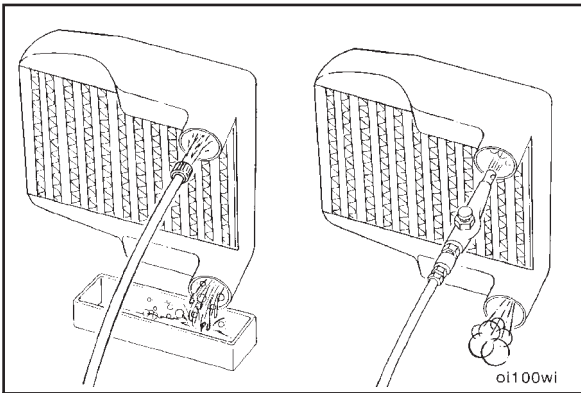
CAUTION

Do not use caustic cleaners to clean the CAC. Damage to the CAC will result.

Flush the CAC internally with solvent in the opposite direction of normal air flow. Shake the CAC and lightly tap on the end tanks with a rubber mallet to dislodge trapped debris. Continue flushing until all debris or oil is removed.

NOTE: Be sure the tubes are in the vertical direction when flushing.

If the debris **cannot** be totally removed from the CAC, the CAC **must** be replaced.

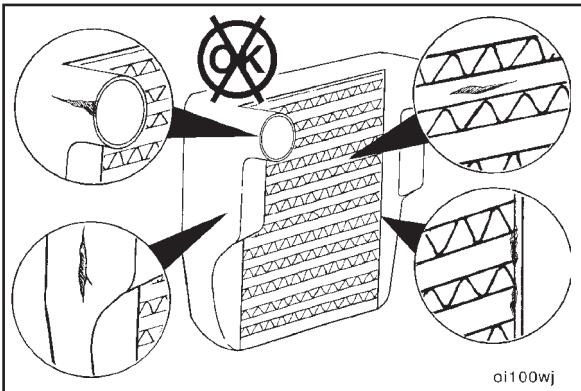


After the CAC has been thoroughly cleaned of all oil and debris with solvent, wash the CAC internally with hot soapy water to remove the remaining solvent. Rinse thoroughly with clean water.

Blow compressed air through the inside of the CAC in the opposite direction of normal air flow until the CAC is dry internally.

CAUTION

The CAC **must** be rinsed, dried and free of solvent, oil and debris or engine damage will result.



Inspect for Reuse (010-027-007)

Visually inspect the CAC for cracks, holes or damage.

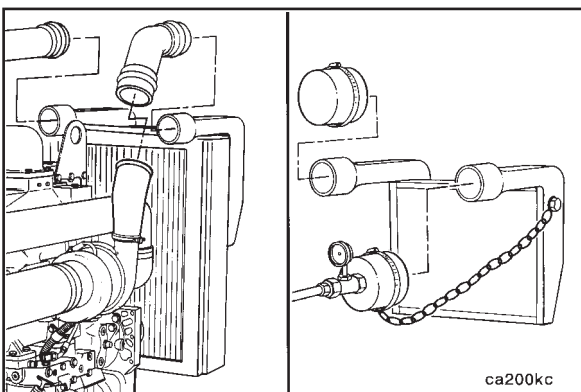


Inspect the tubes, the fins and the welds for tears, breaks or other damage. If any damage causes the CAC to fail the air leak check mentioned earlier in this procedure, the CAC **must** be replaced.



Install the CAC and CAC piping on the vehicle. Refer to the manufacturer's instructions.

NOTE: Always clean and inspect the CAC piping and hoses prior to installation.



Leak Test (010-027-014)

To check the CAC for cracked tubes or header, remove the inlet and outlet hoses from the cooler. The CAC does **not** have to be removed from the chassis.

WARNING

To prevent possible injury if either plug blows off during the test, secure safety chains on the test plugs to any convenient capscrew on the radiator assembly. This test **must not** be performed without securely fastened safety chains.

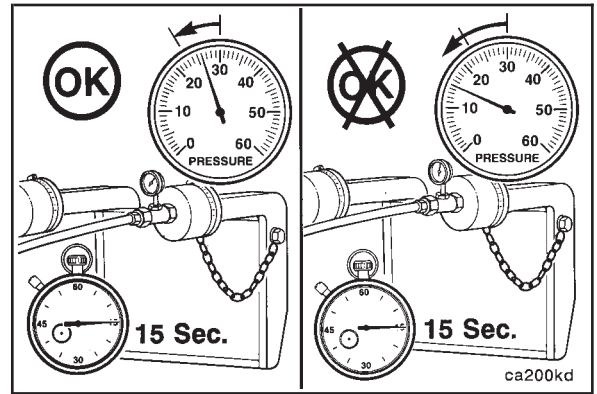
Install a plug or cap over the outlet side of the cooler. Install a pressure gauge and a regulated shop air supply line with a shutoff valve to the inlet side of the cooler.

Apply air pressure to the cooler until the pressure gauge reads a steady 207 kPa [30 psi] of air pressure.

Shut off the air flow to the cooler and start a stopwatch at the same time. Record the leakage at 15 seconds.

If the pressure drop is 34 kPa [5 psi] or less in 15 seconds, the cooler is okay.

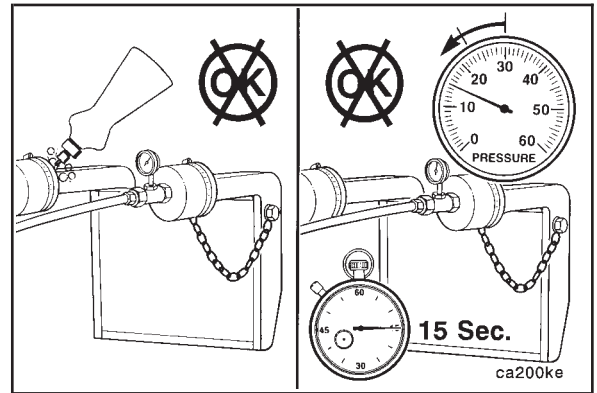
If the pressure drop is greater than 34 kPa [5 psi] in 15 seconds, check all connections again.



Determine if the pressure drop is caused by a leak in the CAC or from a leaky connection. Use a spray bottle filled with soapy water applied to all hose connections, and watch for bubbles to appear at the location of the leak.

If the pressure drop is caused by a leaky connection, repair the connection and repeat the test. If the leak is within the CAC, 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.

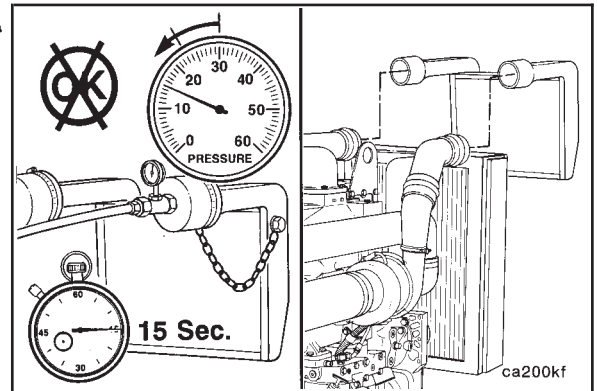
NOTE: If a CAC leaks more than 34 kPa [5 psi] in 15 seconds, it will appear as a major leak in a leak tank.



If the pressure drop is greater than 34 kPa [5 psi] in 15 seconds, the CAC **must** be replaced.

Refer to the manufacturer's repair manual for replacement instructions.

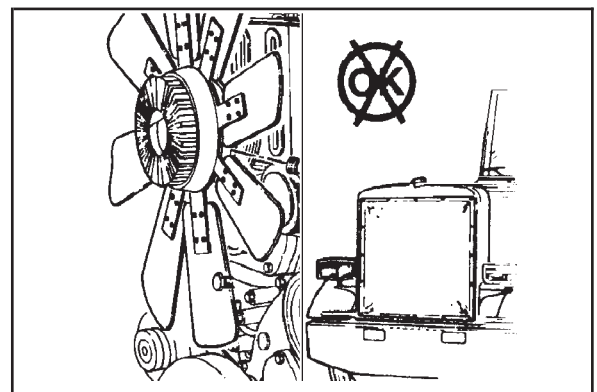
NOTE: Charge air coolers are **not** designed to be 100 percent leak free. If the pressure drop is less than 34 kPa [5 psi] in 15 seconds, then the CAC does **not** need to be replaced.

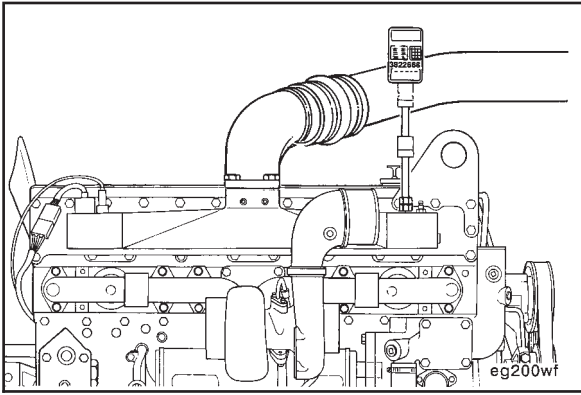


Temperature Differential Test (010-027-049)

Inspect the CAC fins for obstructions to air flow. Remove obstructions such as a winterfront or debris. Manually lock shutters in the open position if equipped.

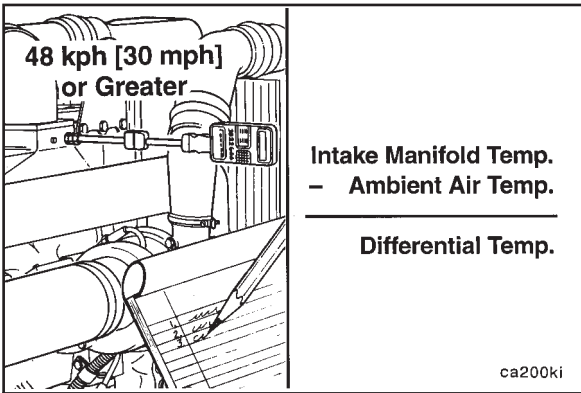
Lock the fan drive in the "ON" mode to prevent erratic test results. This can be done by installing a jumper wire across the temperature switch.





Install Fluke digital thermometer, Part No. 3822666, and thermocouple wire kit, Part No. 3822988, into the intake manifold at the 1/8 inch NPT tap near the air horn connection with the intake manifold.

Install another thermocouple at the air cleaner inlet to measure ambient air temperature.

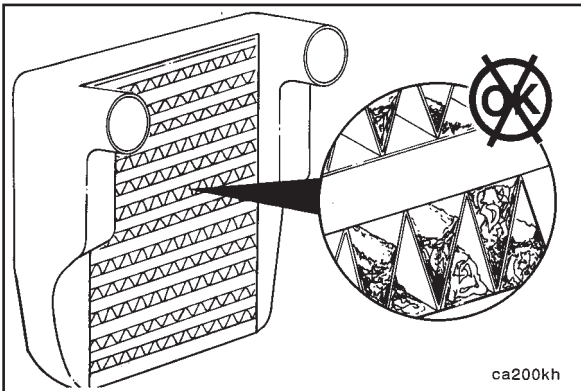


Perform a road test with the engine at peak power and a vehicle speed of 48 kph [30 mph] or greater.

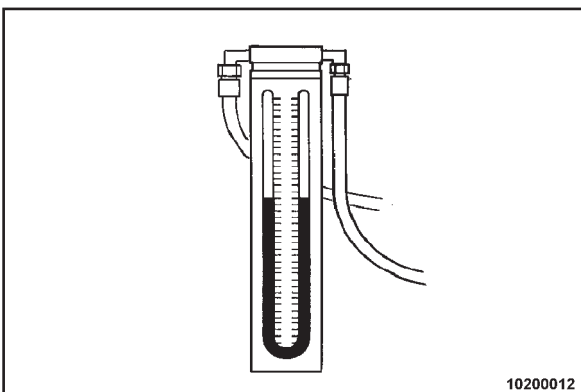
Record the intake manifold temperature and the ambient air temperature.

Calculate the differential temperature:

Intake Manifold Temperature	-	Ambient Air Temperature	=	Differential Temperature
Maximum Differential Temperature 28°C [50°F]				



If the temperature differential is greater than the specifications, check the CAC for dirt and debris on the fins and clean as necessary. If the problem still exists, check the CAC for debris in the fins or between the CAC and radiator. Confirm full fan engagement.



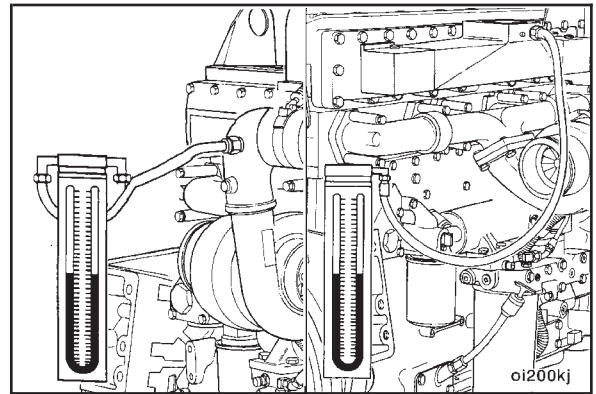
Pressure Differential Test (010-027-063)

Preferred Method

Measure the charge air cooler (CAC) system pressure drop with a mercury manometer.

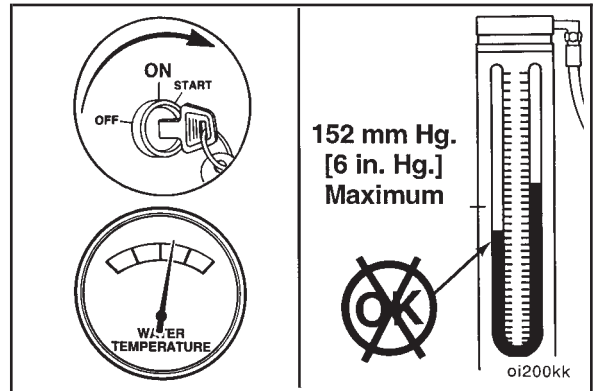
Install one end of a mercury manometer to the fitting in the turbocharger compressor outlet elbow.

Install the other end of the mercury manometer to the intake manifold.



Operate the engine at rated rpm and load. Record the readings on the manometer.

If the differential pressure is greater than 152 mm Hg [6 in. Hg], check the CAC and associated piping for plugging. Clean or replace if necessary.

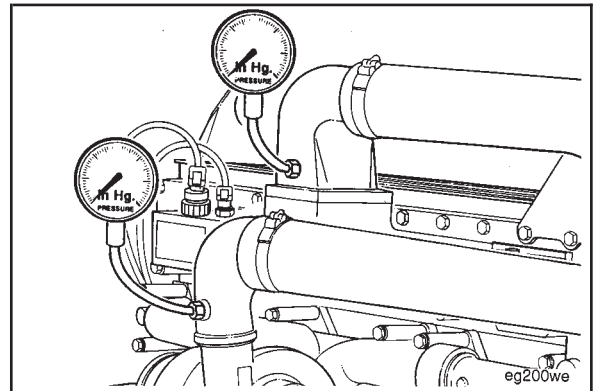


Optional Method

Obtain two (2) pressure gauges, Part No. ST-1273. Check both gauges on the same pressure source at 206 kPa [30 psi] to ensure consistency.

Install pressure gauge, Part No. ST-1273, to the 1/8 inch fitting in the turbocharger compressor outlet elbow.

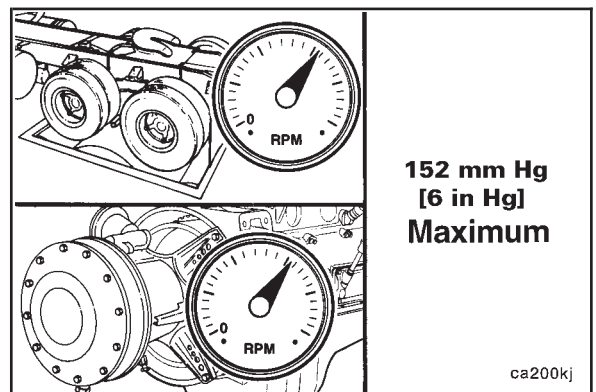
Install the other pressure gauge in the intake manifold.

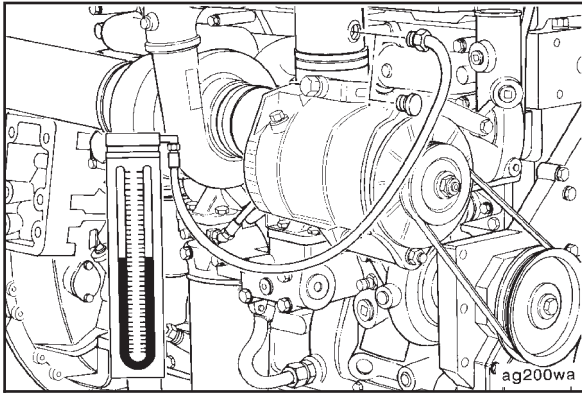


Operate the engine at rated rpm and load. Record the readings on the two gauges.

If the differential pressure is greater than 152 mm Hg [6 in. Hg], check the CAC and associated piping for plugging, restrictions or damage.

Clean or replace if necessary.



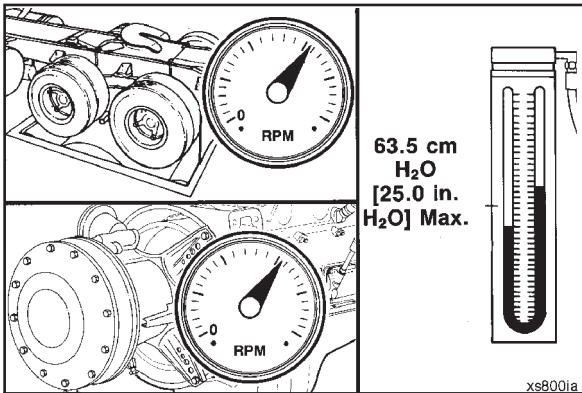


Air Intake Restriction (010-031)

Measure (010-031-010)

Install a vacuum gauge or water manometer in the intake air piping.

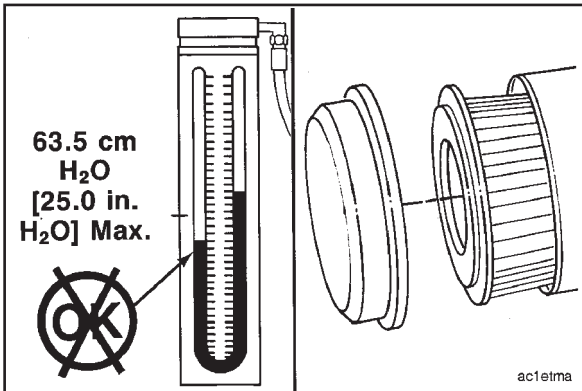
The gauge adapter **must** be installed at a 90 degree angle to the air flow in a straight section of pipe, one pipe diameter before the turbocharger.



Operate the engine at full throttle and rated RPM with maximum load.

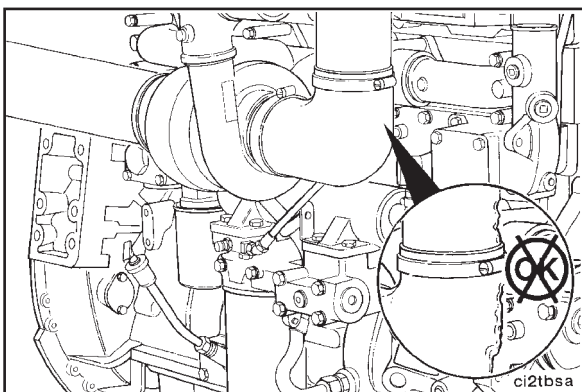
Record the data on the gauge or manometer.

Inlet Air Restriction		
mm H ₂ O		in H ₂ O
63.5	MAX	25.0



If restriction exceeds specifications:

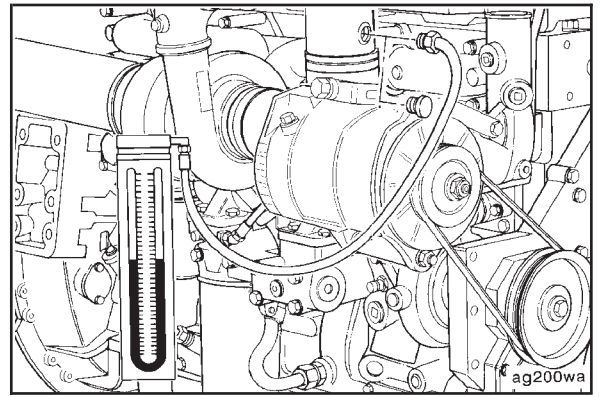
- Replace or clean the air filter element. Refer to the equipment manufacturer's instructions.



- Inspect the intake piping for damage. Refer to the equipment manufacturer's repair instructions.



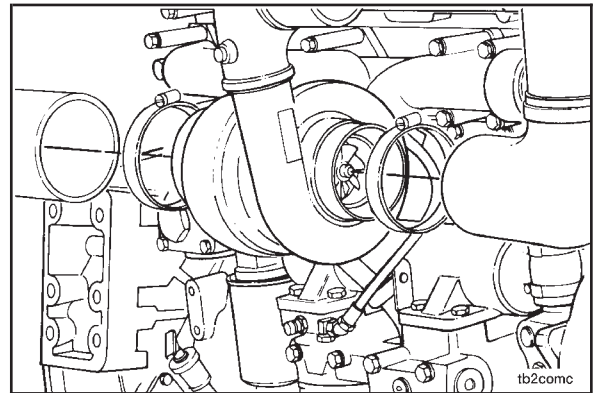
Remove the test equipment.



Turbocharger (010-033)

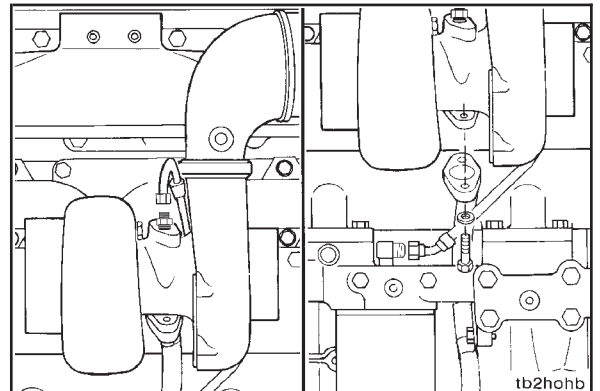
Remove (010-033-002)

Remove the intake and exhaust pipes from the turbocharger.



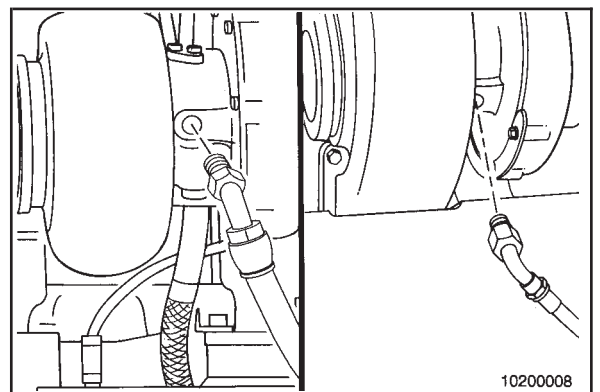
Remove the oil supply line from the turbocharger.

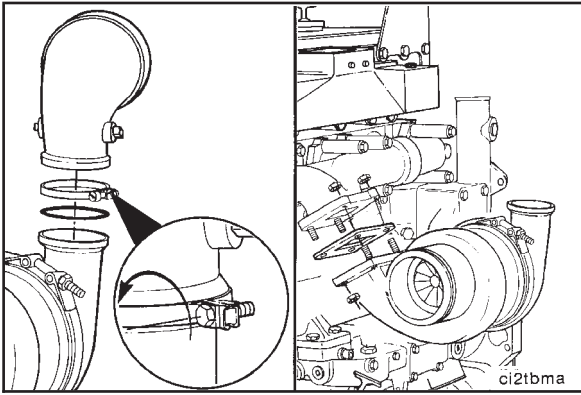
Remove the oil drain line from the turbocharger.



NOTE: Some applications use water-cooled turbochargers.

If a water-cooled turbocharger is used, drain the cooling system and remove the water supply and return lines from the turbocharger.

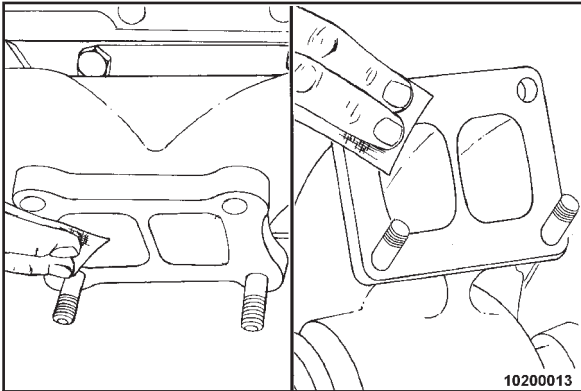




Remove the v-band clamp, discharge elbow and o-ring from the turbocharger compressor discharge outlet.

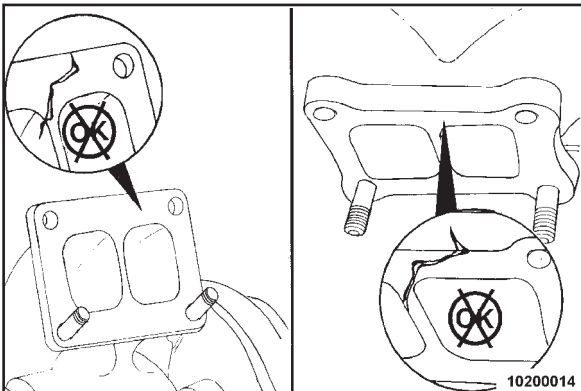
Remove the four turbocharger mounting nuts.

Remove the turbocharger and gasket.



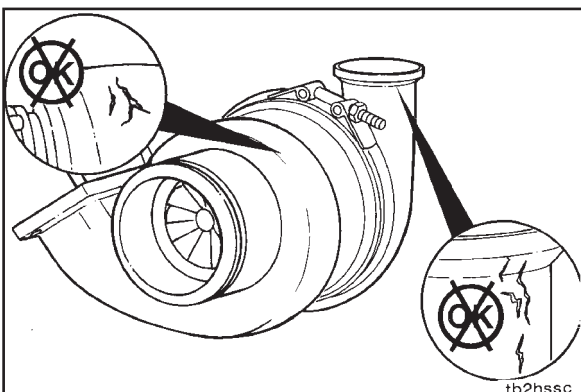
Clean (010-033-006)

Clean the turbocharger and exhaust manifold gasket surfaces.



Inspect for Reuse (010-033-007)

Visually inspect the turbocharger and exhaust manifold gasket surfaces, and mounting studs for cracks or damage.



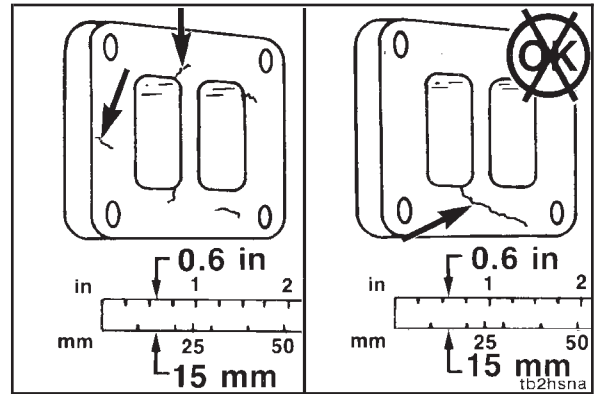
Visually inspect the turbine and compressor housings.

If cracks that go all the way through the outer walls are found, the housing **must** be replaced.

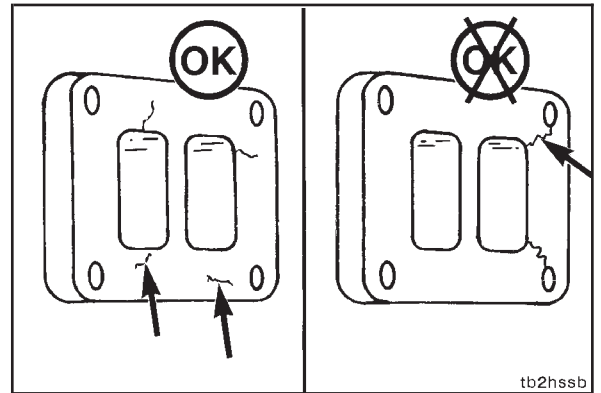


NOTE: A charge air cooler failure can cause progressive damage to the turbine housing. If the turbine housing is damaged, check the charge air cooler. Refer to Procedure 010-027.

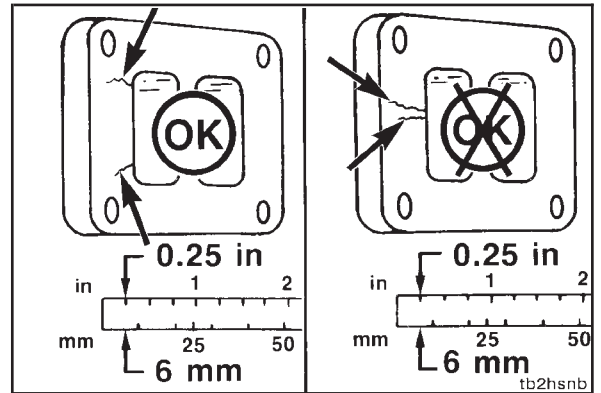
Cracks in the mounting flange longer than 15 mm [0.6 inch] are **not** acceptable.



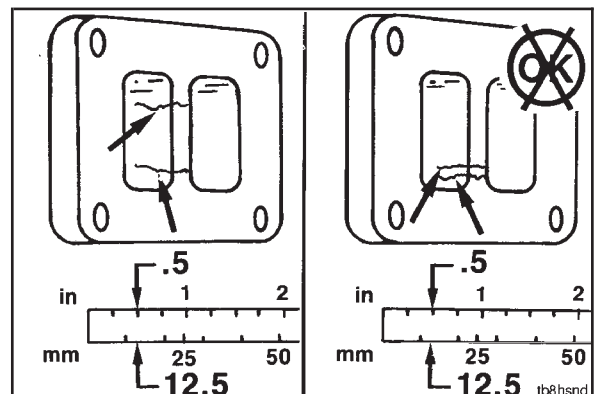
Cracks of any length that reach mounting holes are **not** acceptable.

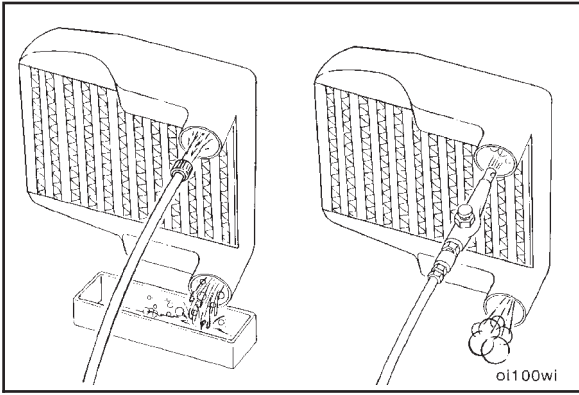


Two cracks **must** be separated by at least 6.4 mm [0.25 inch].

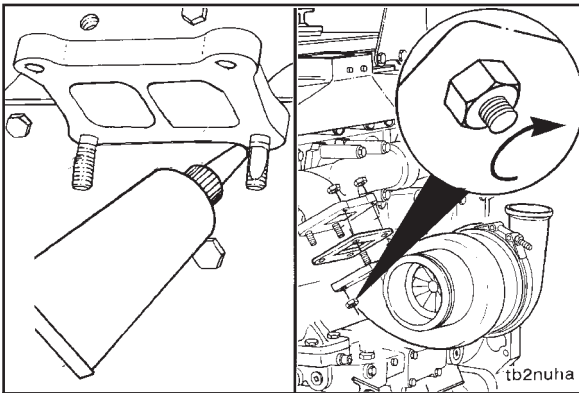


Cracks of any length that extend through the divider are acceptable only if they are separated by at least 12.5 mm [0.50 inch].





NOTE: If the engine experiences a turbocharger failure or any other occasion where oil or debris is put into the charge air system, the charge air system **must** be inspected and cleaned. Refer to Procedures 010-027 and 010-023.



Install (010-033-026)

Apply a film of high temperature anti-seize compound to the turbocharger mounting studs.

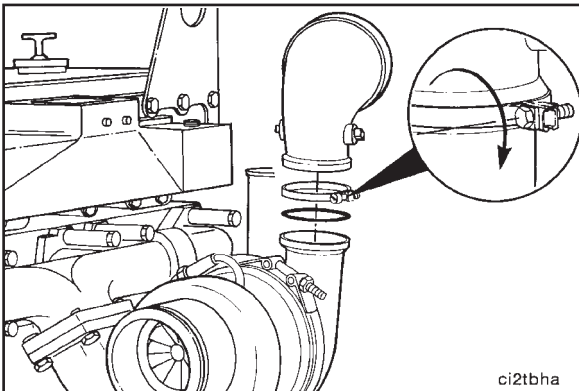


Use a new gasket and install the turbocharger.

Install and tighten the four mounting nuts.

NOTE: The torque values given have been established using anti-seize compound as a lubricant.

Torque Value: 61 N•m [45 ft-lb]

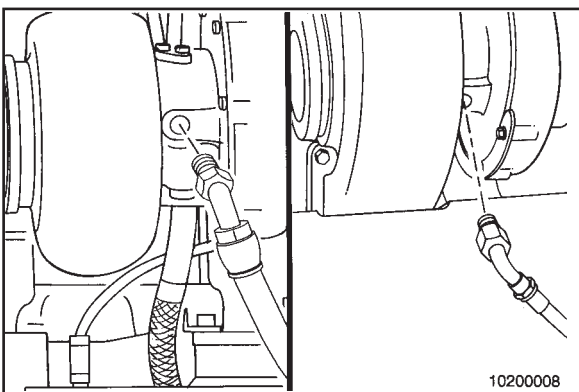


Install the discharge elbow, v-band clamp, and new o-ring seal on the turbocharger compressor discharge outlet.

Tighten the clamp.



Torque Value: 8 N•m [75 in-lb]

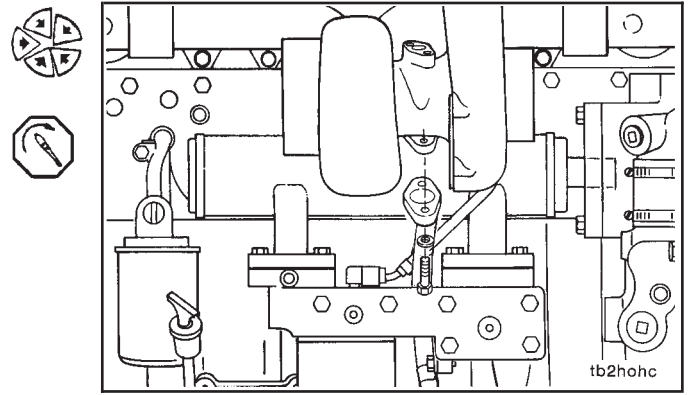


NOTE: Some applications use water-cooled turbochargers.

If a water-cooled turbocharger is used, install the water supply and return lines to the turbocharger.

Install and tighten the turbocharger oil drain line.

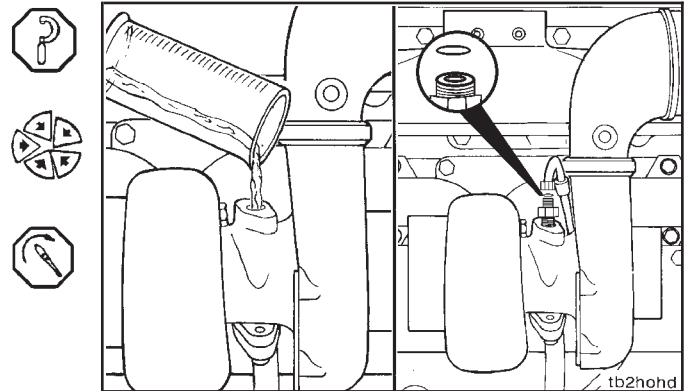
Torque Value: 27 N•m [20 ft-lb]



Pour 50 to 60 cc [2.0 to 3.0 ounces] of clean 15W-40 engine oil in the turbocharger oil supply line fitting.

Install and tighten the turbocharger oil supply line.

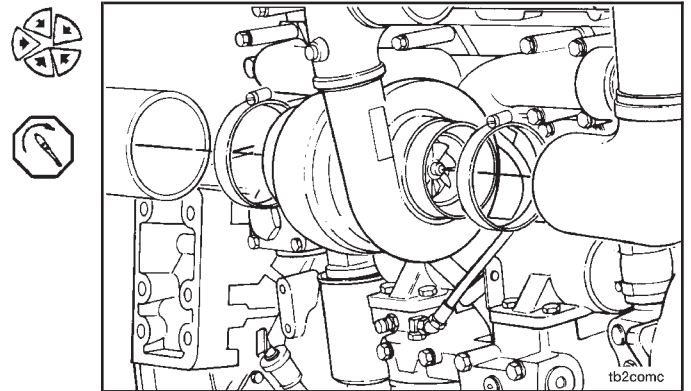
Torque Value: 20 N•m [15 ft-lb]



Install the intake pipe and tighten the clamp.

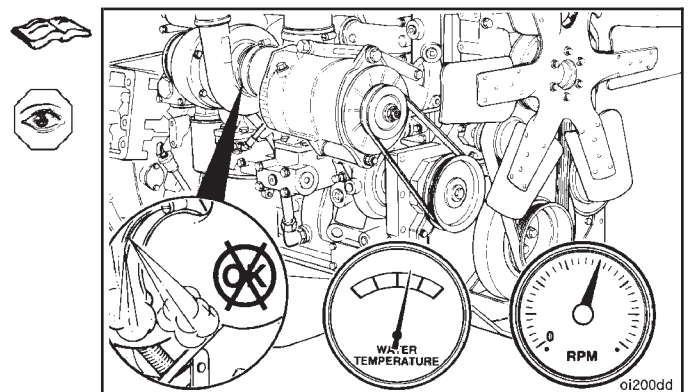
Install the exhaust pipe and tighten the clamp.

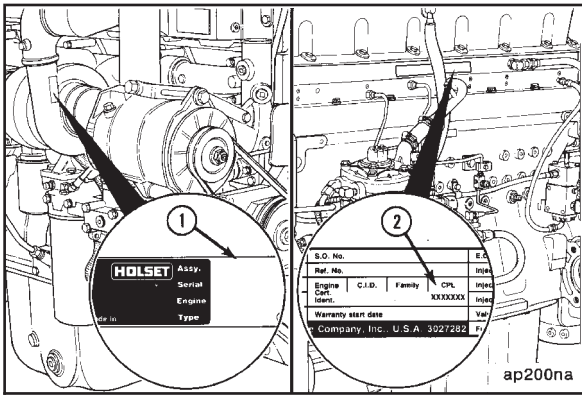
Torque Value: 8 N•m [72 in-lb]



NOTE: If a water-cooled turbocharger is used, fill the cooling system. Refer to Procedure 008-018-028.

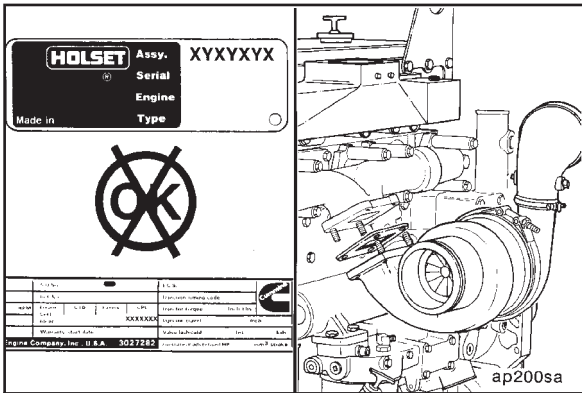
Operate the engine and check for air leaks.



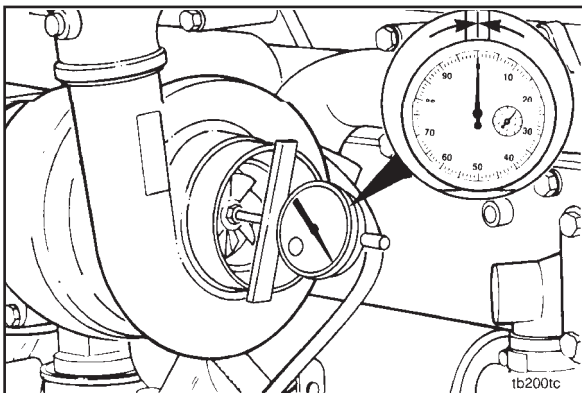


Check for Correct Component (010-033-048)

Compare the assembly number (1) on the turbocharger data tag with the turbocharger specified in the engine control parts list (CPL) number (2) listed on the engine data tag.



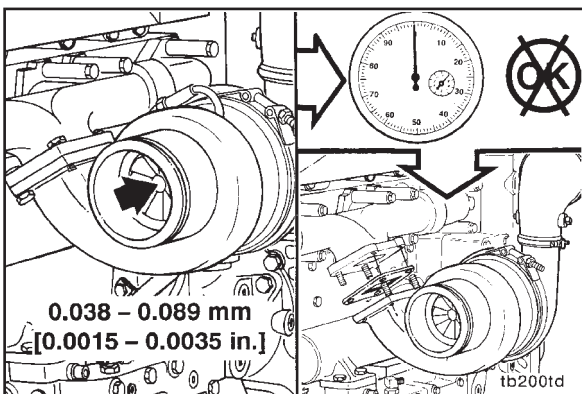
If the correct turbocharger was **not** installed, remove it and install the correct turbocharger. Refer to Procedure 010-033.



Turbocharger Axial Clearance (010-038)

Measure (010-038-010)

Use dial depth gauge, Part No. ST-537.
Push the rotor assembly away from the gauge.
Set the gauge on zero (0).



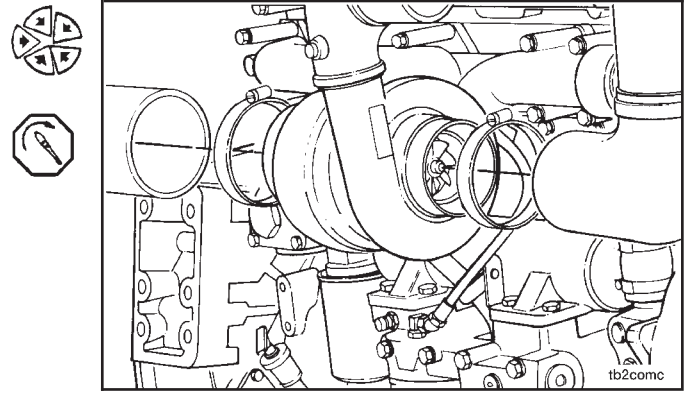
Push the rotor assembly toward the gauge and record the reading.



Axial Clearance		
mm		in
0.038	MIN	0.0015
0.089	MAX	0.0035

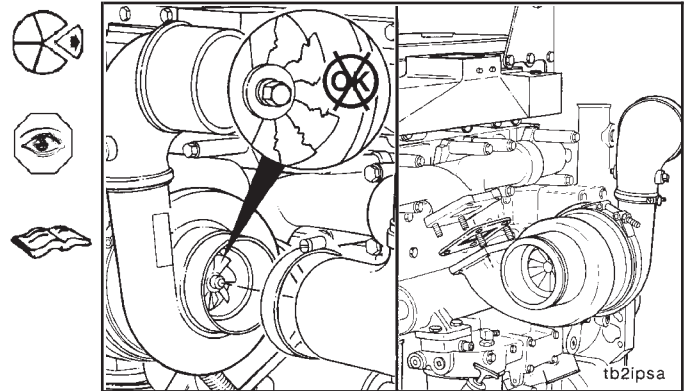
Replace the turbocharger if the clearance does **not** meet the specifications. Refer to Procedure 010-033 for the replacement procedure.

Install the exhaust pipe and tighten the clamp.
Install the intake pipe and tighten the clamp.
Torque Value: 8 N•m [72 in-lb]

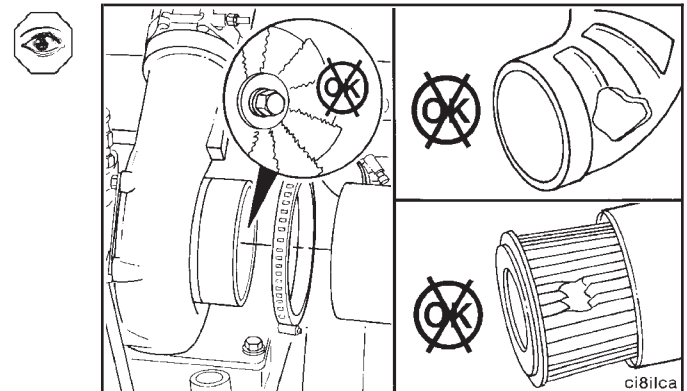


Turbocharger Blade Damage (010-039) Inspect for Reuse (010-039-007)

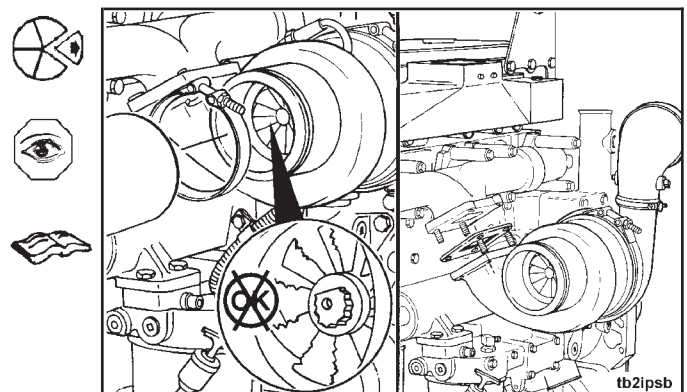
Remove the intake pipe from the turbocharger.
Visually inspect the turbocharger compressor impeller blades for damage.
Replace the turbocharger if damage is found. Refer to Procedure 010-033.

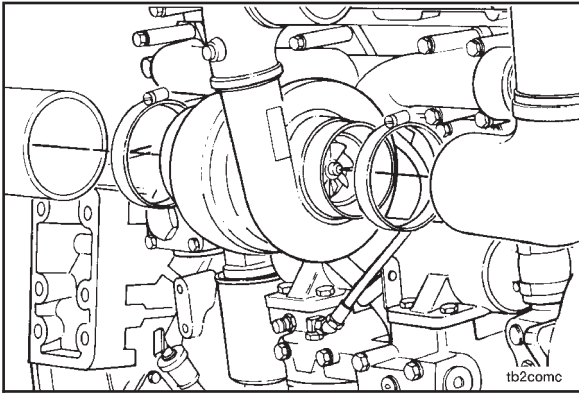


If the compressor impeller is damaged, inspect the intake piping and filter element for damage.
Repair any damage before operating the engine.



Remove the exhaust pipe from the turbocharger.
Inspect the turbine wheel for damage.
Replace the turbocharger if damage is found. Refer to Procedure 010-033.

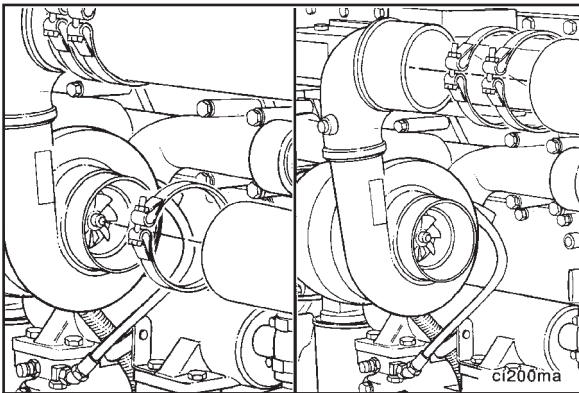




Install the intake pipe and tighten the clamp.
Install the exhaust pipe and tighten the clamp.



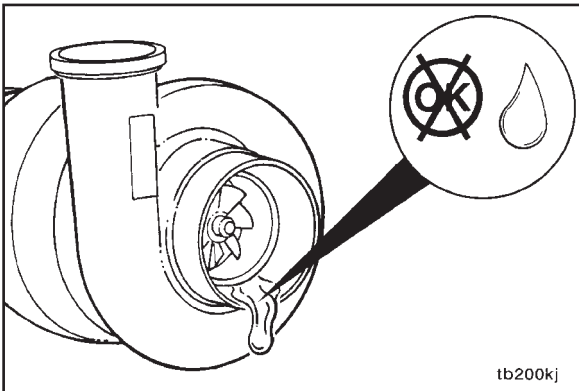
Torque Value: 8 N•m [72 in-lb]



Turbocharger Compressor Seal Leaks (010-040)

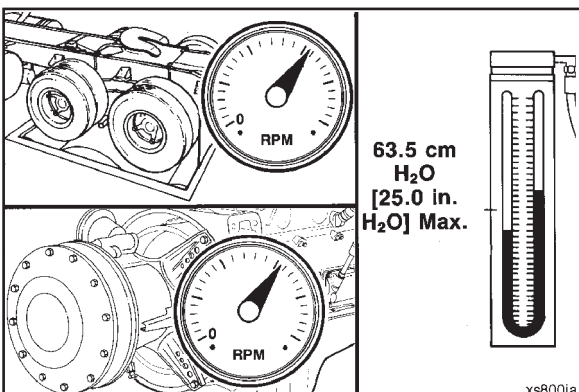
Leak Test (010-040-014)

Remove the air intake and charge air cooler (CAC) piping from the turbocharger.



Inspect the compressor intake and discharge for oil.

If oil is present in the compressor intake as well as in the discharge, check upstream of the turbocharger for the source of the oil.



If oil is present only in the discharge side, install the air intake and CAC piping.



Check for intake restriction. Refer to Procedure 010-031-010.

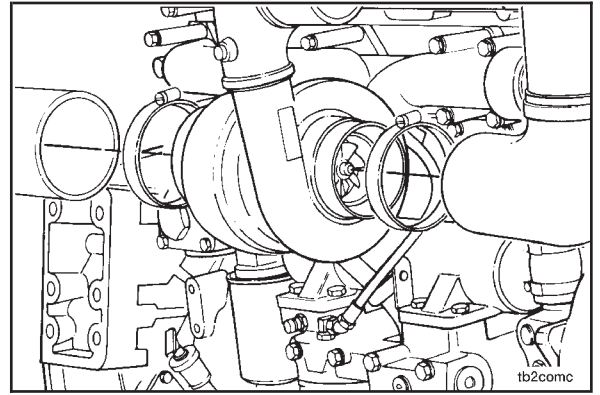
If no intake restriction is found, replace the turbocharger. Refer to Procedure 010-033.



Turbocharger Radial Bearing Clearance (010-047)

Measure (010-047-010)

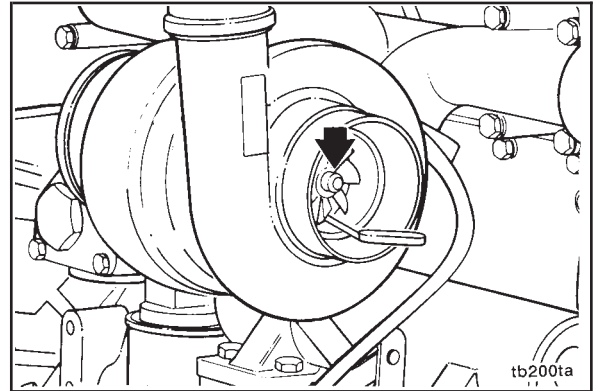
Remove the intake and exhaust pipes from the turbocharger.



Use a narrow blade or a wire type feeler gauge to measure the clearance between the compressor wheel and housing.

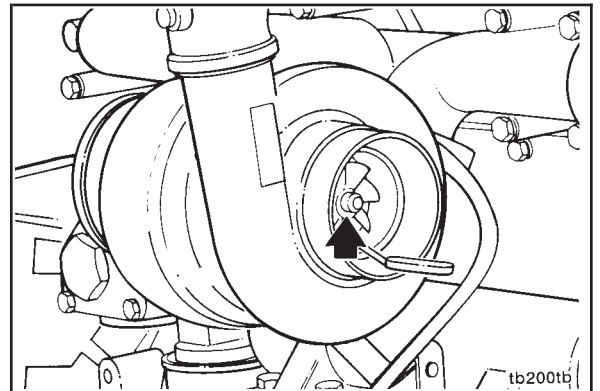
Gently push the compressor wheel toward the compressor housing and gauge.

Record this clearance.



With the feeler gauge in the same location, gently push the compressor wheel away from the compressor housing and measure the clearance between the compressor wheel and housing.

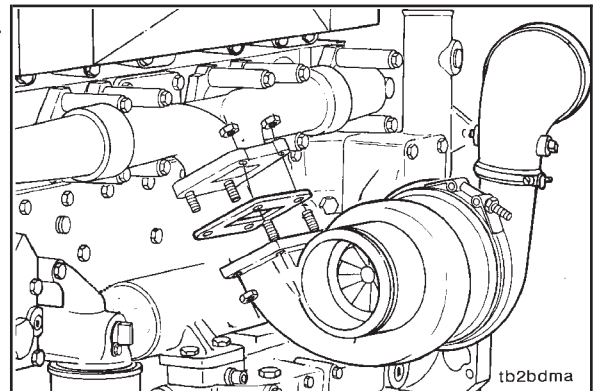
Record this clearance.

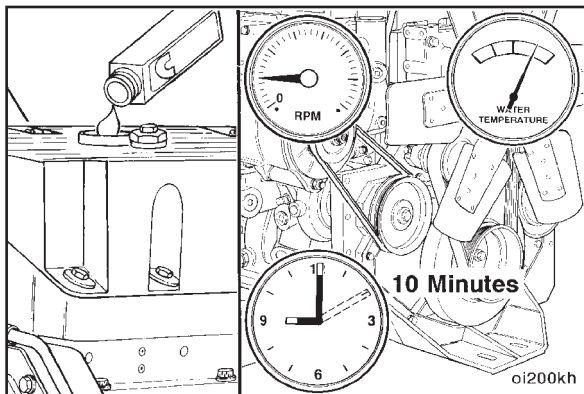


Subtract the smaller clearance from the larger clearance. This is the radial bearing clearance.

Radial Bearing Clearance		
mm		in
0.15	MIN	0.006
0.64	MAX	0.025

Replace the turbocharger if the radial bearing clearance does **not** meet the specifications. Refer to Procedure 010-033 for the replacement procedure.



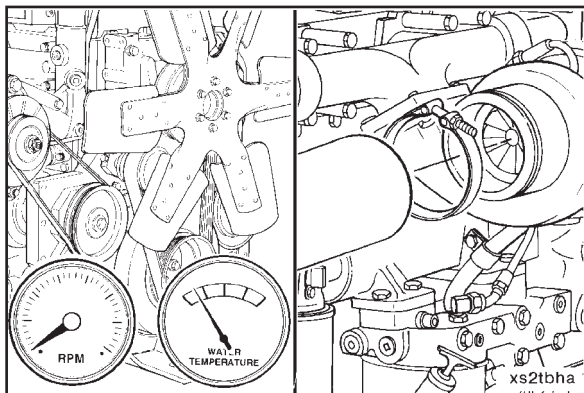


Turbocharger Turbine Seal Leaks (010-049)

Leak Test (010-049-014)

Add one unit of fluorescent tracer, Part No. 3376891, to each 38 liters [10.0 U.S. gallons] of engine lubricating oil.

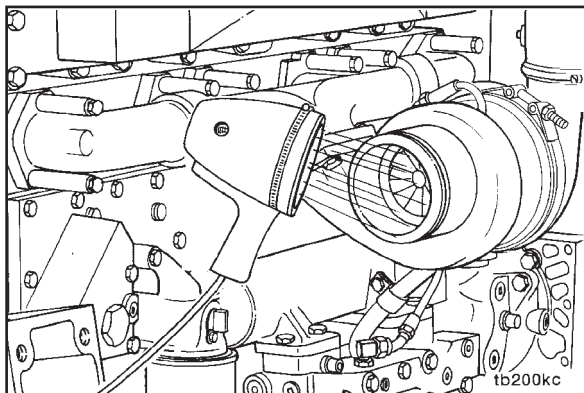
Operate the engine at low idle for 10 minutes.



Shut off the engine.

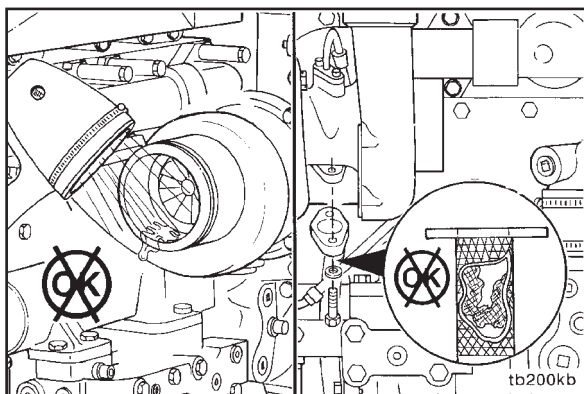
Allow the turbocharger to cool.

Remove the exhaust pipe from the turbine housing.



Use a high intensity black light, Part No. 3377253 or 3377394, to inspect the turbine outlet for leaks.

A dark blue glow indicates a fuel leak. Refer to Procedure 007-044. A yellow glow indicates an oil leak.



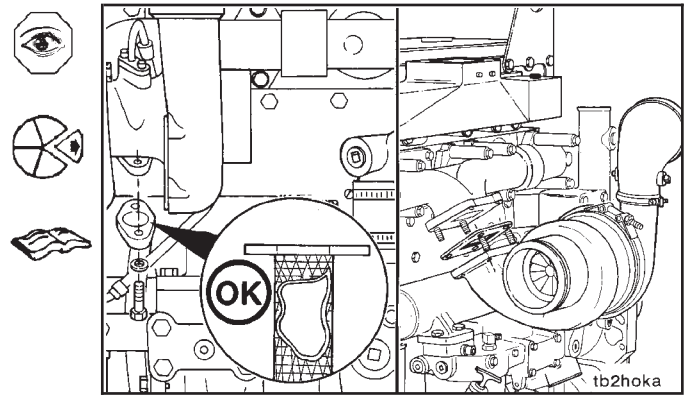
If oil is found on the turbine housing, remove the oil drain line and check for restrictions. Clear any restrictions found, or replace damaged components as required.



If the engine is equipped with a turbocharger oil drain fitting with a screen, remove the fitting and check to make sure the screen is clean.

M11 Series
Section 10 - Air Intake System - Group 10

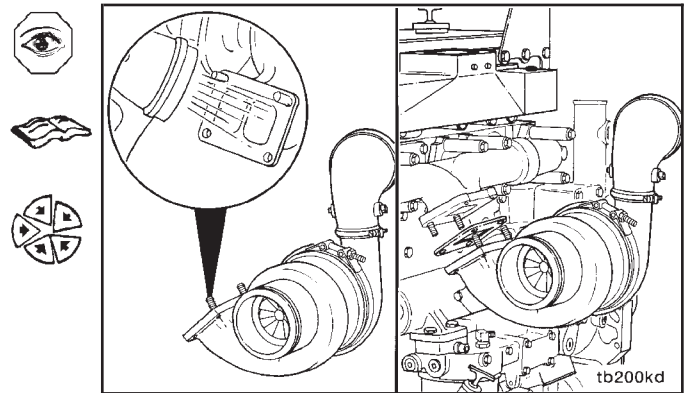
If the oil drain line is **not** restricted, remove the turbocharger. Refer to Procedure 010-033-002.



Use a high intensity black light, Part No. 3377253 or 3377394, to inspect the turbine inlet for leaks.

A yellow glow indicates an oil leak from the engine.

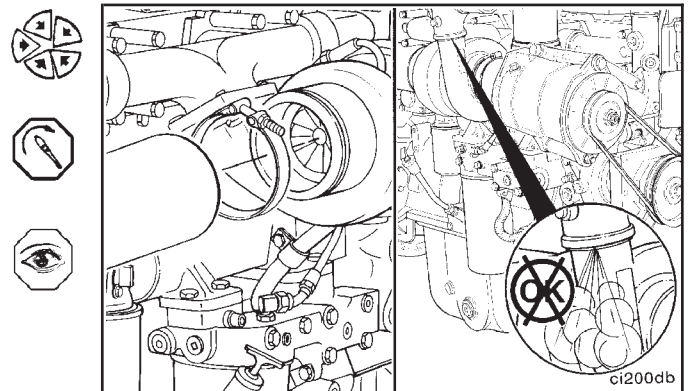
If a yellow glow is **not** seen in the turbine inlet, replace the turbocharger. Refer to Procedure 010-033.



Install the exhaust pipe to the turbocharger and tighten the clamp.

Torque Value: 8 N•m [72 in-lb]

Operate the engine and check for air leaks.



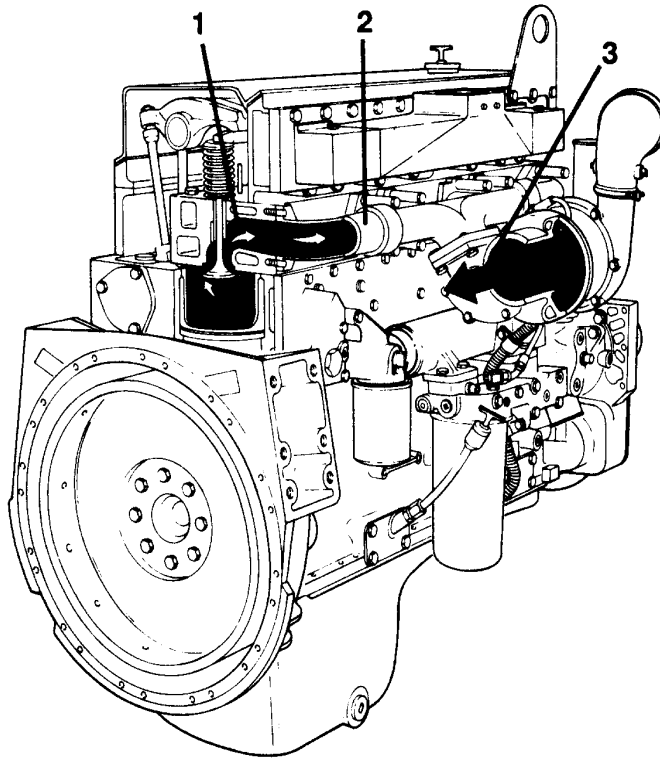
Section 11 - Exhaust System - Group 11

Section Contents

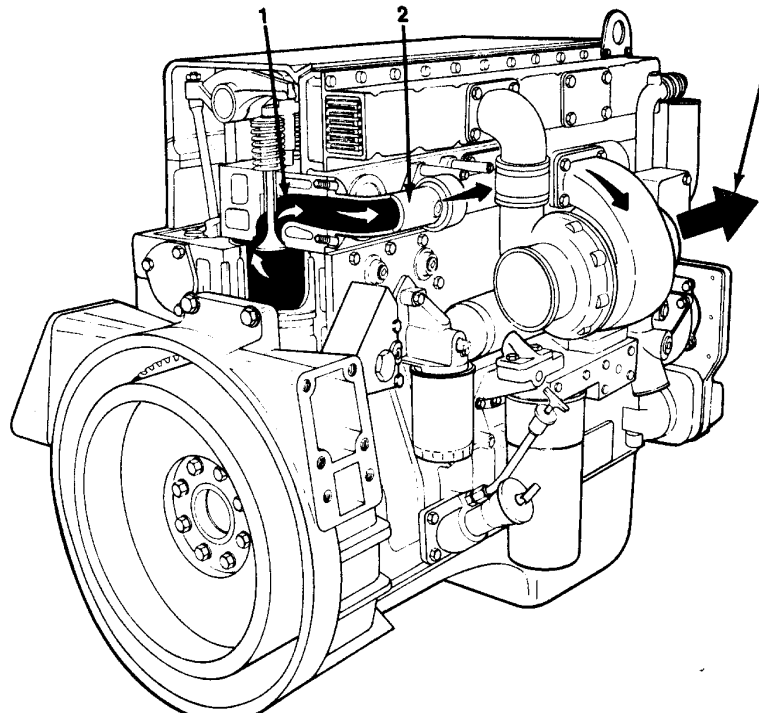
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Disassemble	11-3
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Install	11-4
Remove	11-3
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Flow Diagram, Exhaust System	11-1
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Flow Diagram, Exhaust System

- 1. Exhaust Valve Ports
- 2. Exhaust Manifold
- 3. Turbocharged Exhaust Outlet



- 1. Exhaust Valve Ports
- 2. Exhaust Manifold
- 3. Turbocharged Exhaust Outlet



Specifications

Exhaust System

Maximum Back Pressure at Turbocharger:

Without Catalyst

Hg 76 mm [3 in.]

H₂O 1016 mm [40 in.]

With Catalyst

Hg 152 mm [6 in.]

H₂O 2082 mm [82 in.]

Exhaust Pipe Size (Normally Acceptable Inside Diameter)

CELECT™ and CELECT™ Plus 127 mm [5 in.]

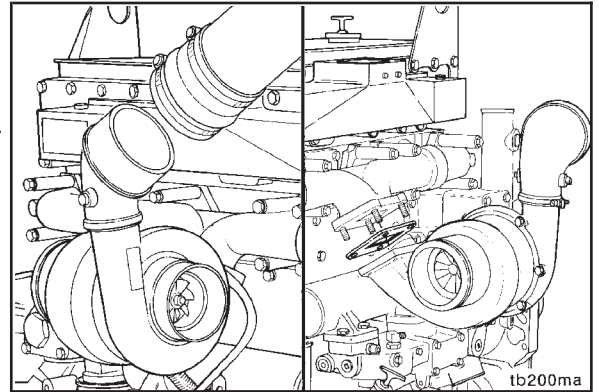
STC 102 mm [4 in.]

Exhaust Manifold, Dry (011-007)

Remove (011-007-002)

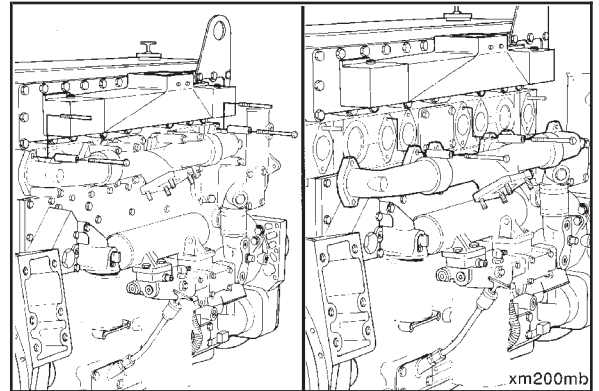
Remove the air piping from the turbocharger.

Remove the turbocharger. Refer to Procedure 010-033-002.



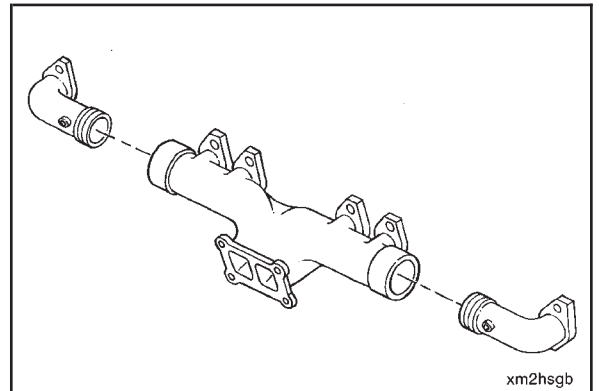
Remove two upper capscrews from the end sections of the exhaust manifold and install two guide studs, Part No. 3376488.

Remove the remaining capscrews, exhaust manifold assembly and gaskets.



Disassemble (011-007-003)

Remove the exhaust manifold end sections.



Clean (011-007-006)

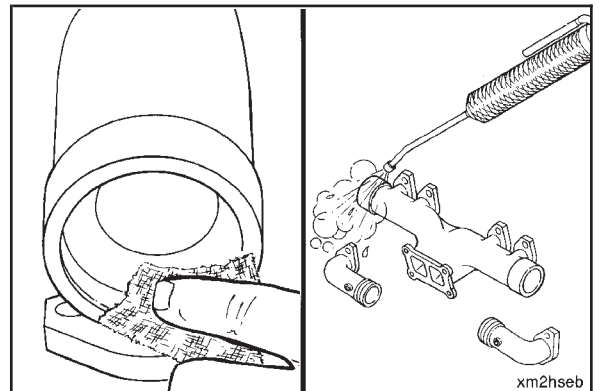
Use 240 grit emery cloth to remove carbon deposits from the sealing surfaces.

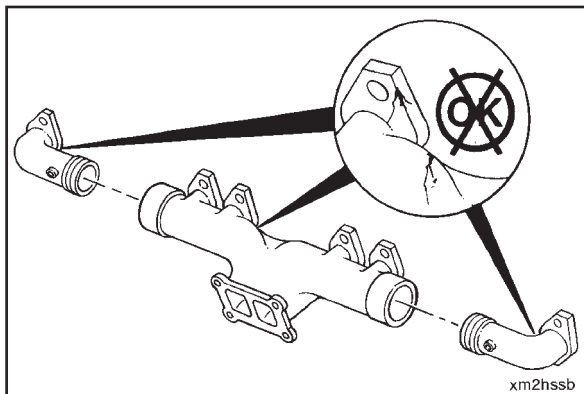


WARNING

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

Use steam to clean the exhaust manifold. Dry with compressed air.



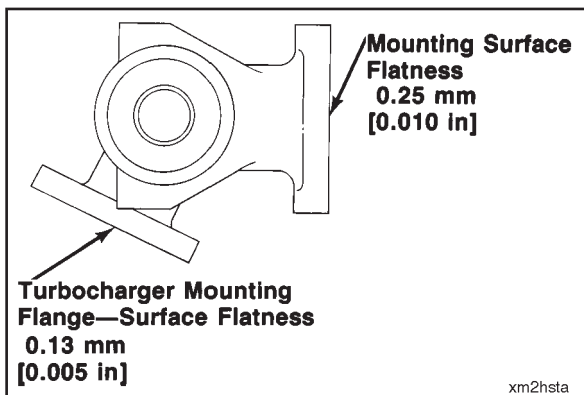


Inspect for Reuse (011-007-007)

Visually inspect the parts for cracks or damage.



NOTE: A charge air cooler failure can cause progressive damage to the exhaust manifold. If the exhaust manifold is damaged, check the charge air cooler. Refer to Procedure 010-027.

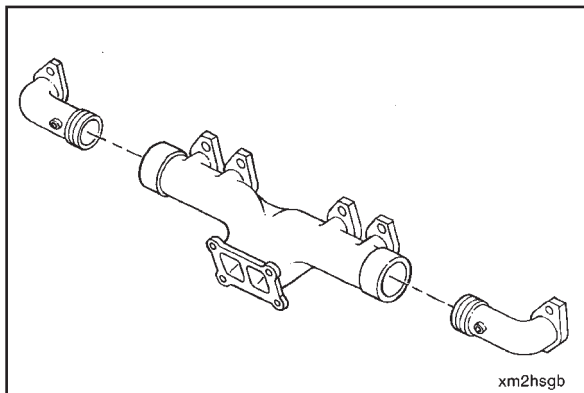


Inspect the mounting surfaces for flatness.

The exhaust manifold mounting surface **must** be flat to within 0.25 mm [0.010 inch]. The turbocharger mounting flange **must** have a surface flatness of 0.13 mm [0.005 inch].

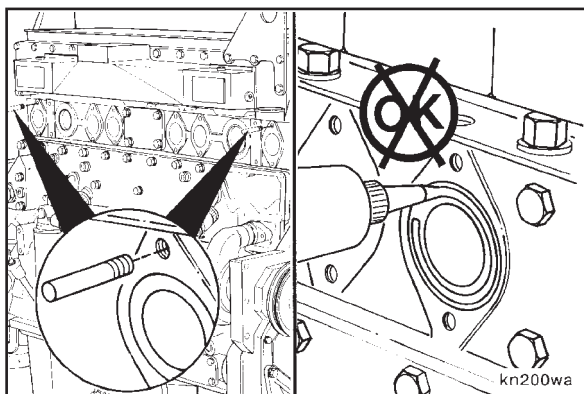


If these surfaces are **not** within the flatness specifications, refer to Alternative Repair Manual, Bulletin No. 3810310.



Assemble (011-007-025)

Install the exhaust manifold end sections to the center section.



Install (011-007-026)

Install two guide studs, Part No. 3376488, in the two top end holes of the cylinder head exhaust ports.

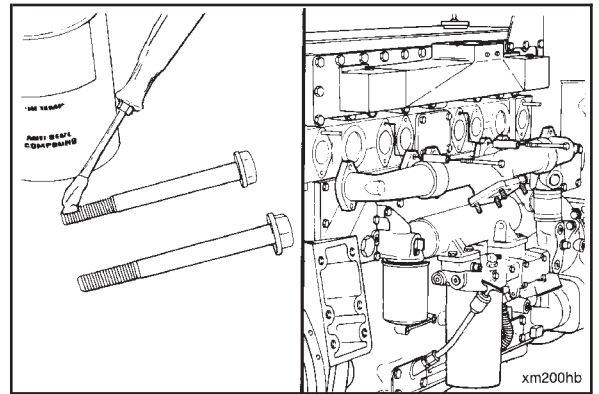
Install a new gasket over each guide stud.

Do **not** use any kind of adhesive to hold the gaskets.

To aid in future capscrew removal, apply a coating of high temperature anti-seize compound to the capscrew threads.

Install the exhaust manifold, tubular spacers, and capscrews.

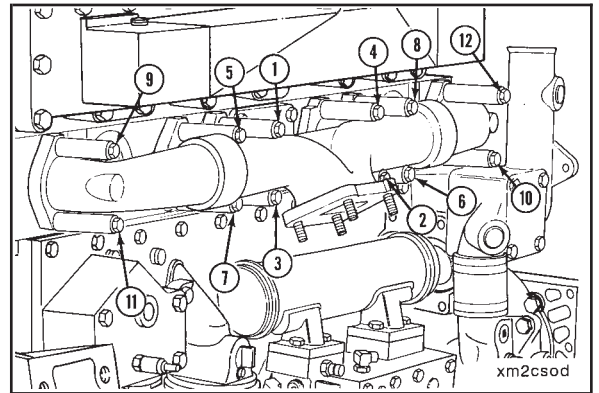
NOTE: The exhaust manifold can be titled back enough to install a new gasket on each exhaust port as the capscrews are being installed.



Tighten the capscrews in the sequence shown.

NOTE: The torque values given have been established using anti-seize compound as a lubricant.

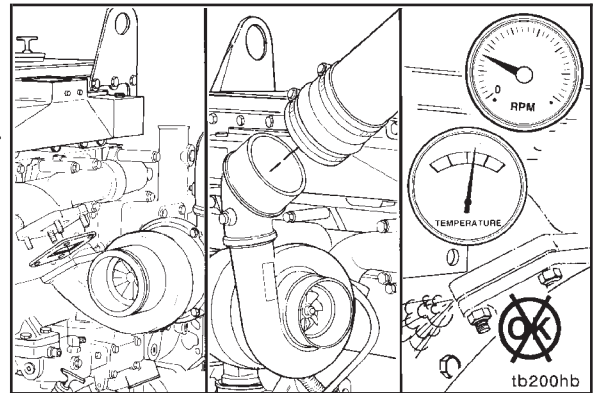
Torque Value: Step 1 27 N•m [20 ft-lb]
 Step 2 47 N•m [35 ft-lb]



Install the turbocharger. Refer to Procedure 010-033-026.

Install the air piping to the turbocharger. Refer to the manufacturer's specifications for the correct torque value.

Operate the engine to check for leaks.

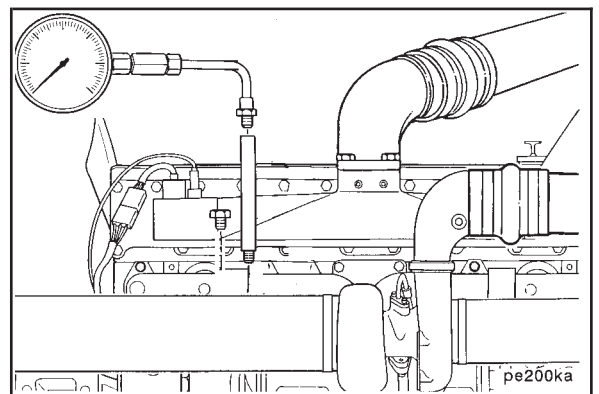


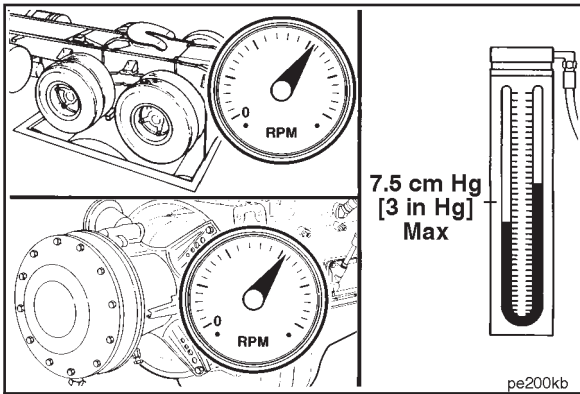
Exhaust Restriction (011-009)

Measure (011-009-010)

Connect a manometer or pressure gauge, Part No. ST-1273, in a straight section of the exhaust pipe located one pipe diameter from the turbine outlet.

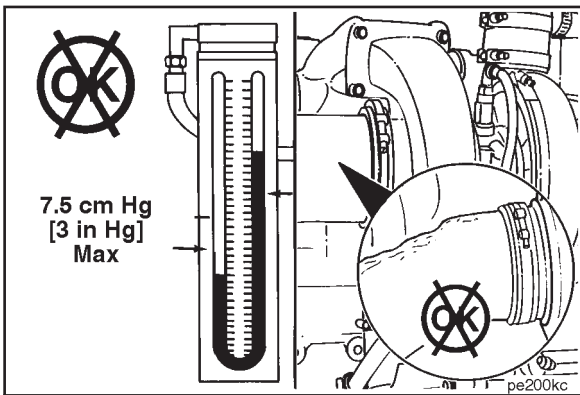
Protect the hose from heat by using a 305 mm [12 inch minimum] length of metal tubing leading from the exhaust pipe connection.



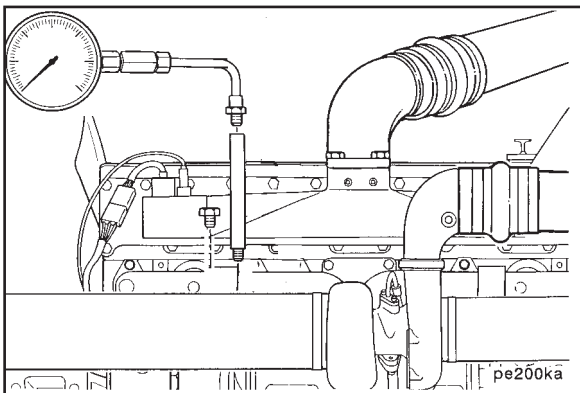


Operate the engine at rated rpm and load. Record the reading on the manometer.

Exhaust Restriction (Without Catalyst)			
	mm		in
Hg	75	MAX	3
H ₂ O	1016	MAX	40
Exhaust Restriction (With Catalyst)			
	mm		in
Hg	152	MAX	6
H ₂ O	2082	MAX	82



If exhaust pressure exceeds the specifications, visually inspect the exhaust piping for damage. Refer to the equipment manufacturer's repair instructions.



Remove the test equipment.

Section 12 - Compressed Air System - Group 12

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Compressed Air System - General Information

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

The Holset and Cummins single and two cylinder air compressors are engine-driven piston-type compressors which supply compressed air to operate air activated devices. The compressor runs continuously but has a loaded and unloaded operating mode.

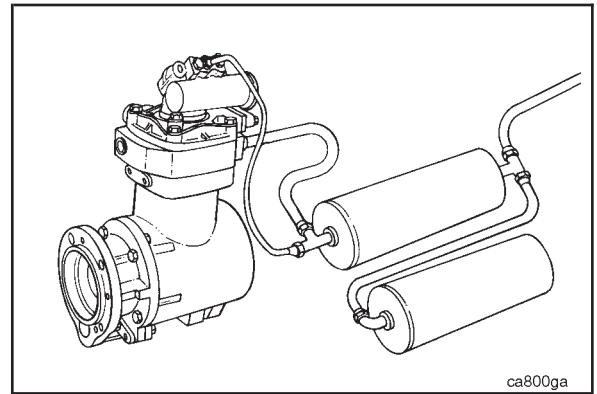
The operating mode is controlled by a pressure-activated governor and the compressor unloading assembly. When the air system reaches a predetermined pressure, the governor applies an air signal to the air compressor unloader assembly causing the unloader valve to hold the compressor intake valve open so compressed air stops flowing into the air system.

As the air in the air 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 air system.

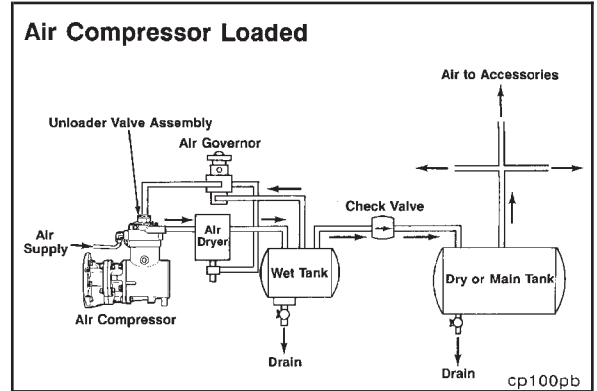
E-Type Air Compressor

Holset SS and ST model air compressors built with the E-Type unloader can be identified by the letter "E" (SS296E, SS338E, ST676E, and ST773E), and by the caution on the data plate.

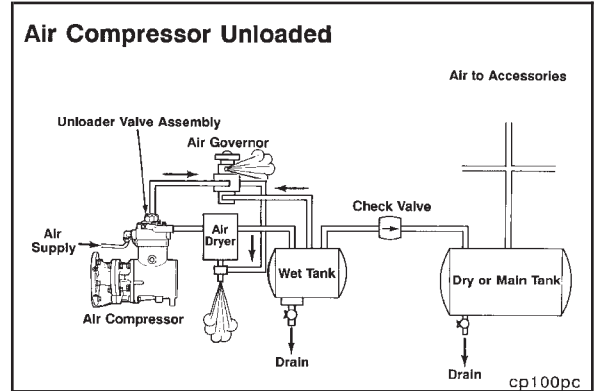
All QE (QE296 and QE338) model air compressors are equipped with the E-Type unloader.



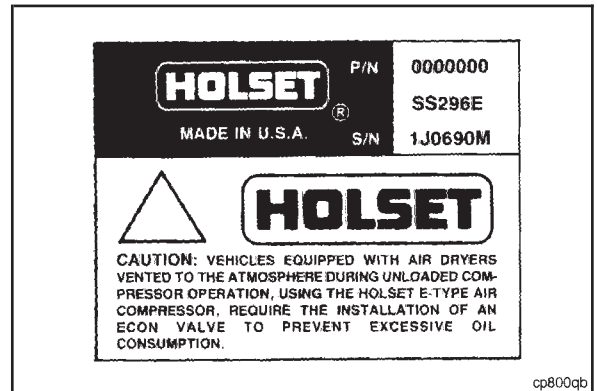
ca800ga



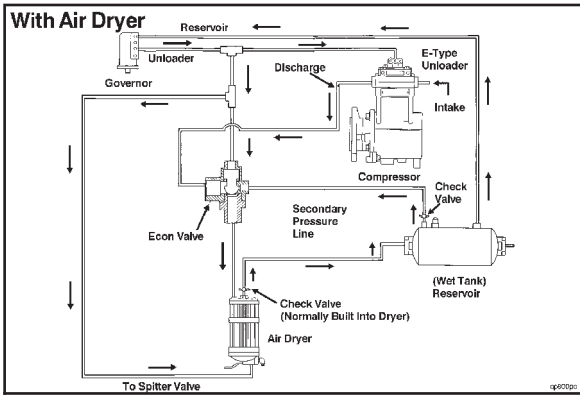
cp100pb



cp100pc



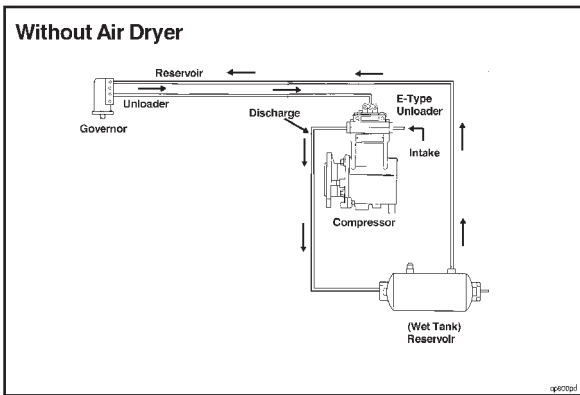
cp800qb



E-Type System With Air Dryer

Vehicles equipped with air dryers vented to the atmosphere during unloaded compressor operation, using the Holset E-Type air compressor, require the installation of an econ valve to prevent excessive oil consumption.

NOTE: Some air dryers can have a built in econ valve. Check with the manufacturer as to which type is installed.



E-Type System Without Air Dryer

Air systems **without** air dryers, or with air dryers **not** vented to the atmosphere during unloaded compressor operation, can use the Holset E-Type unloader valve without modifying the air system.

Specifications

Compressed Air System (018-001-207)

Holset® SS296/SS296E/QE296 A/C Models

Cylinders	1
Compressor Swept Volume @ 1250 RPM	6.2 L per sec. [13.20 CFM]
Piston Displacement	296 cc [18.06 C.I.D.]
Bore	92.08 mm [3.625 in.]
Stroke	44.45 mm [1.750 in.]
Speed	Engine Speed
Cooling	Engine Coolant
Lubrication	Engine Lubricating Oil
Plumbing Line Sizes	
Coolant Inlet and Outlet (Pipe Fitting)	0.375 in. NPTF
Air Inlet (Inside Diameter)	22.22 mm [0.875 in.]
Air Outlet (Minimum Inside Diameter)	12.7 mm [0.50 in.]
Height, Overall (Approximate)	31.1 cm [12.25 in.]
Width, Overall (Approximate)	14.6 cm [5.75 in.]
Length, Overall (Approximate)	22.9 cm [9.00 in.]
Weight (Approximate)	18 kg [40.0 lbs]

Holset® SS338/QE338 A/C Models

Cylinders	1
Compressor Swept Volume @ 1250 RPM	7.1 L per sec. [15.0 CFM]
Piston Displacement	338 cc [20.63 C.I.D.]
Bore	98.4 mm [3.875 in.]
Stroke	44.5 mm [1.75 in.]
Speed	Engine Speed
Cooling	Engine Coolant
Lubricating	Engine Lubricating Oil
Plumbing Line Sizes:	
Coolant Inlet and Outlet (Pipe Fitting)	0.375 in NPTF
Air Inlet	22.22 mm [0.875 in.]
Air Outlet	12.7 mm [0.50 in.]
Height, Overall (Approximate)	31.1 cm [12.25 in.]
Width, Overall (Approximate)	14.6 cm [5.75 in.]
Length, Overall (Approximate)	22.9 cm [9.00 in.]
Weight (Approximate)	18 Kg [40.0 lbs]

Holset® ST676 A/C Model


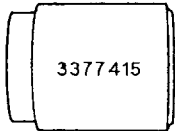
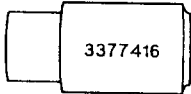
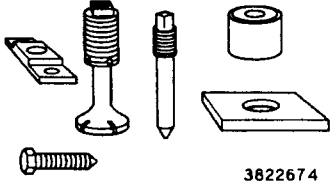
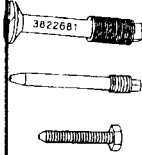
Cylinders	2
Compressor Swept Volume @ 1250 RPM	14.2 L per sec. [30.00 CFM]
Piston Displacement	676 cc [41.3 C.I.D.]
Bore	92.08 mm [3.625 in]
Stroke	50.8 mm [2.00 in]
Speed	Engine Speed
Cooling	Engine Coolant
Lubrication	Engine Lubricating Oil
Plumbing Line Sizes:	
Coolant Inlet and Outlet (Pipe Fitting)	12.70 mm NPTF [0.50 in. NPTF]
Air Inlet (Inside Diameter)	22.22 mm [0.875 in.]
Air Outlet (Minimum Inside Diameter)	15.88 mm [0.625 in.]
Height, Overall (Approximate)	34.3 cm [13.50 in.]
Width, Overall (Approximate)	17.8 cm [7.00 in.]
Length, Overall (Approximate)	28.7 cm [11.30 in.]
Weight (Approximate)	33.5 kg [74.50 lbs.]

NOTE: In applications where duty cycles average 10 percent or more, or air pressures are above 862 kPa [125 psi], use a discharge line with a minimum inside diameter of 19 mm [0.75 inch] to prevent carbon buildup. Examples of these applications are as follows: refuse trucks, pickup and delivery trucks, transit buses, and equipment with high accessory air usage.

Spring Part No.	Spring Use	Approx. Free Length mm [inch]	Number of Coils	Load Required to Compress Spring to Measurement Length			
				Wire Diameter mm [inch]	Measurement Length mm [inch]	Minimum kg [lb]	Maximum kg [lb]
128080	Exhaust Valve	17.02 [0.670]	3.0	2.03 [0.080]	7.11 [0.280]	3.6 [8.55]	4.7 [10.35]
190334	Intake Valve	12.70 [0.500]	2.8	1.58 [0.062]	7.11 [0.280]	0.35 [0.65]	0.5 [1.10]
150631	Unloading Valve (naturally aspirated) center unloading valve - twin	41.91 [1.650]	11.5	2.03 0.080	24.89 [0.980]	14.5 [32.00]	17.2 [38.00]
3023101	Unloading Valve (all turbocharged engines)	41.91 [1.650]	10.8	1.65 [0.065]	24.89 [0.980]	5.9 [13.00]	7.7 [17.00]
3049553	E-Type Unloader Valve	41.91 [1.650]	11.25	1.93 [0.076]	24.89 [0.980]	10.4 [23.00]	12.2 [27.00]
800399-XW	Unloader	17.02 [0.67]	6	1.04 [0.041]	6.60 [0.260]	N/A	2.54 [5.60]
					10.03 [3.95]	1.71 [3.78]	N/A
802000-FZ	Intake and Exhaust	10.16 [0.40]	4.25	0.79 [0.031]	4.57 [0.18]	N/A	0.36 [0.80]
					5.99 [0.275]	0.20 [0.45]	N/A
3054489	Exhaust Valve	21.49 [0.846]	4.5	2.54 [0.100]	15.21 [0.599]	3.88 [8.55]	4.74 [10.45]

Service Tools Compressed Air System

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

Tool No.	Tool Description	Tool Illustration
3375182	Spring Compression Tester Measures spring force at a given spring height	 <small>kn8togs</small>
3377415	Air Compressor Seat Installation Tool Used to install the air compressor seat.	 <small>3377415</small>
3377416	Air Compressor Seat Removal Tool Used to remove the air compressor seat.	 <small>3377416</small>
3822674	Exhaust Valve Seat Puller Used to pull the exhaust valve seat when the head is mounted to the air compressor.	 <small>3822674</small>
3822681	Two Cylinder Exhaust Valve Seat Puller Use in conjunction with Part No. 3822674 to remove exhaust valve seats from two cylinder air compressor.	

Air Compressor Carbon Buildup (012-003)

Initial Check (012-003-001)



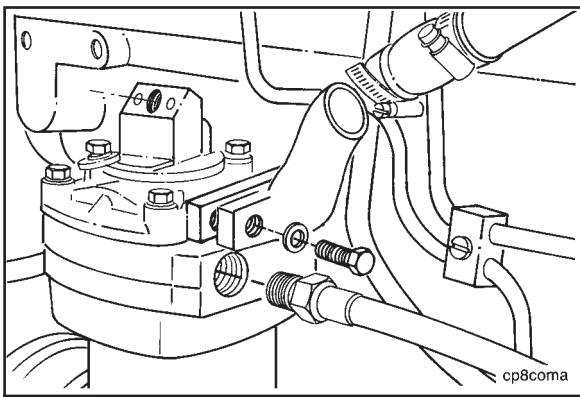
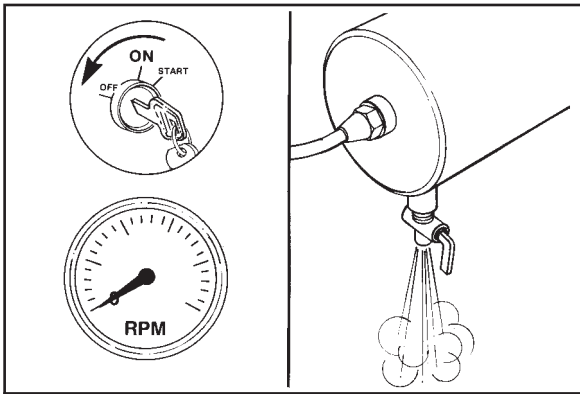
WARNING

Compressed air can drive debris into eyes and ears. Keep head well away and wear protective eye wear.

NOTE: The illustrations shown will be of the SS model single cylinder air compressor. Differences in procedures for SS, QE and ST model Holset air compressors will be shown where necessary.

Shut off the engine.

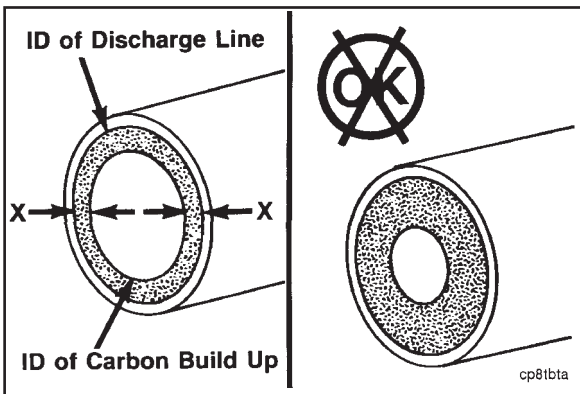
Open the drain cock on the wet tank to release compressed air from the system.



WARNING

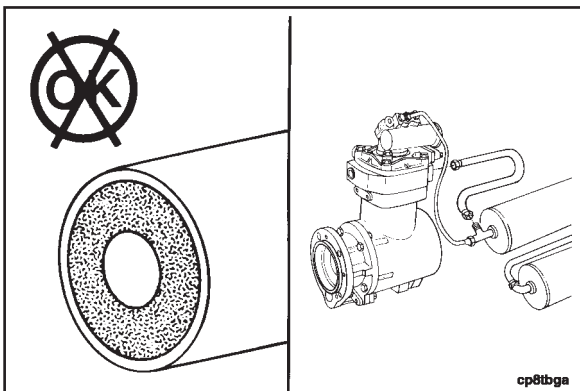
Air discharge lines can be very hot. Be sure the lines are cool before touching to prevent personal injury.

Remove the air inlet and outlet connections from the air compressor.



Measure the total carbon deposit thickness inside the air discharge line as shown.

NOTE: The carbon deposit thickness **must not** exceed 1.6 mm [0.06 (1/16)-inch].



WARNING

The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the manufacturer's specifications.



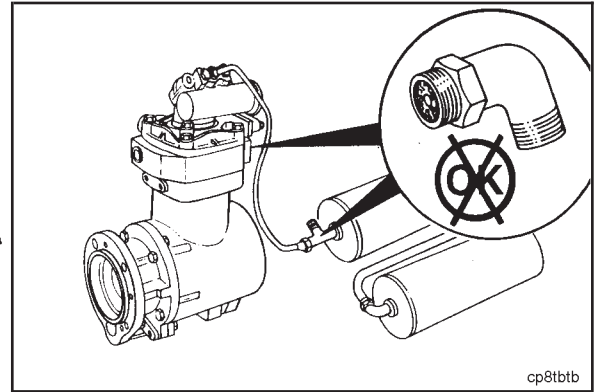
NOTE: If the total carbon deposit thickness exceeds specification, remove and clean, or replace the air discharge line. Refer to the manufacturer's material specifications.

▲ WARNING ▲

The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the manufacturer's specifications.

Continue to check for carbon buildup in the air discharge line connections up to the first connection, or wet tank.

Clean or replace any lines and fittings with carbon deposits greater than 1.6 mm [0.06 (1/16)-inch]. Refer to the manufacturer's specifications for cleaning or replacement instructions.



▲ CAUTION ▲

Do not use a sharp object to remove carbon. The sealing surfaces can be damaged.

Remove the air compressor head and valve assembly. Refer to Air Compressor Cylinder Head, Procedure 012-101, 012-103, 012-104, or 012-106.

NOTE: Not all air compressors referenced may be used on your engine or application.

▲ CAUTION ▲

Do not use caustic cleaners on aluminum parts.

Clean the compressor head and valve assembly components with solvent and a nonmetallic brush to remove carbon.

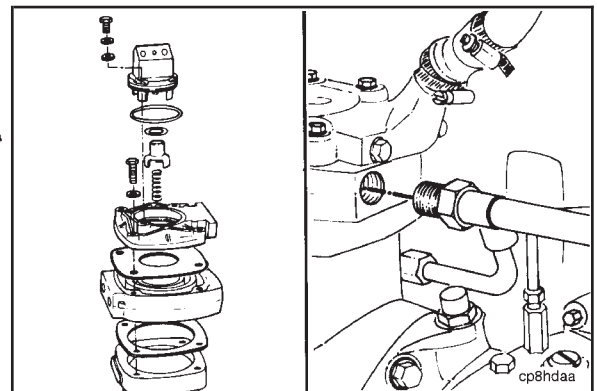
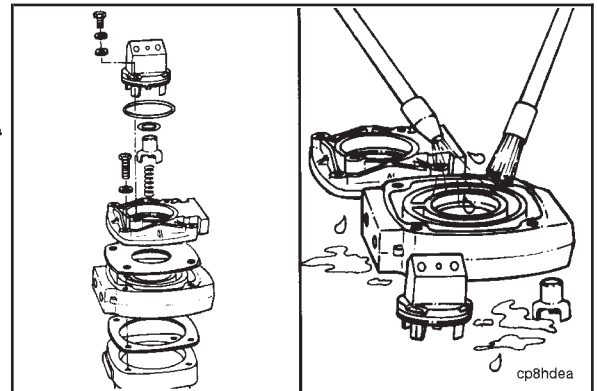
Inspect the valve assembly components for reuse. Refer to Air Compressor Cylinder Head, Procedure 012-101, 012-103, 012-104, or 012-106.

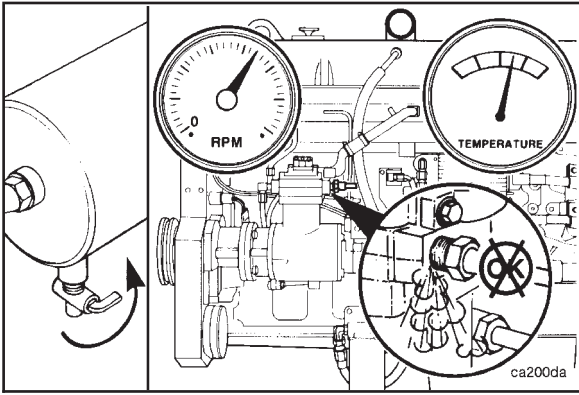
NOTE: Not all air compressors referenced may be used on your engine or application.

Assemble the air compressor using new gaskets and o-rings. Refer to Air Compressor Cylinder Head, Procedure 012-101, 012-103, 012-104, or 012-106.

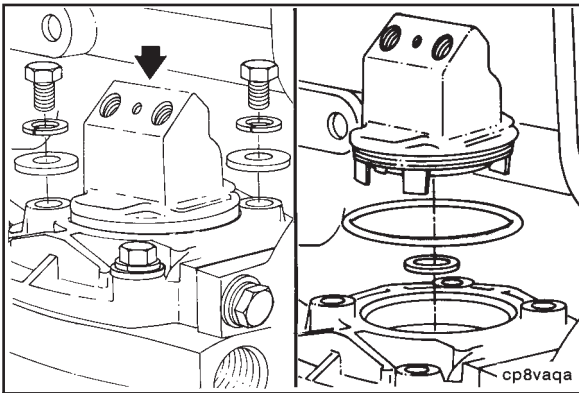
NOTE: Not all air compressors referenced may be used on your engine or application.

Install and tighten the air inlet and outlet connections.





Close the wet tank drain cock.
Operate the engine and check for air leaks.



Air Compressor Pin Bore Wear (012-010)

Initial Check (012-010-001)

NOTE: This procedure applies to SS and ST models only.

⚠ WARNING ⚠

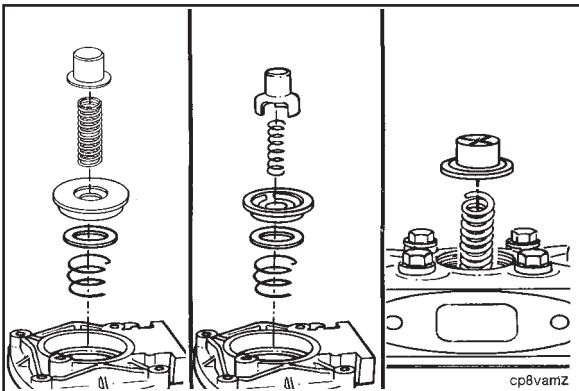
The unloader valve body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eye wear.

Hold the unloader valve body down and remove the two captive washer capscrews and the two plain washers.

Remove the unloader valve body.

Remove the o-ring seal.

Remove the rectangular ring seal.



Remove the unloader valve cap and the unloader valve spring.

NOTE: Disassembly of the center unloader valve on Holset two cylinder air compressors is similar to the single cylinder unloader valve.

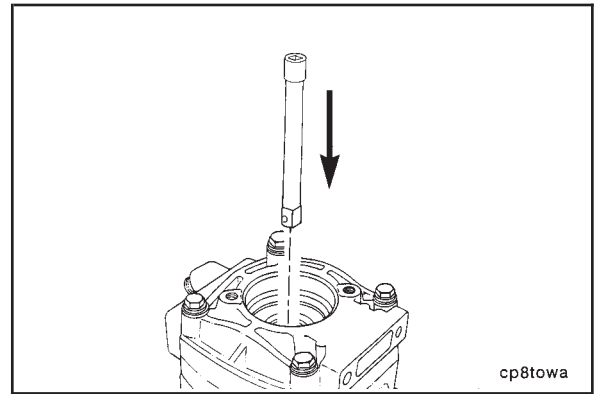
Remove the intake valve seat and valve.

Remove the intake valve spring.

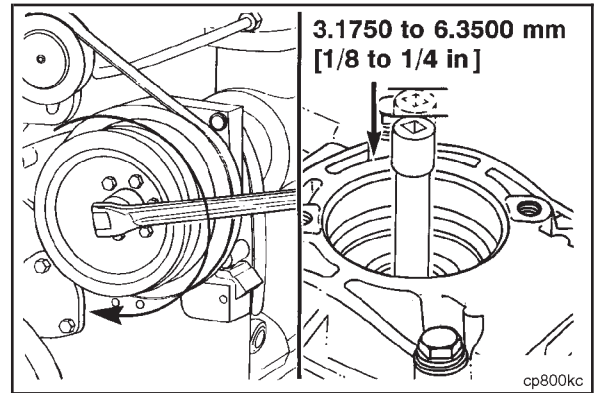
To avoid damage to the air compressor, do **not** allow any debris to fall into the air compressor cylinder.

NOTE: Do **not** use a screwdriver. A screwdriver can gouge the top of the piston.

Insert the small end of a 3/8 inch drive socket extension (6 to 10 inches long) through the exhaust valve seat onto the top of the piston.

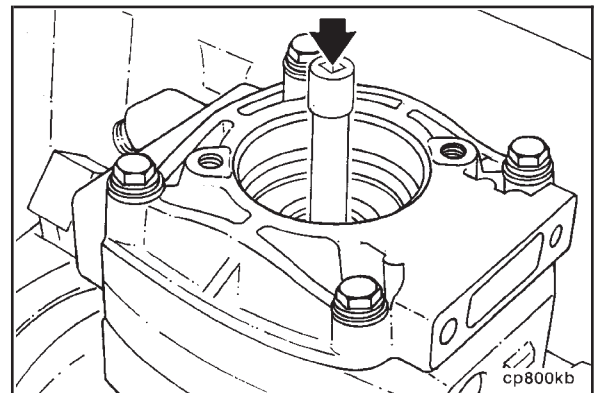


Bar the crankshaft over until the compressor piston reaches top dead center (TDC), and the extension starts to move downward approximately 3 to 6 mm [1/8 to 1/4 inch].

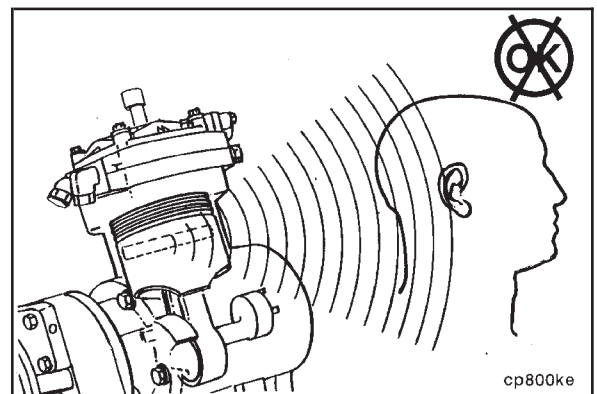


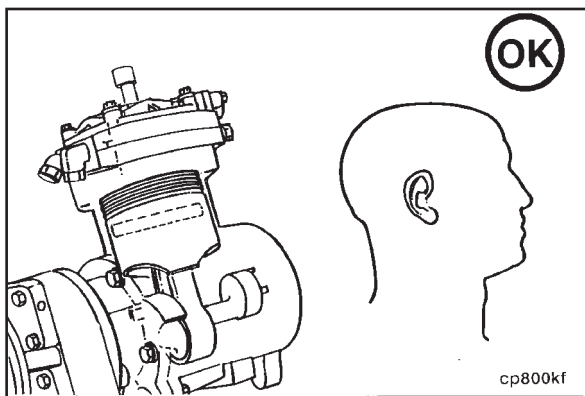
NOTE: To prevent damage to the top of the piston, do **not** use a hammer.

Give a quick hard push downward on the extension and listen for a metallic click as wear clearance is taken up.



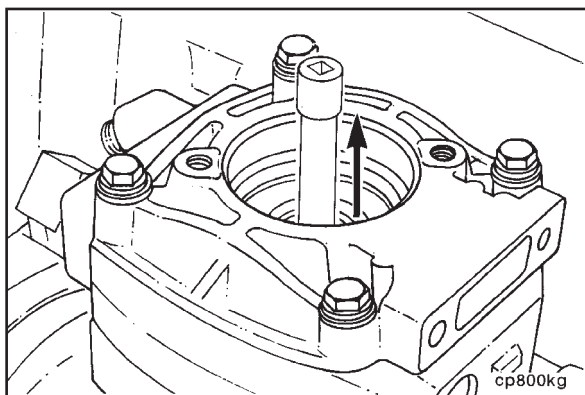
If significant piston motion is felt or a metallic click is heard, the pin bores can be worn, and the compressor **must** be examined further.



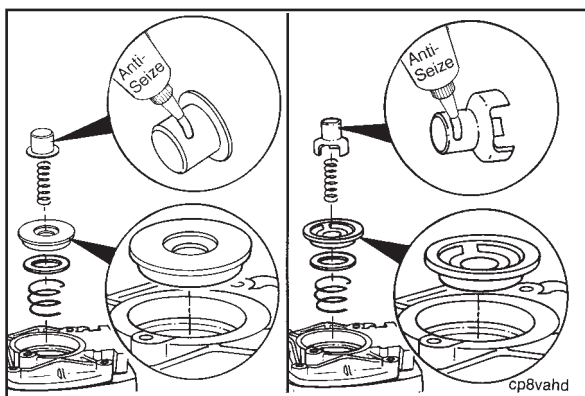


If no motion or sound is heard, the compressor is in satisfactory condition and does **not** need to be replaced.

NOTE: Not all air compressors will exhibit pin bore wear.



Remove the extension.



Install the intake valve spring with the tang down.

Install the intake valve.

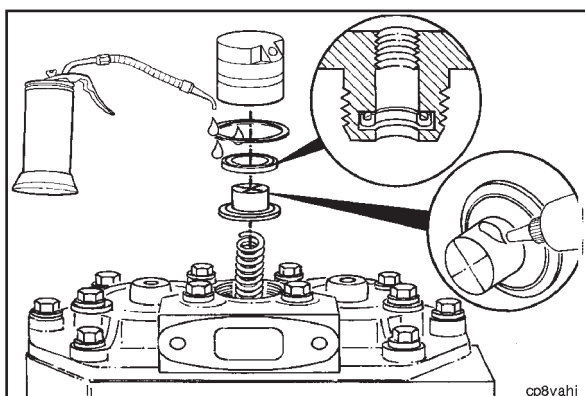
Install the intake valve seat with the flange side up.



Install the unloader valve cap spring.

Install the unloader valve cap.

Use high temperature grease (Accrolube Lubrication Teflon Grease or equivalent) to lubricate the outside diameter of the cap.



NOTE: The rectangular ring seal **must** be installed with the grooved side up.

Install the rectangular ring seal.



Install the o-ring seal.

Use clean engine oil to lubricate the o-ring seal.

Install the unloader valve body.

NOTE: Press the unloader valve body down to be sure the tangs of the unloader valve cap are in the three slots of the intake valve seat.

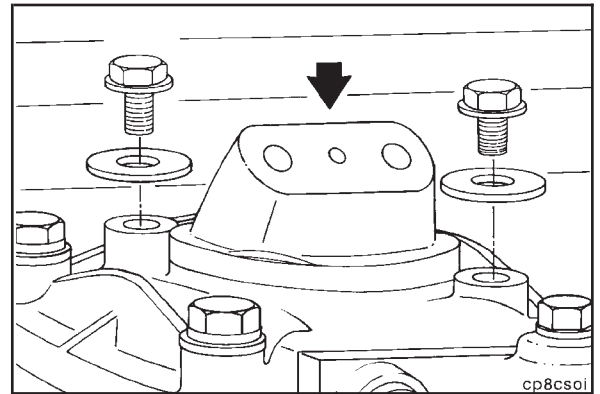
CAUTION

Do not overtorque. Compressor damage will result.

Hold the unloader body down and install the two plain washers and captive washer capscrews.

Tighten the capscrews.

Torque Value: 14 N•m [10 ft-lb]



Air Compressor Unloader and Valve Assembly (012-013)

Initial Check (012-013-001)

WARNING

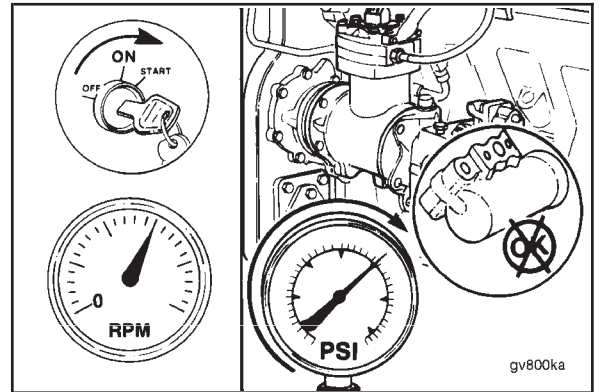
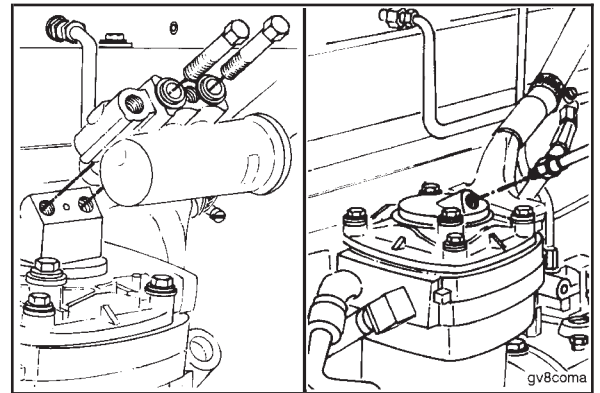
Air pressure must be released from system before removing the air governor.

NOTE: The illustrations shown will be of the SS model single cylinder air compressor. Differences in procedures for SS, QE and ST model Holset air compressors will be shown where necessary.

Remove the air governor or air governor hose from the air compressor unloader body.

Operate the engine to activate the air compressor.

If the air compressor is **not** pumping, the unloader valve is malfunctioning, and **must** be repaired or replaced.



Remove (012-013-002)

Holset SS, E-Type, and ST Models

WARNING

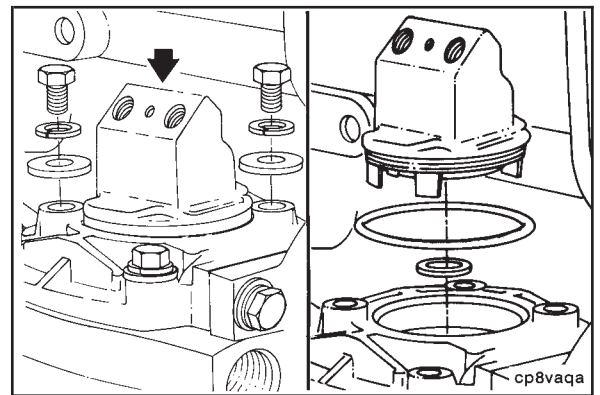
The unloader valve body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eye wear.

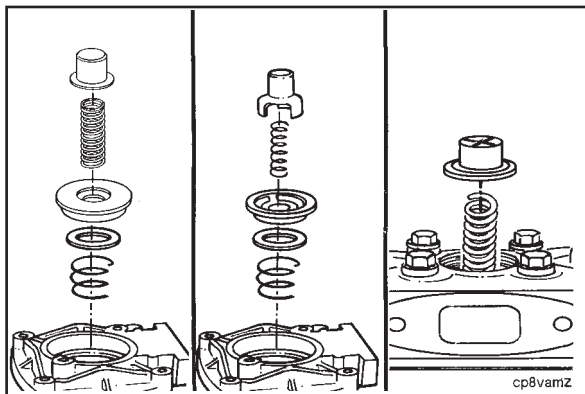
Hold the unloader valve body down and remove the two captive washer capscrews and the two plain washers.

Remove the unloader valve body.

Remove the o-ring seal.

Remove the rectangular ring seal.



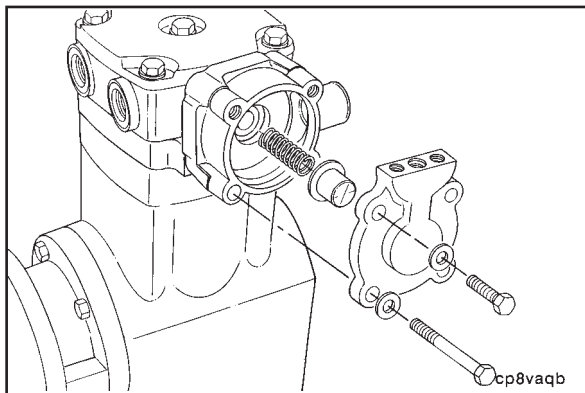


Remove the unloader valve cap and the unloader valve spring.

NOTE: Disassembly of the center unloader valve on Holset two cylinder air compressors is similar to the single cylinder unloader valve.

Remove the intake valve seat and valve.

Remove the intake valve spring.



Holset QE Models

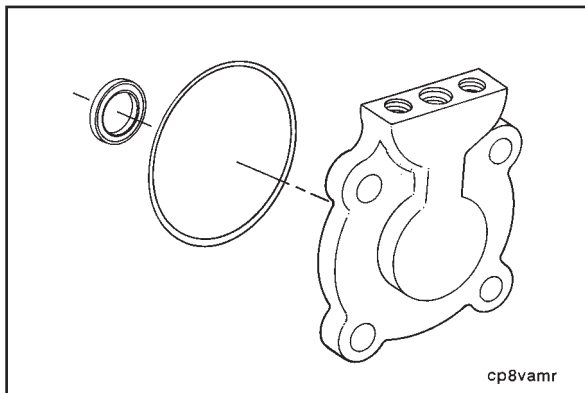
▲ WARNING ▲

The unloader body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eye wear.

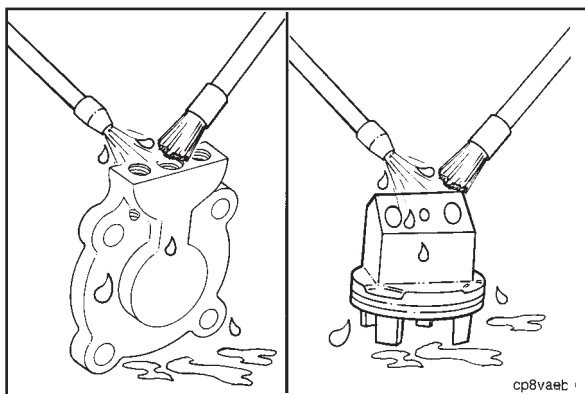
Hold the unloader valve body down and remove the four capscrews.

Remove the unloader valve spring.

Remove the unloader valve cap.



Remove the unloader body gasket and unloader valve cap rectangular ring seal.



Clean (012-013-006)

▲ CAUTION ▲

Do not use caustic cleaners.

Remove all carbon and varnish from the unloader valve cap body.

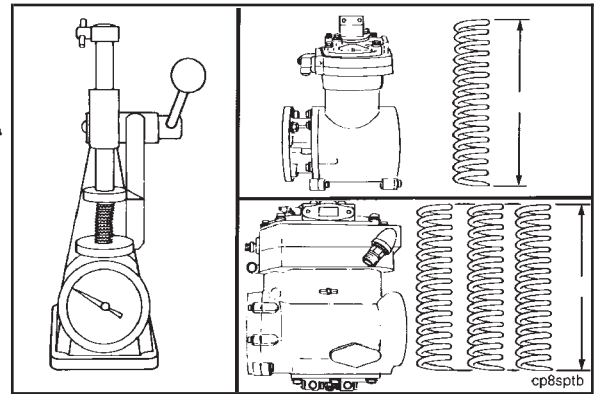
Inspect for Reuse (012-013-007)

Use a valve spring tester to check the unloader spring.

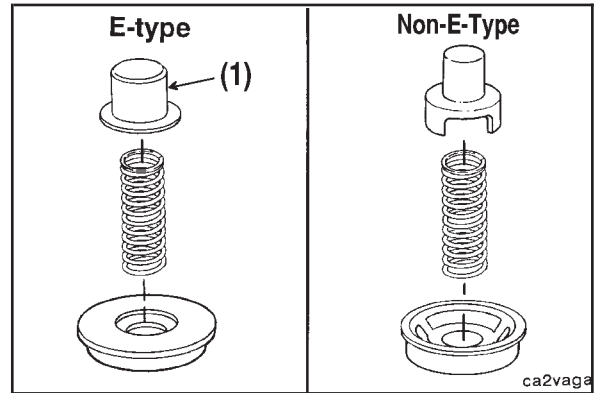
Refer to the Compressor Spring Force Specifications chart shown at the beginning of this section.

Replace the unloader spring if it does **not** meet the specifications shown, or the wrong spring has been used.

NOTE: For Holset two cylinder air compressors, check both cylinder and center unloader springs. Holset Engineering Co., Inc., recommends that new springs be installed during rebuild.



NOTE: If the compressor has a flat hat type unloader cap (1), it **must** use an unloader spring and valve seat different than that used with the three prong unloader.



Install (012-013-026)

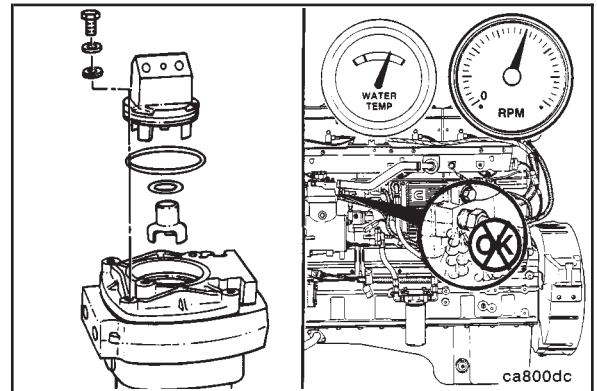
Holset SS, E-Type, and ST Models

Assemble the air compressor.

- Grease rectangular ring seal, unloader cap and unloader body bore with high temperature grease (Accrolube Lubrication Teflon Grease or equivalent)

Torque Value: 14 N•m [10 ft-lb]

Operate the engine and check the compressor for air leaks.

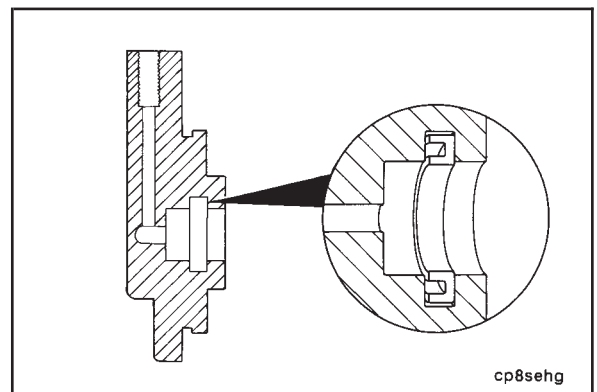


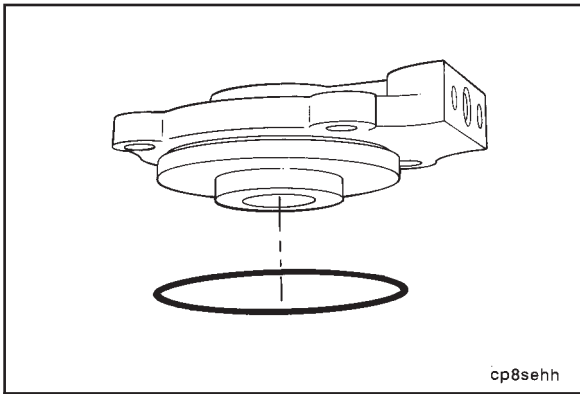
Holset QE Models

Install the new rectangular vee seal into the unloader body.

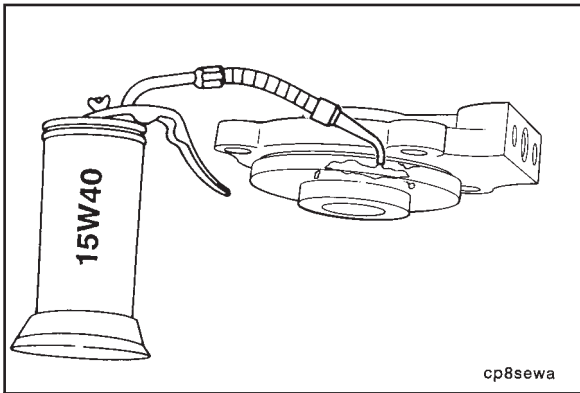
NOTE: The seal **must** be installed with the grooved side up.

Liberally lubricate the unloader valve bore above and below the rectangular ring seal with high temperature grease. (Accrolube Lubrication Teflon Grease or equivalent.)

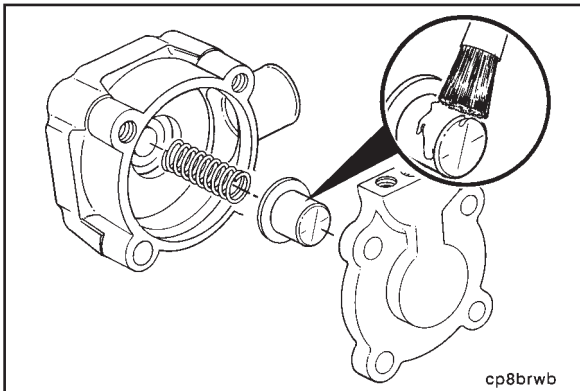




Install a new o-ring seal on the unloader valve body.



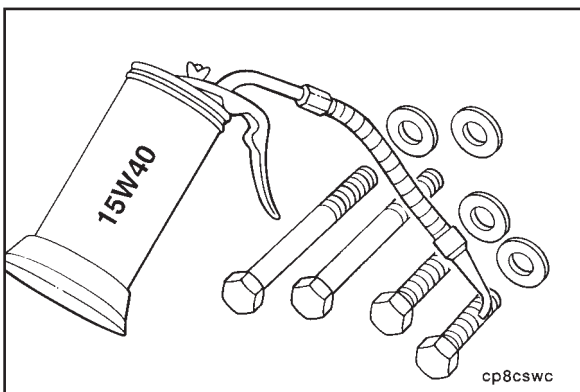
Use clean 15W40 oil or Accrolube Lubrication Teflon Grease (or equivalent) to lubricate the seal.



Liberaly lubricate the unloader valve body bore and unloader cap with high temperature grease (Accrolube Lubrication Teflon Grease or the equivalent).

Install the unloader cap.

Install the unloader spring.



Lubricate the unloader screw threads and underhead with clean engine oil (SAE 15W40), before installation.



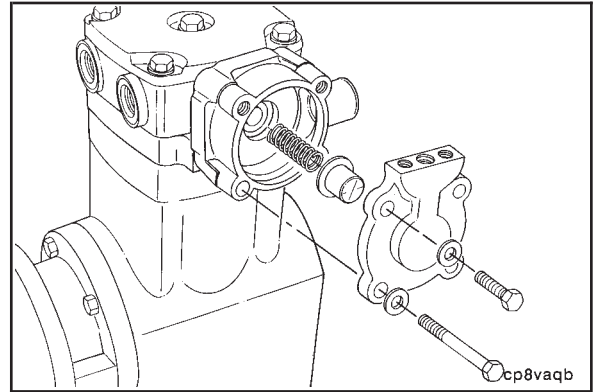
NOTE: The two unloader body screws **must not** be used to attach any brackets.

Assemble the unloader components and attach the unloader assembly to the valve plate with the four capscrews and washers.

NOTE: The longer capscrews are used to mount the manifold to the air compressor.

Torque Value: 27 N•m [20 ft-lb]

Operate the engine and check the air compressor for air leaks.



Air Compressor (012-014)

Remove (012-014-002)



WARNING

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

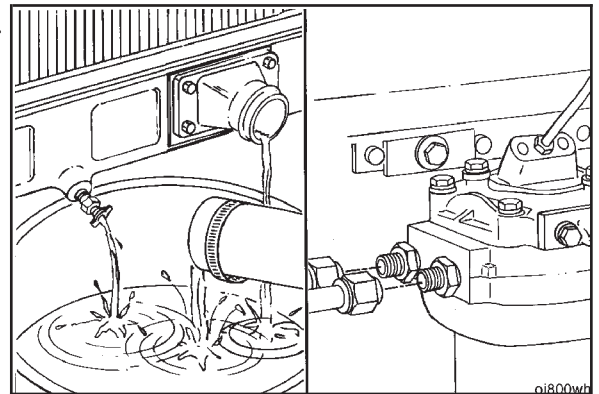
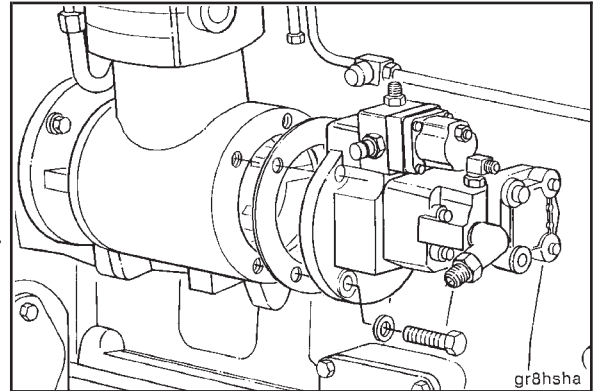
NOTE: The illustrations shown will be of the SS model single cylinder air compressor. Differences in procedures for SS, QE and ST model Cummins air compressors will be shown where necessary.

Use steam to clean the air compressor. Dry with compressed air.

Remove the fuel pump. Refer to Procedure 005-016-002.

Drain the engine coolant. Refer to Procedure 008-018-005.

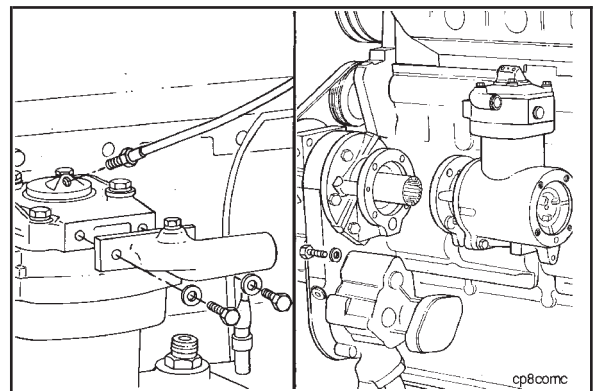
Remove the coolant lines from the air compressor.

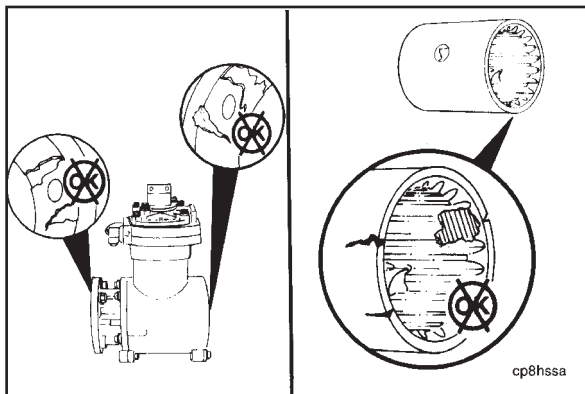


Remove the air connections from the air compressor.

Remove the air compressor support bracket and capscrews.

Remove the four capscrews, the air compressor, and splined coupling.

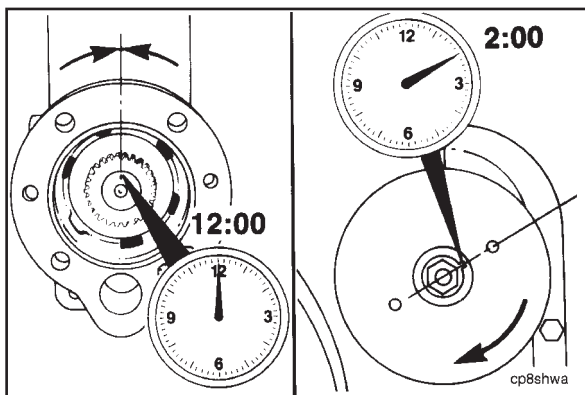




Inspect for Reuse (012-014-007)

Visually inspect the compressor housing for cracks or damage.

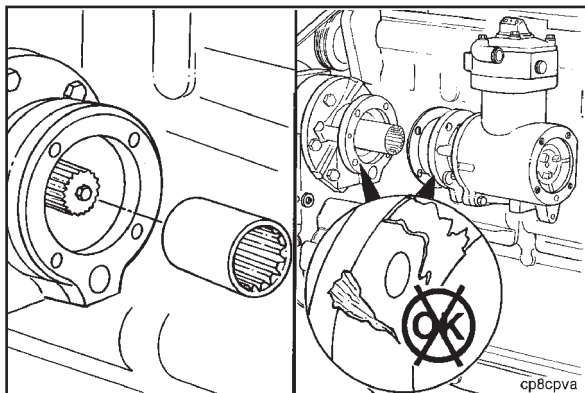
Visually inspect the splined coupling for cracks or damage.



Install (012-014-026)

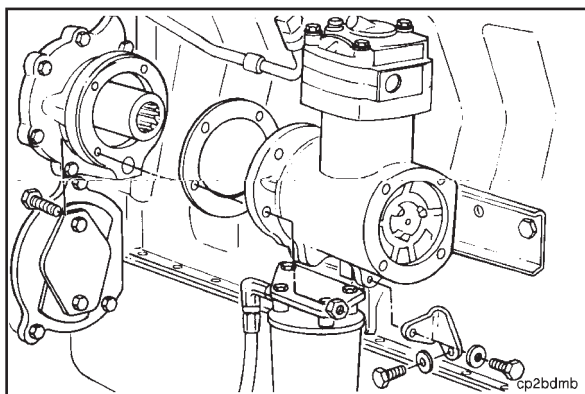
Position the timing mark on the air compressor crankshaft at the 12:00 o'clock position.

Position the accessory drive shaft dowel pin at the 2:00 o'clock position as viewed from the front of the engine.



Install the splined coupling on the accessory drive shaft.

Be sure the gasket surfaces of the accessory drive and air compressor are clean and **not** damaged.



Use a new gasket to install the air compressor and four capscrews to the accessory drive.

Torque Value: 68 N•m [50 ft-lb]

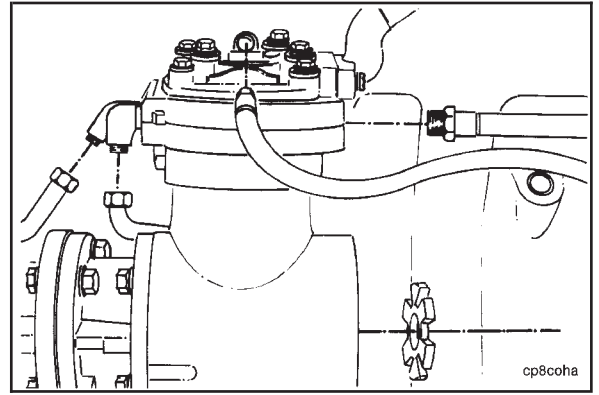
Install the air compressor support bracket.

Torque Value: 47 N•m [35 ft-lb]

NOTE: If rubber grommets are used on the coolant lines, be sure they are installed carefully to prevent cuts or tears to the grommets which will cause coolant leaks. When flexible tubing is used make sure that it does **not** rub any other surfaces.

Install the coolant and air lines to the air compressor and tighten.

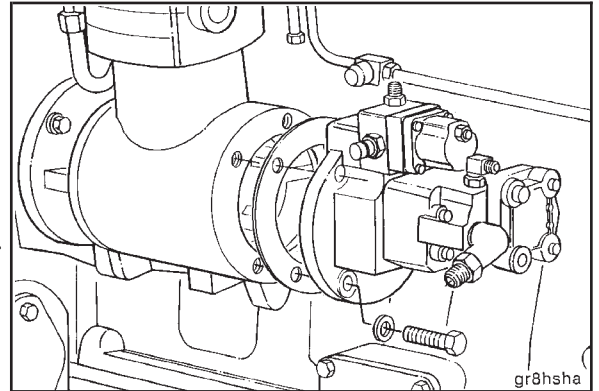
Install the fuel pump drive coupling on the air compressor.



Be sure the gasket surfaces of the air compressor and fuel pump are clean and **not** damaged.

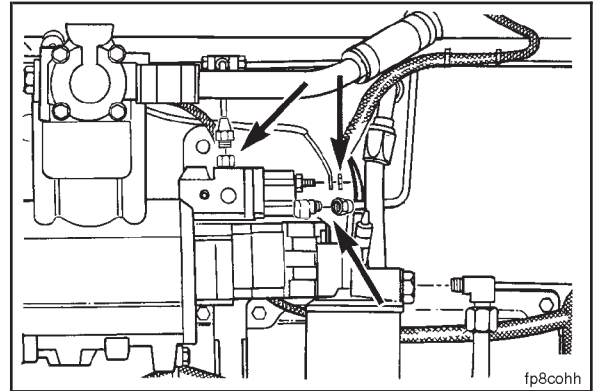
Use a new gasket when installing the fuel pump to the air compressor.

Install the fuel pump. Refer to Procedure 005-016-026.



Install all fuel tubing to the fuel pump and tighten.

Connect the electrical wiring to the fuel pump.



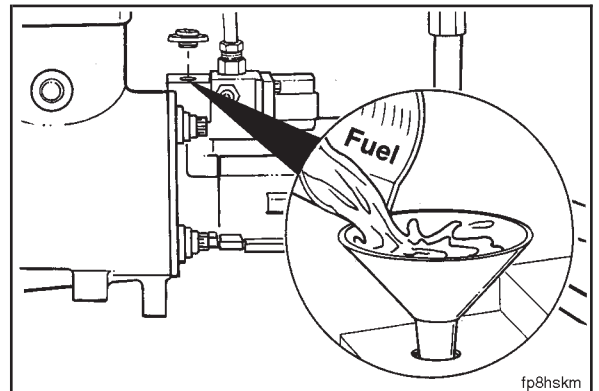
Whenever the fuel pump is removed, it is necessary to prime the pump after installing it on the engine to remove any trapped air.

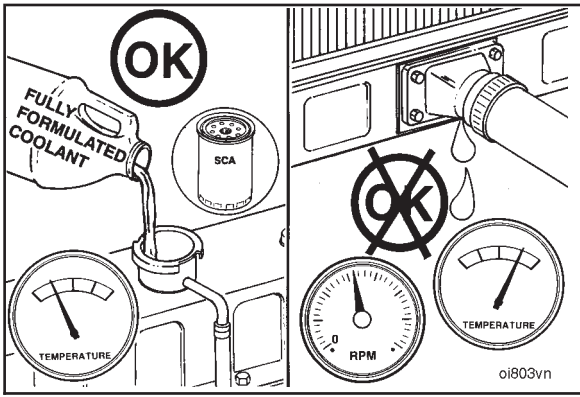
NOTE: If the fuel pump is dirty, clean the outside of the pump.

Remove the filter cap from the top of the front support.

Fill the housing with clean fuel. Install and tighten the filter cap.

Torque Value: 18 N•m [13 ft-lb]

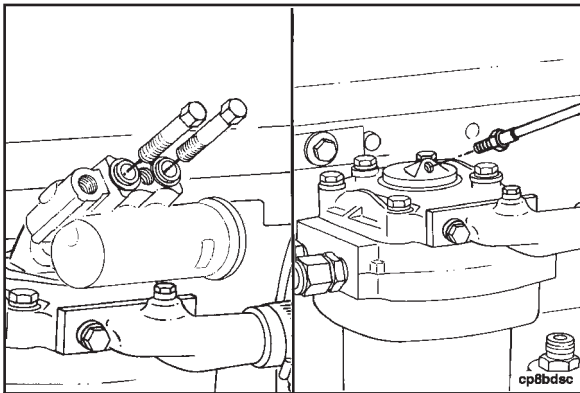




Fill the engine cooling system. Refer to Procedure 008-018-028.



Operate the engine and check for leaks.

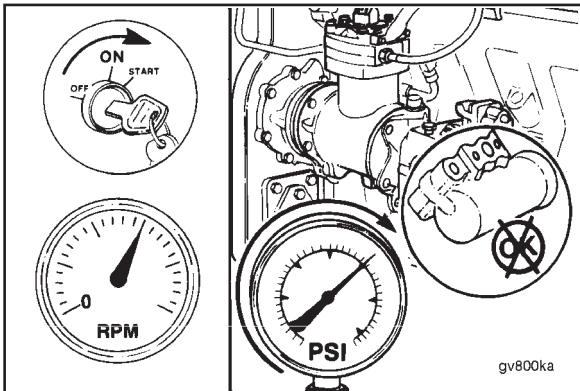


Air Governor (Air Compressor Will Not Pump) (012-017)

Initial Check (012-017-001)

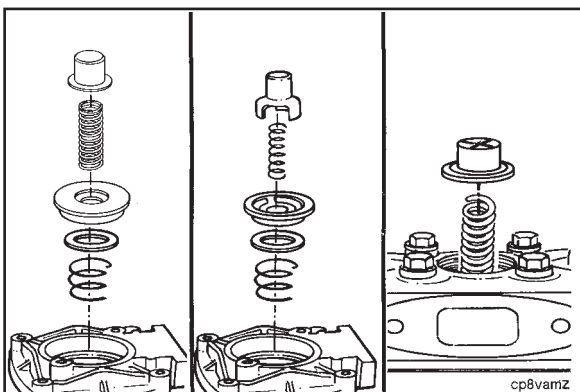
NOTE: The illustrations shown will be of the SS model single cylinder air compressor. Differences in procedures for SS, QE and ST model Holset air compressors will be shown where necessary.

Remove the air governor or air governor line from the air compressor unloader body.



Operate the engine to activate the air compressor.

If the air compressor is pumping, the air governor is malfunctioning and **must** be repaired or replaced. Refer to the manufacturer's instructions.



If the air compressor does **not** pump, remove, clean, and inspect the air compressor unloader valve assembly. Refer to Air Compressor Unloader Valve, Procedure 012-013.



If the unloader valve assembly is okay, clean and inspect the exhaust valve assembly. Refer to Air Compressor Cylinder Head, Procedure 012-101, 012-103, 012-104, or 012-106.



NOTE: Not all air compressors referenced may be used on your engine or application.

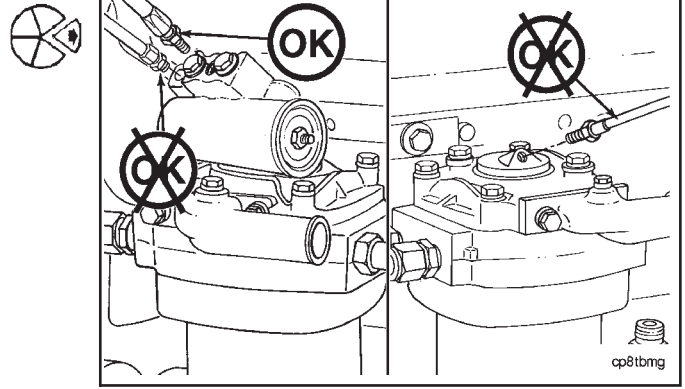


Air Governor (Air Compressor Pumps Continuously) (012-018)

Initial Check (012-018-001)

NOTE: The illustrations shown will be of the SS model single cylinder air compressor. Differences in procedure for SS, QE and ST model Holset air compressors will be shown where necessary.

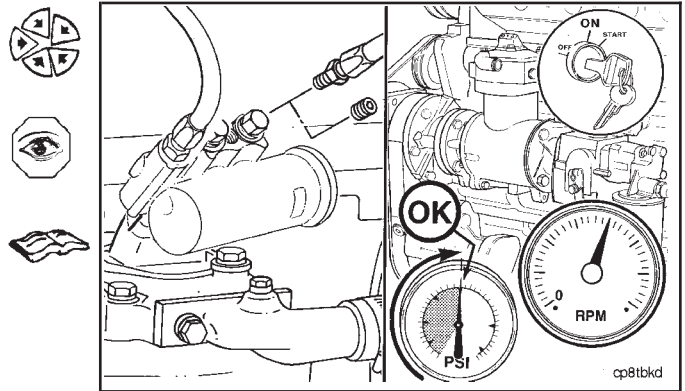
Remove the air accessory air lines from the air compressor governor.



Install pipe plugs in the air governor unloader ports where accessory air lines were removed.

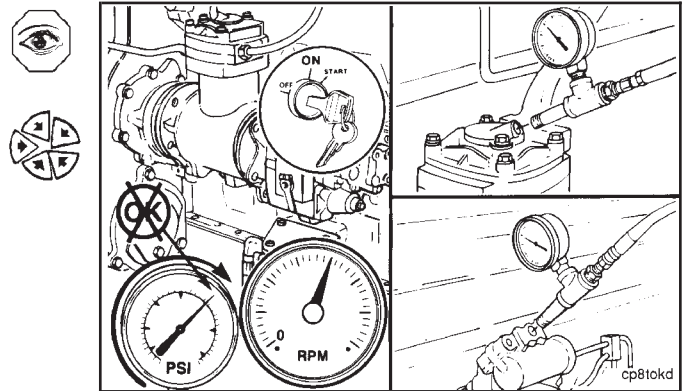
Operate the engine to activate the air compressor.

If the air compressor stops pumping (air pressure stops rising) at the governed air pressure, there is a leak in an accessory or an accessory air line. Refer to the equipment manufacturer's instructions for troubleshooting and repair.



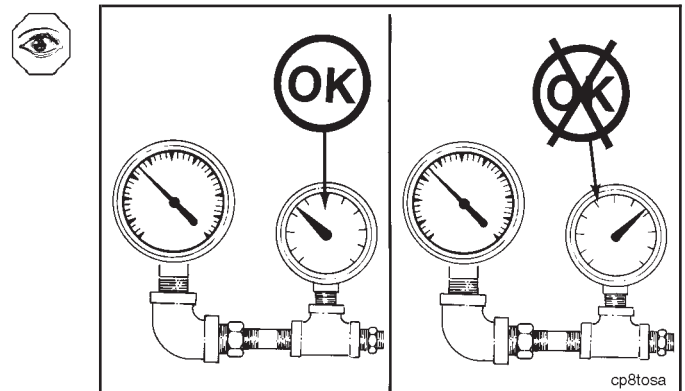
If the air compressor does **not** stop pumping (air pressure continues to rise) at the governed air pressure, connect a regulated shop air pressure line to one of the following:

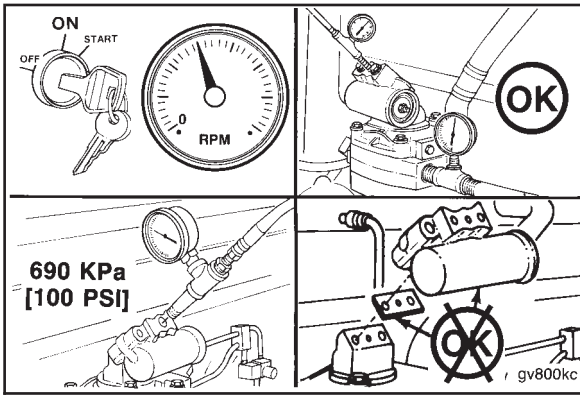
- The air compressor unloader valve port
- One of the air governor unloader valve ports.



NOTE: Be sure the air pressure gauge is accurate, and the supply lines and fittings are in good condition before performing any air pressure checks.

Use a master gauge of known accuracy to check the air pressure gauge.

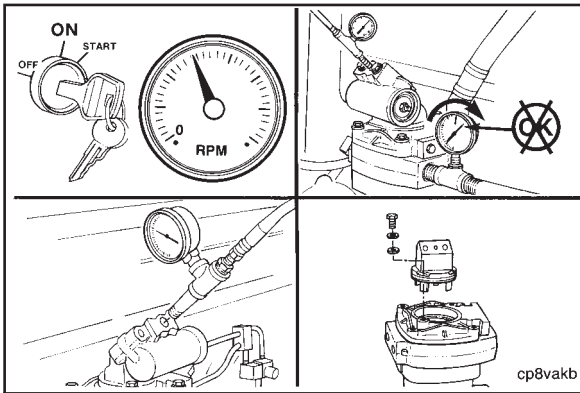




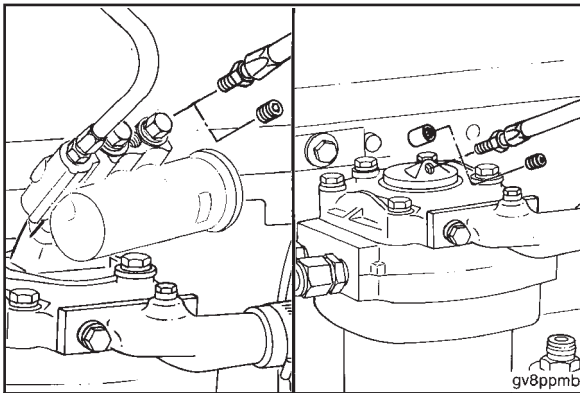
Apply 690 kPa [100 psi] air pressure to the unloader port.



If the air compressor stops pumping (air pressure stops rising), the air governor is malfunctioning and **must** be repaired or replaced, or the air governor mounting gasket is leaking. Refer to the manufacturer's instructions.



If the air compressor continues to pump (air pressure continues to rise), the unloader valve is malfunctioning, and **must** be repaired or replaced. Refer to Air Compressor Unloader Valve, Procedure 012-013.

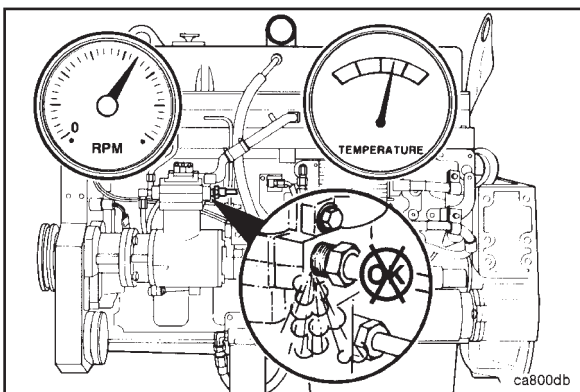


Remove the pipe plugs from the unloader ports used for accessory air lines.

Install and tighten the accessory air lines.



Connect the line to the unloader valve.



Operate the engine and check for air leaks.

Air Leaks, Compressed Air System (012-019)

Initial Check (012-019-001)



WARNING

Compressed air can drive debris into eyes and ears. Keep head well away and wear protective eye wear.

NOTE: The illustrations shown will be of the single cylinder air compressor. Differences in procedures for SS, QE and ST model Holset air compressors will be shown where necessary.

Shut off the engine.

Open the drain cock on the wet tank to release air from the system. Close the drain cock after the pressure is released.

Operate the engine to activate the air compressor.

With the air compressor pumping between 550 to 690 kPa [80 to 100 psi], use a solution of soapy water to check for air leaks in the following areas:

- Air Compressor cover gasket
- Unloader body o-ring
- Air Compressor head gasket
- Air Compressor valve plate gasket (QE models only)
- Hose and fitting leaks

If air leaks are found, replace the leaking gasket or o-ring. Refer to Air Compressor Cylinder Head, Procedure 012-101, 012-103, 012-104, or 012-106.

NOTE: Not all air compressors referenced may be used on your engine or application.

Air Compressor Cylinder Head (Holset SS and E-Type Models) (012-103)

Disassemble (012-103-003)



WARNING

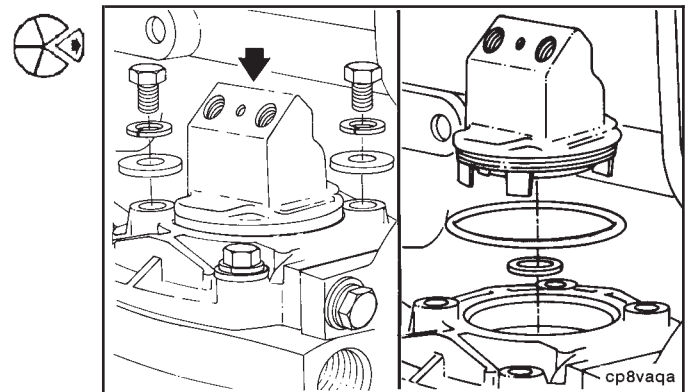
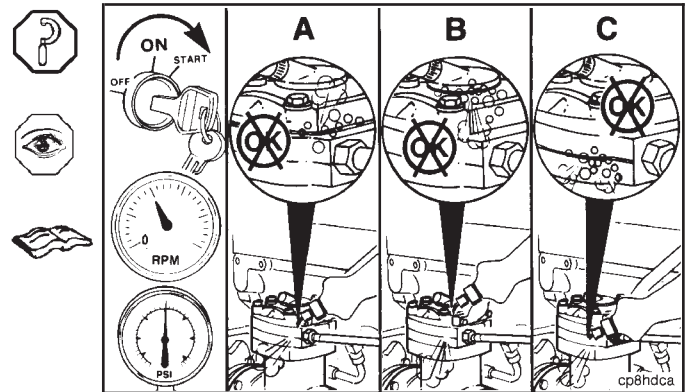
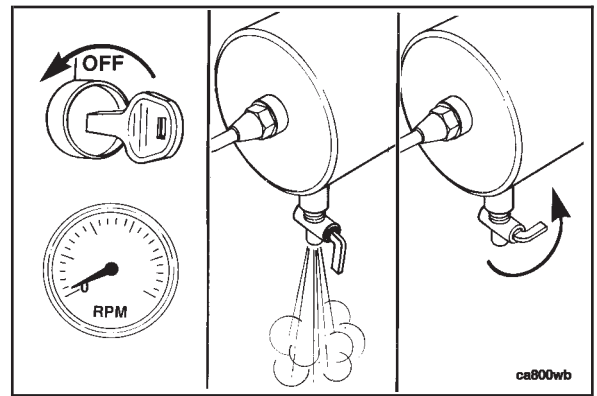
The unloader valve body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eye wear.

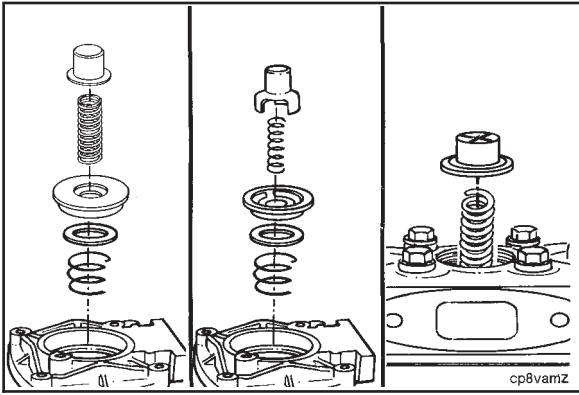
Hold the unloader valve body down and remove the two captive washer capscrews and the two plain washers.

Remove the unloader valve body.

Remove the o-ring seal.

Remove the rectangular ring seal.

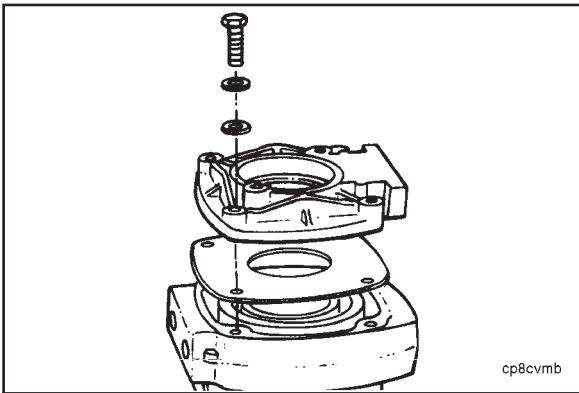




Remove the unloader valve cap and the unloader valve spring.

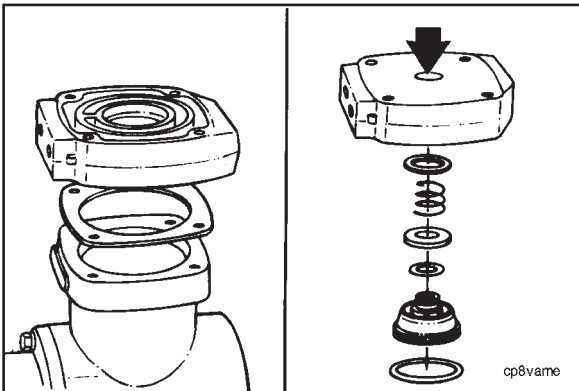
Remove the intake valve seat and valve.

Remove the intake valve spring.



Remove the capscrews, lock washers and plain washers that hold the cover and head to the crankcase.

Remove the cover and discard the gasket.



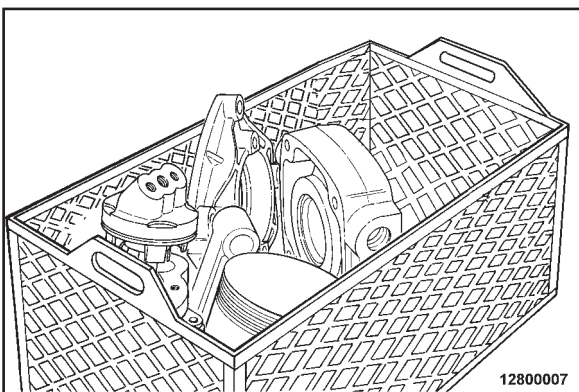
Remove the head and discard the gasket.

Hold the head bottom side up, and use thumb pressure to remove the exhaust valve seat assembly.

NOTE: If the exhaust valve seat assembly can **not** be removed by thumb pressure, use valve seat puller, Part No. 3822674. A press and air compressor seat removal tool, Part No. 3377416, can be used to remove the exhaust valve seat.

Remove the o-ring seal from the exhaust valve seat or head. Remove the exhaust valve.

Remove the compression spring and wear plate from the head.



Clean (012-103-006)



WARNING

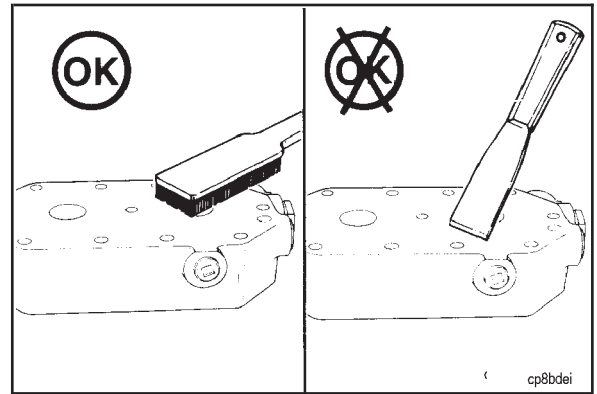


When using solvents, acids, or alkaline materials for cleaning, follow the manufacturers recommendations for use. Wear goggles and protective clothing.

Soak the parts in a kerosene emulsion based cleaner designed to remove carbon. The cleaner **must** have a pH of 9.5 or less to avoid turning aluminum parts black. The cleaner manufacturer or supplier **must** be contacted about solution concentration, temperature and soak time.

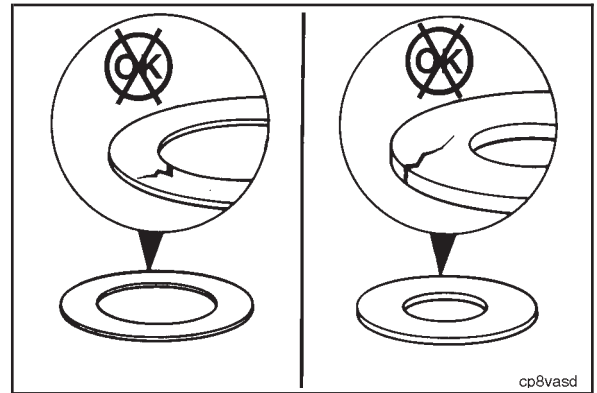
NOTE: Do **not** use a scraper to remove carbon and scale, the sealing surfaces can be damaged.

The parts can be scrubbed with a stiff non-metallic bristle brush.



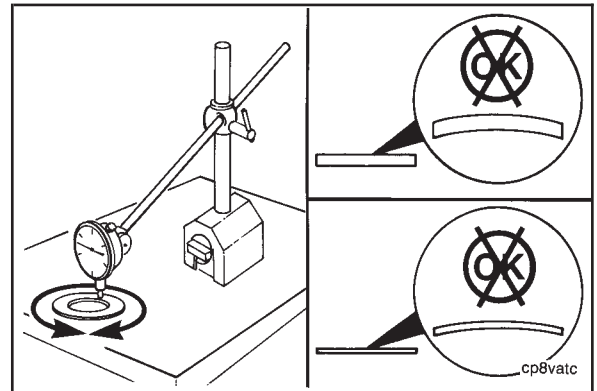
Inspect for Reuse (012-103-007)

Visually inspect the intake and the exhaust valves for cracks or damage.



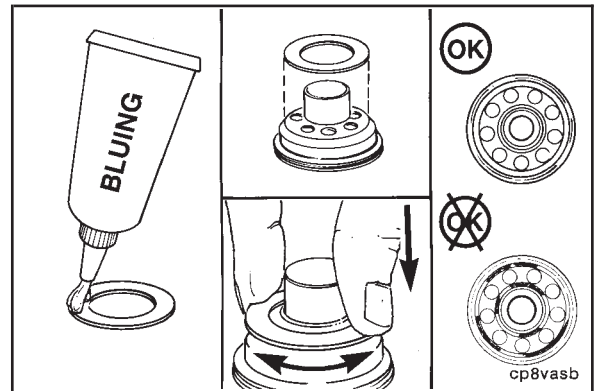
Measure the flatness of the intake and exhaust valves. Both valves **must** be flat within 0.03 mm [0.001-inch].

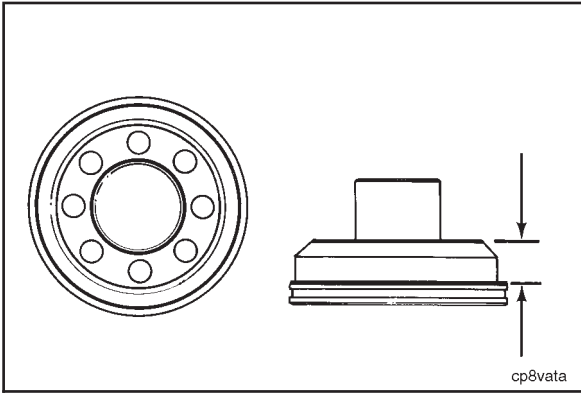
NOTE: Holset Engineering Co., Inc. recommends that new valves be installed.



Apply a bluing compound to the exhaust valve seating surface.

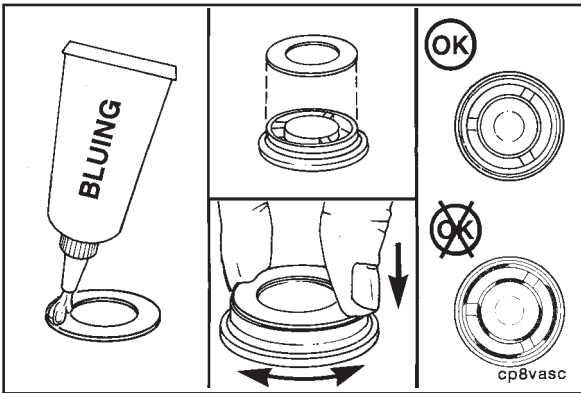
Install the exhaust valve on the valve seating surface and check the seating area. Replace the seat if the contact area is **not** 100 percent.





Measure the exhaust valve seat height.

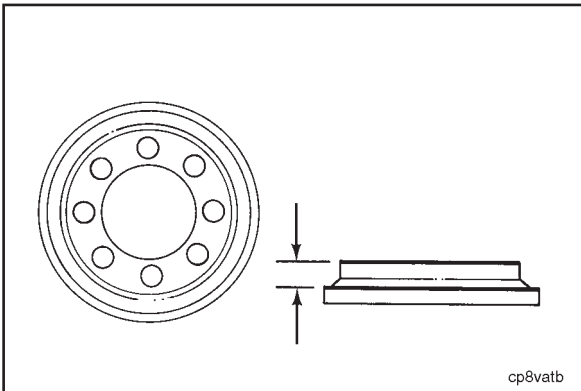
If the seat height is less than 12.32 mm [0.485-inch], replace the seat.



Apply a bluing compound to the intake valve seating surfaces.

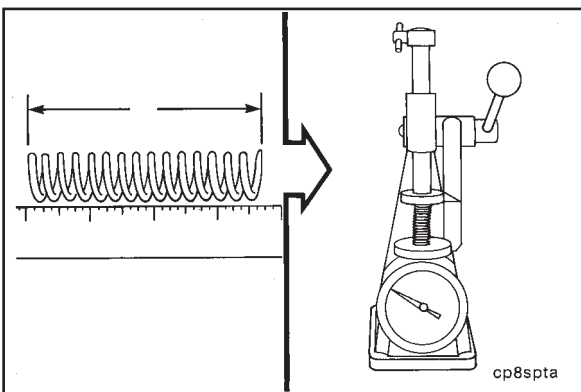


Install the intake valve on the valve seating surface and check the seating area. Replace the seat if the contact area is **not** 100 percent.



Measure the intake valve seat height.

If the seat height is less than 6.86 mm [0.270-inch], replace the seat.



Use valve spring tester, Part No. 3375182, to check the intake, exhaust and unloader valve springs. Replace any springs that do **not** meet specifications.



NOTE: Holset Engineering Co., Inc. recommends that new springs be installed.

Refer to the Compressor Spring Force Specifications chart shown at the front of this section.

Assemble (012-103-025)

Install the wear plate and compression spring in the head as shown.

Install the exhaust valve on the exhaust valve seat.

Install the o-ring seal on the seat.

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

Use hand pressure to install the exhaust valve assembly in the head.

NOTE: For SS-296 and ST-676 air compressor models, a press and air compressor seat installation tool, Part No. 3377415, can be used. Exhaust valve seat puller, Part No. 3822674, can also be used to install the valve seat.

Use new gaskets to install the cylinder head and cover.

Install the flat washers, lock washers and capscrews.

Tighten the cylinder head capscrews of the single cylinder compressor in an alternating sequence.

Torque Value:	Step 1	7 N•m	[5 ft-lb]
	2	14 N•m	[10 ft-lb]
	3	20 N•m	[15 ft-lb]
	4	27 N•m	[20 ft-lb]

Install the intake valve spring with the tang down.

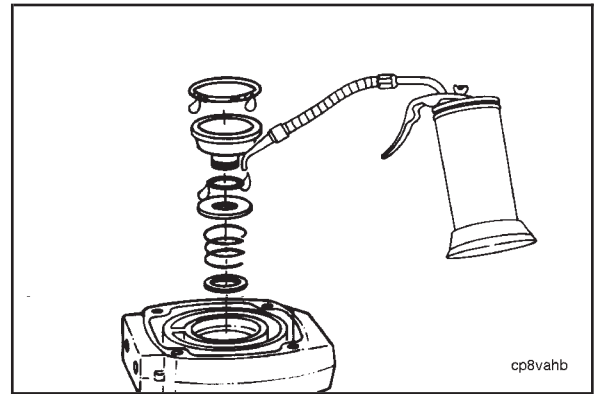
Install the intake valve.

Install the intake valve seat with the flange side up.

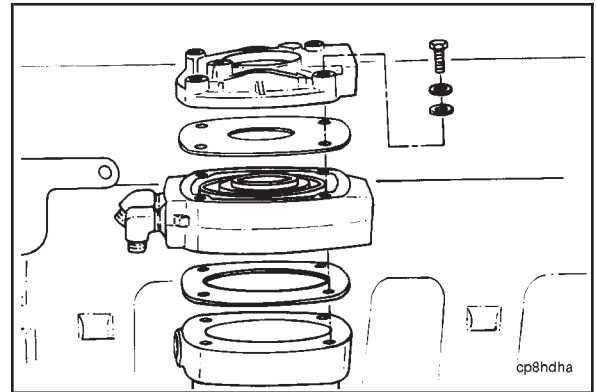
Install the unloader valve cap spring.

Install the unloader valve cap.

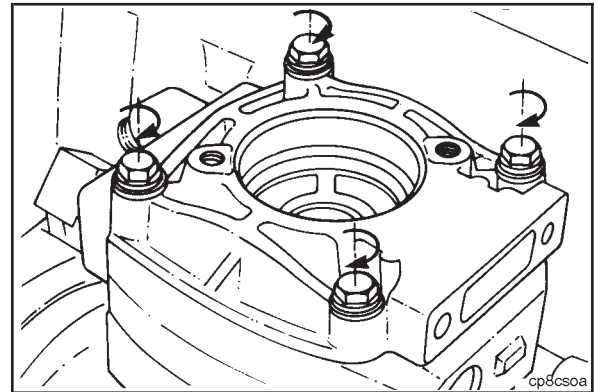
Use high temperature grease (Accrolube Lubrication Teflon Grease or equivalent) to lubricate the outside diameter of the cap.



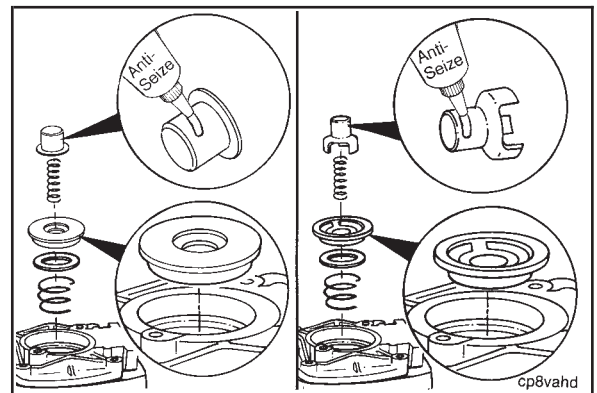
cp8vahb



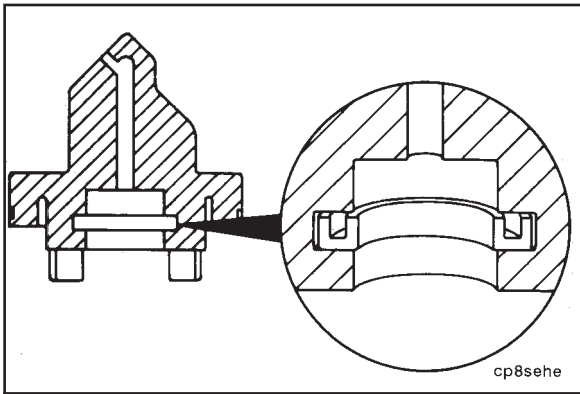
cp8hdha



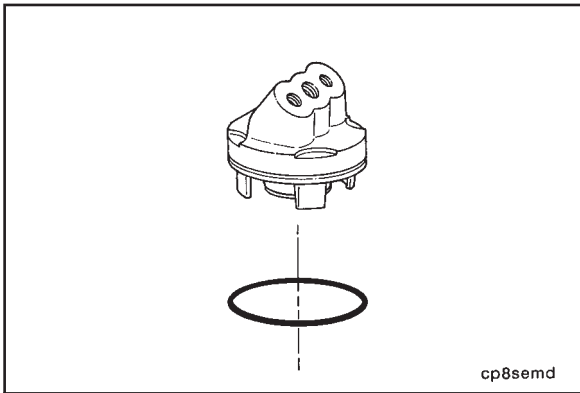
cp8csoa



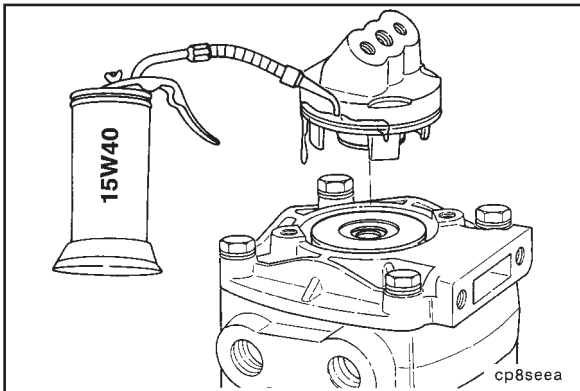
cp8vahd



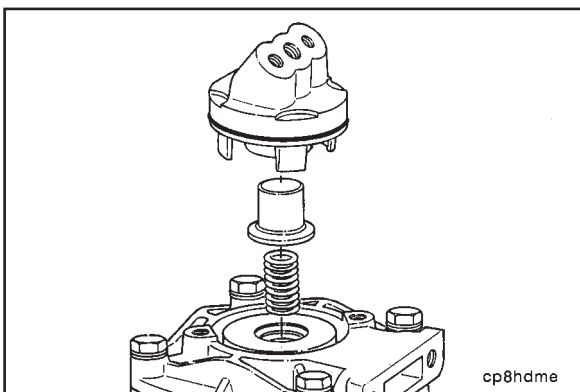
Install the new rectangular ring seal into the unloader body.
NOTE: The seal **must** be installed with the grooved side up.



Install a new o-ring seal on the unloading valve body.



Use clean 15W-40 oil to lubricate the seal.



Install the compression spring.
Use Accrolube Lubrication Teflon Grease to lubricate the outside diameter of the unloader cap and install it into the unloading valve body.
Install the unloading valve body.

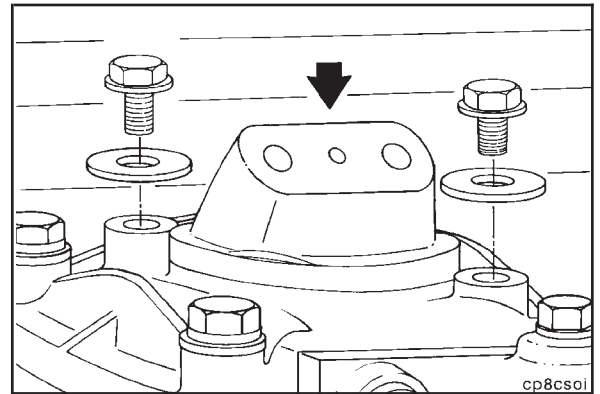
CAUTION

Do not overtorque these screws. Compressor damage will result.

Hold the unloader body down and install the two plain washers and captive washer capscrews.

Tighten the capscrews.

Torque Value: 14 N•m [10 ft-lb]

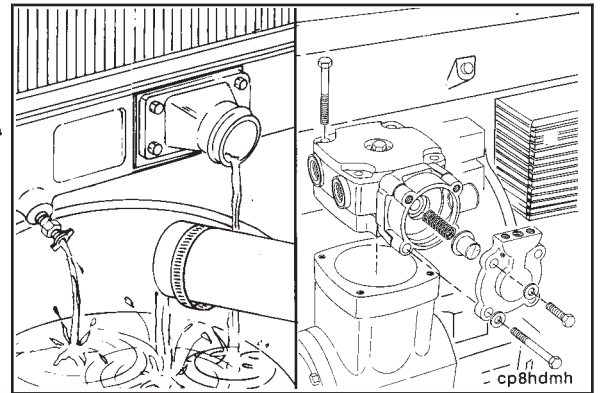


Air Compressor Cylinder Head (Holset QE Models) (012-104)

Disassemble (012-104-003)

NOTE: If the cylinder head is removed while the air compressor is on the engine, drain the engine coolant. Refer to the engine manual.

NOTE: Since the valve plate, head and unloader body are indexible, marking of these parts is recommended to make sure they are reassembled in the proper orientation.



WARNING

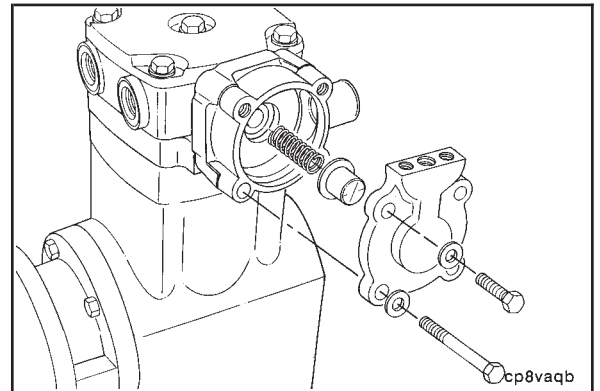
The unloader body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eye wear.

Hold the unloader valve body down and remove the four capscrews.

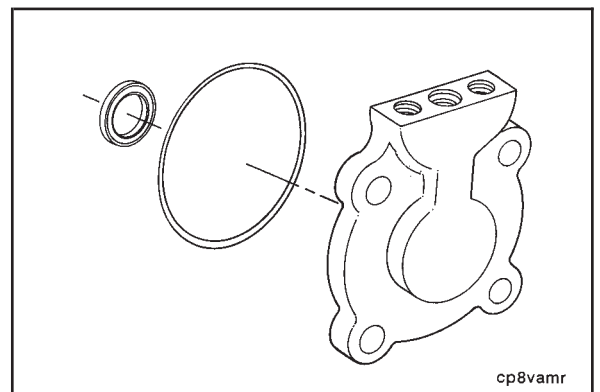
Remove the unloader valve body.

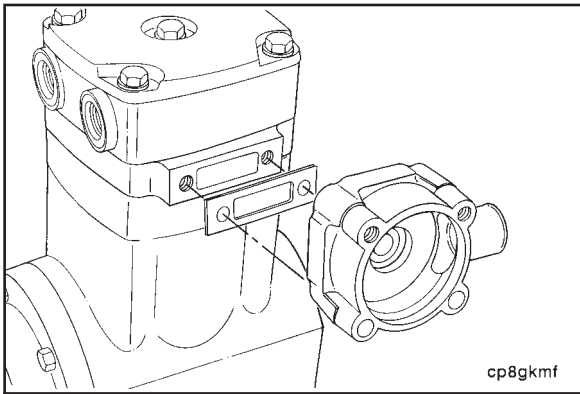
Remove the unloader valve spring.

Remove the unloader valve cap.

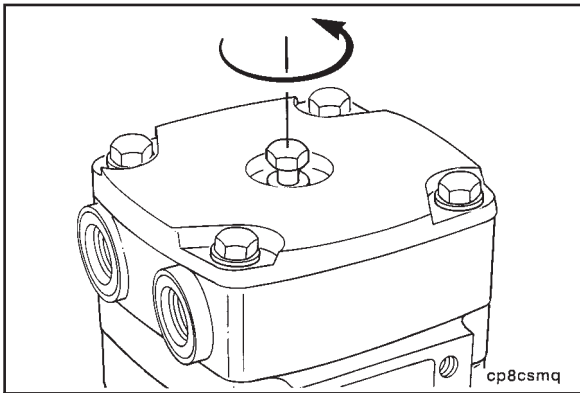


Remove the unloader body gasket and unloader valve cap rectangular ring seal.

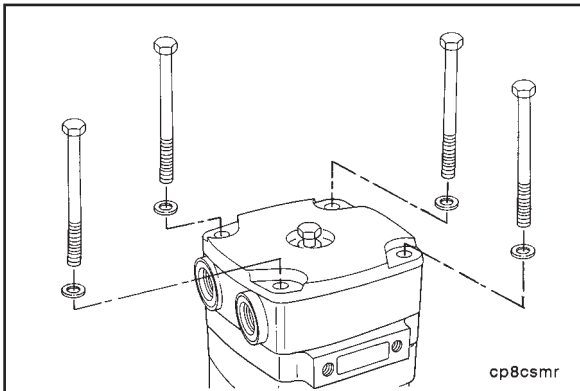




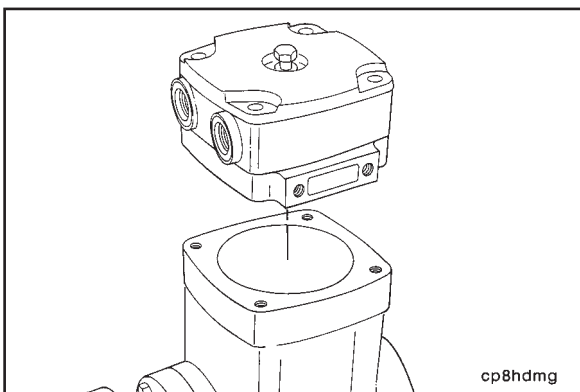
Remove the intake manifold and gasket.



Loosen, but **do not remove** the **center** head capscrew. Mark the head for orientation during assembly.



Loosen and remove the four corner head capscrews. Save the capscrews for reuse.

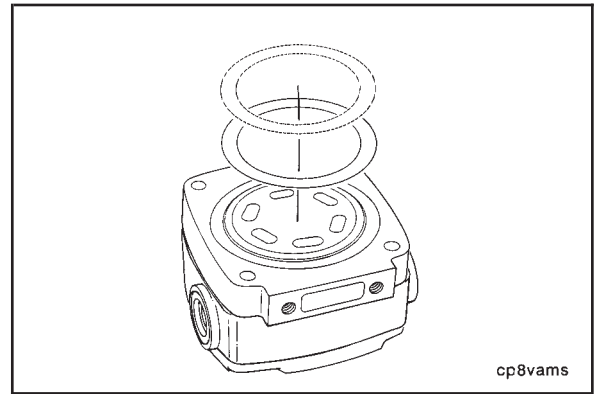


Remove the head, cover, and valve plate assembly and place it on a clean work surface with the intake valve facing upward.

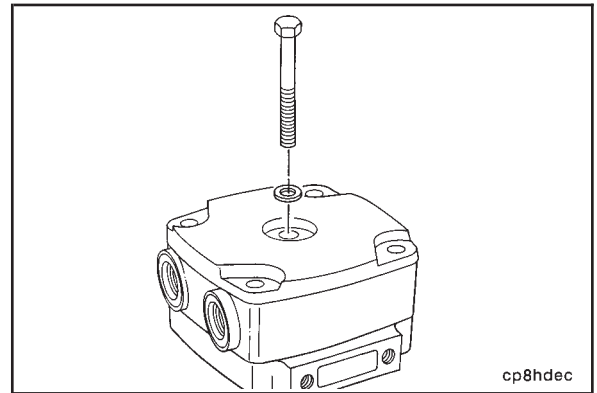
NOTE: If continuing with disassembly of the head, valve plate, and cover, be sure the work surface is clean. Grit pushed into the valve sealing surfaces by setting components on a dirty surface will cause a malfunction after reassembly.

Some units have a press-fit intake valve retainer. If present, carefully remove it to prevent part damage.

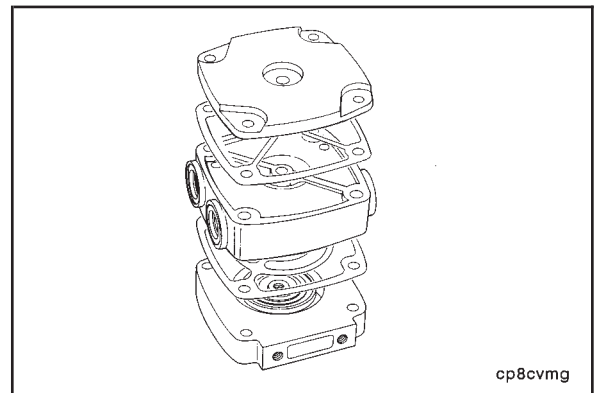
Remove the intake valve.



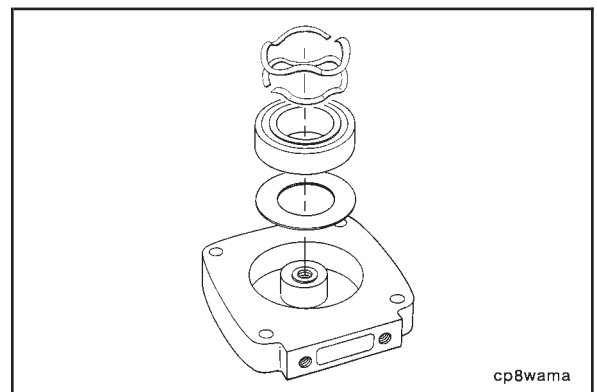
Turn the head assembly over and set it on a clean surface. Remove the center capscrew. This capscrew can be reused. Note that this capscrew is shorter than the four corner capscrews.

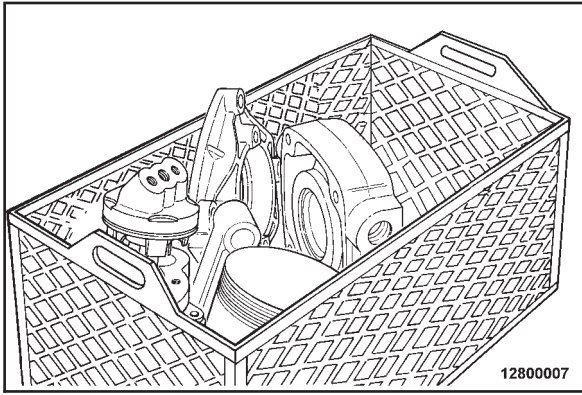


Remove the cover, cover gasket, head and head gasket.



Remove the two wave washers, exhaust valve retainer and exhaust valve. These wave washers **must** be replaced.





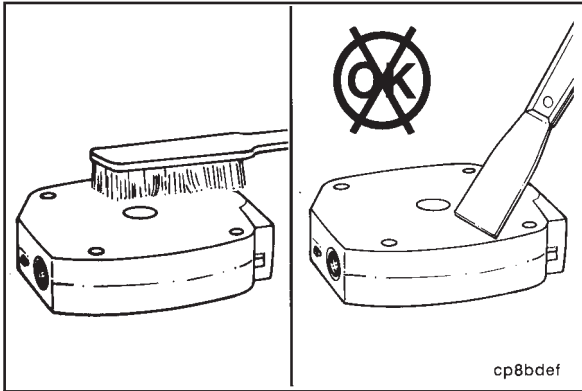
Clean (012-104-006)



WARNING

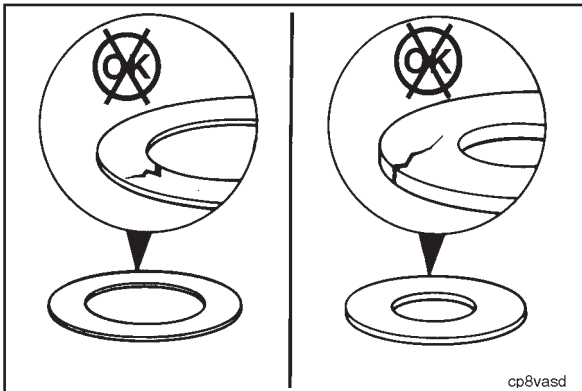
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing.

Soak the parts in a kerosene emulsion based cleaner designed to remove carbon. The cleaner **must** have a pH of 9.5 or less to avoid turning aluminum parts black. The cleaner manufacturer or supplier can be contacted about solution concentration, temperature and soak time.



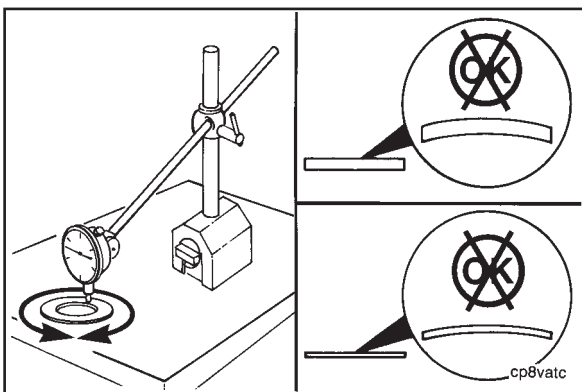
NOTE: Do **not** use a scraper to remove carbon and scale, the sealing surfaces can be damaged.

The parts can be scrubbed with a stiff non-metallic bristle brush.



Inspect for Reuse (012-104-007)

Visually inspect the intake and exhaust valves for cracks or damage.

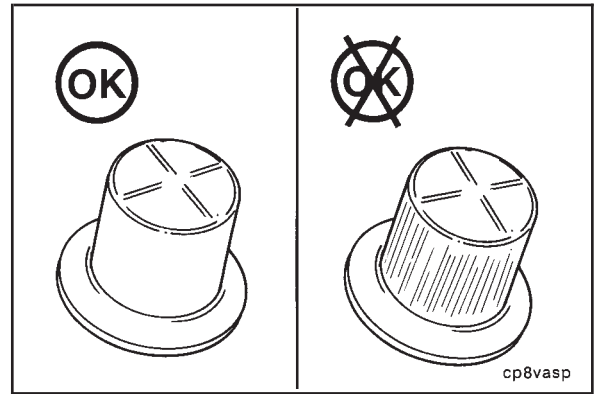


Measure the flatness of the intake and exhaust valves. Both valves **must** be flat within 0.03 mm [0.001-inch].

Replace valves if cracked, damaged, or **not** flat.

NOTE: Holset Engineering Co., Inc., recommends new valves be installed.

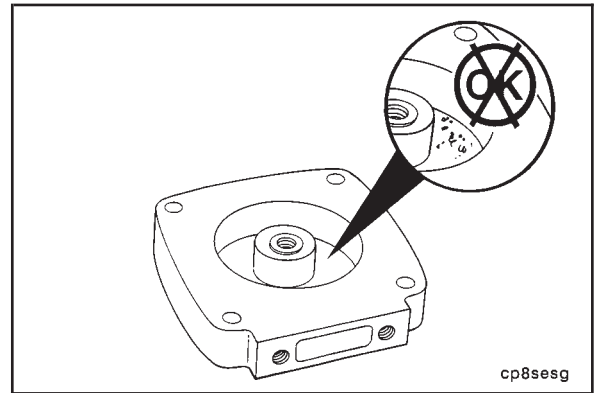
Inspect the upper part of the unloader valve cap where the rectangular vee seal operates. Check for scoring.



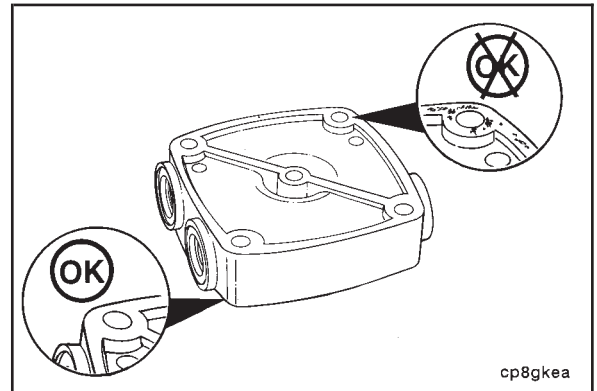
Inspect the valve seat surfaces.

NOTE: Inspection of the valve seats in the valve plate requires specialized equipment and is beyond the scope of field service.

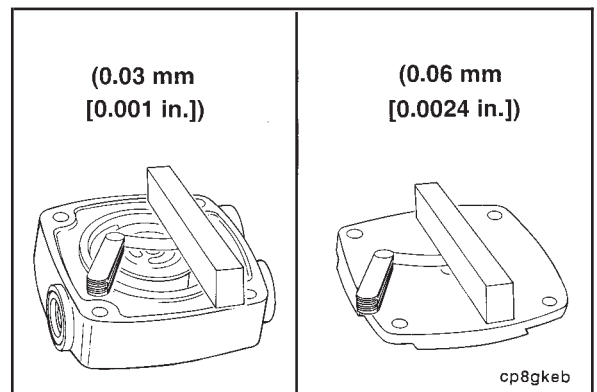
If the valve seat is visibly damaged, or **cannot** be cleaned, a new valve plate is available in a service kit. Otherwise, a QE valve plate service assembly can be used.

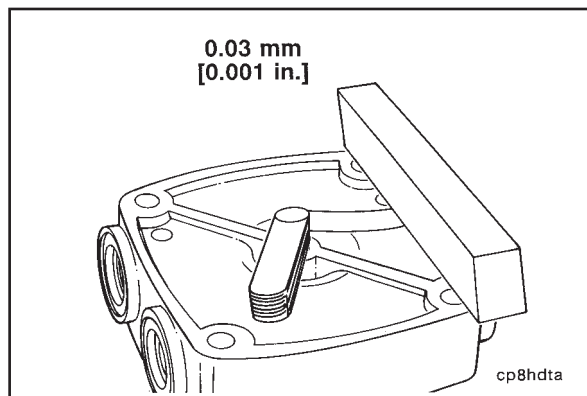


Gasket sealing surfaces **must** be clean and free of all old gasket material, carbon, rust, and other buildup. Surfaces **must** be free of scratches, gouges, burrs, and other deformities.

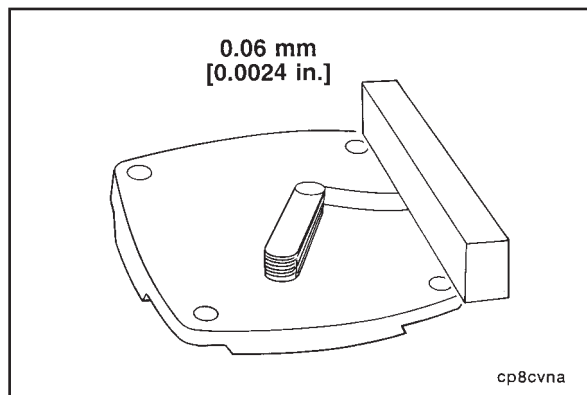


After making sure all gasket surfaces are clean and free of the above, inspect the head and cover for flatness. Use the flat plate and the feeler gauges.

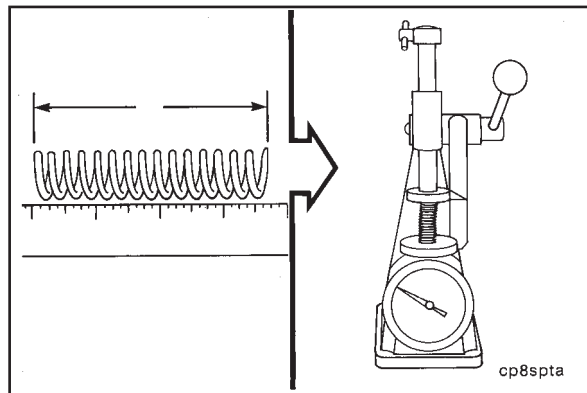




Single cylinder heads **must** be flat within 0.03 mm [0.001-inch] between any two adjacent capscrew holes.



Single cylinder top cover **must** be flat within 0.06 mm [0.0024-inch] between any two adjacent capscrew holes and 0.10 mm [0.004-inch] total.

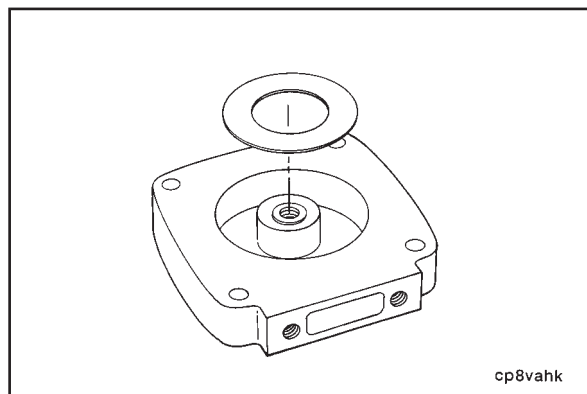


Use valve spring tester, Part No. 3375182, to check the unloader valve spring. Replace any spring that does **not** meet specifications.



NOTE: Holset Engineering Co., Inc., recommends that new springs be installed.

Refer to the Compressor Spring Specifications chart shown at the front of this section.

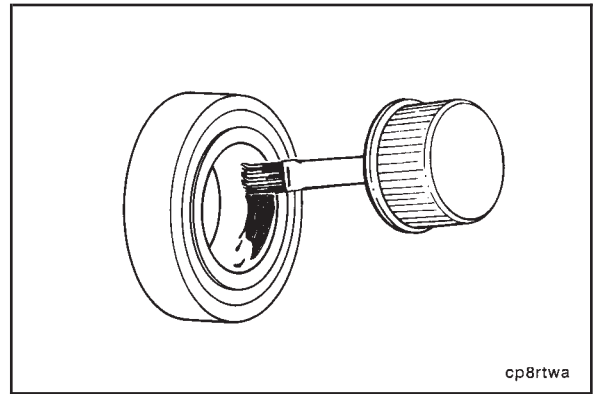


Assemble (012-104-025)

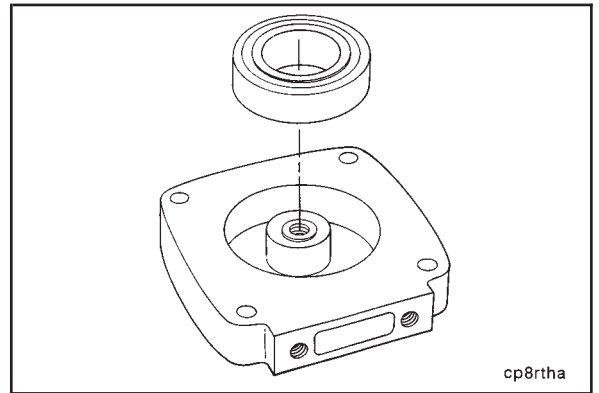
QE, Non-European

Install the exhaust valve over the post in the valve plate.

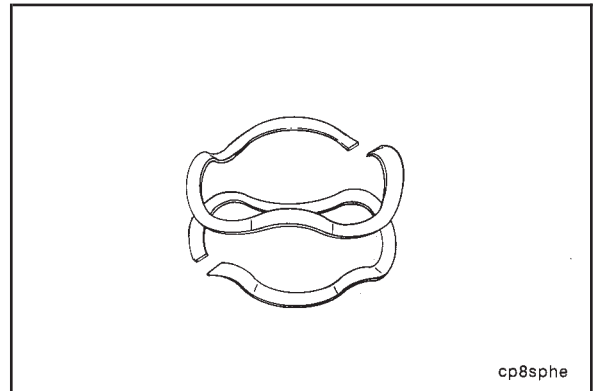
Apply a thin coating of anti-seize to the inside diameter of the exhaust valve retainer.



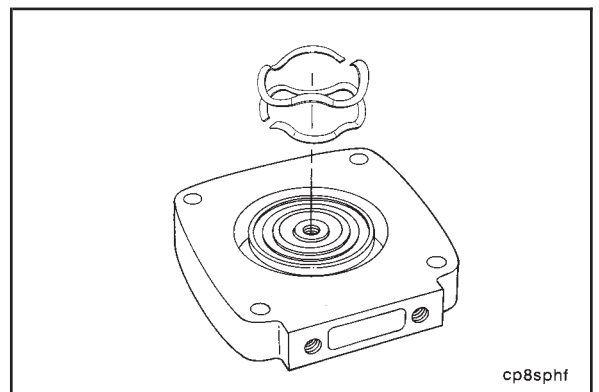
Slide the exhaust valve retainer over the valve plate. Make sure that the end of the retainer with the groove faces upward.

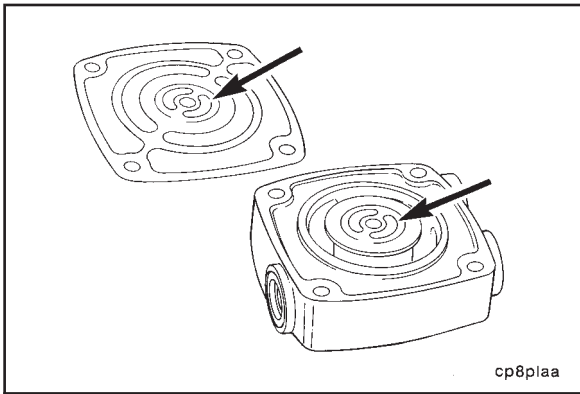


Align the wave spring gaps 180 degrees from each other so they do **not** overlap.



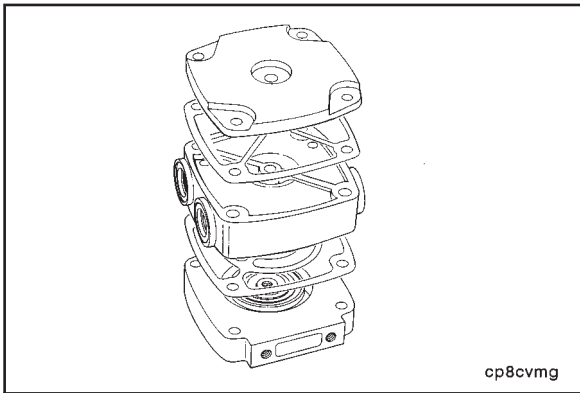
Place the wave springs in the retainer groove.



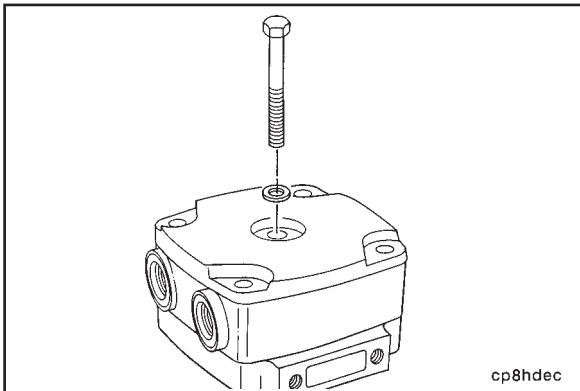


Determine the final orientation of the valve plate (air intake location) and the head (coolant ports with respect to air inlet or manifold location). Align the kidney-shaped slots in the head with the kidney shaped slots in the gasket.

If orientation marks were made before disassembly, use them.



Assemble the cover, cover gasket, head, head gasket, and valve plate.

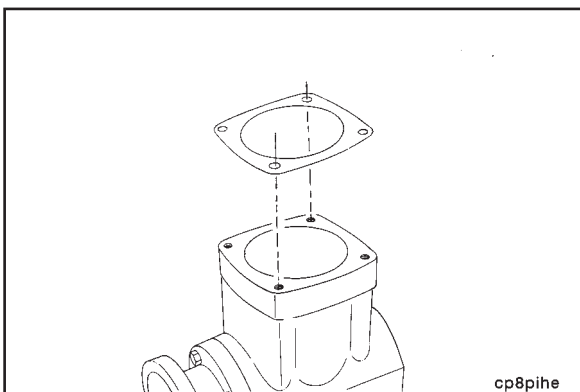


NOTE: Make sure corner capscrew holes are aligned.

Lubricate the threads under the head.

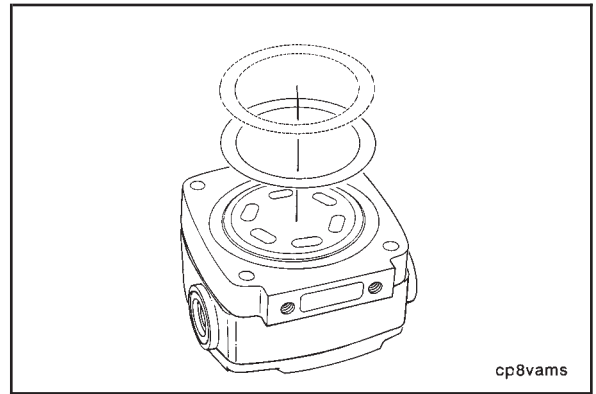
Install the shorter capscrew with washer through the center hole.

Torque Value: 14 N•m [120 in-lb]

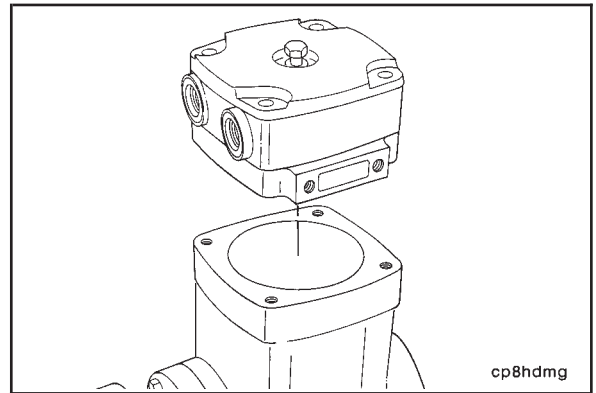


Install the valve plate gasket.

Carefully place the intake valve in the valve plate. Install the intake valve retainer.



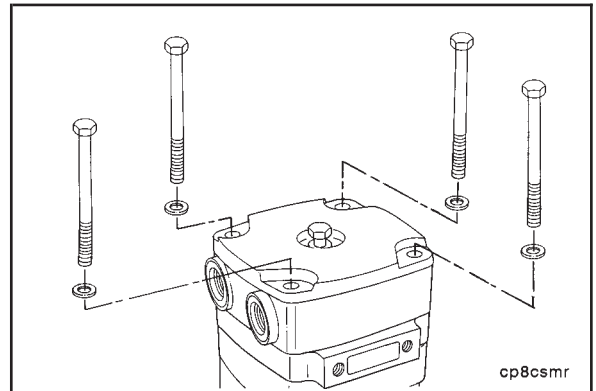
Install the valve plate assembly.



Lubricate the threads under the head and washer of the capscrews if initially installed.

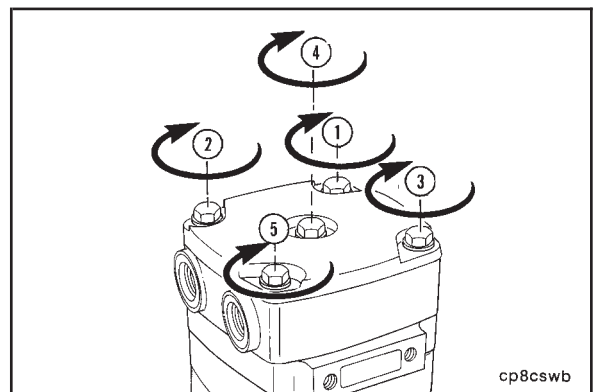


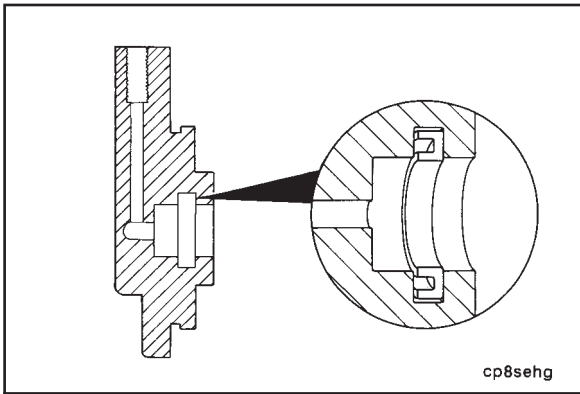
Install the four head capscrews and washers.



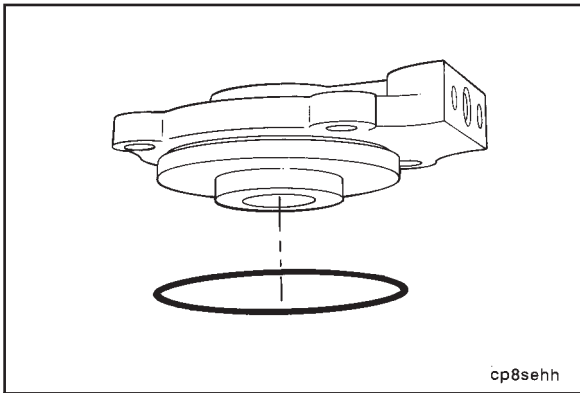
Tighten all five capscrews.

Torque Value: 28 N•m [250 in-lb]

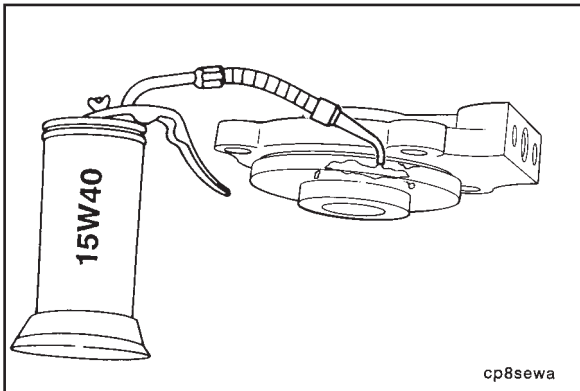




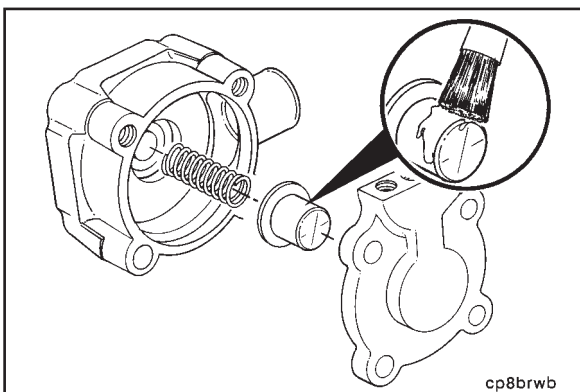
Install the new rectangular vee seal into the unloader body.
NOTE: The seal **must** be installed with the grooved side up.
Liberaly lubricate the unloader valve bore above and below the rectangular ring seal with high temperature grease (Accrolube Lubrication Teflon Grease or equivalent).



Install a new o-ring seal on the unloader valve body.



Use clean 15W40 oil or Accrolube Lubrication Teflon Grease (or equivalent) to lubricate the seal.

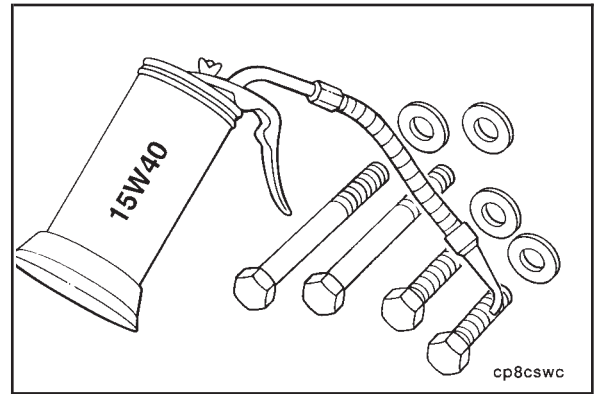


Liberaly lubricate the unloader valve body bore and unloader cap with high temperature grease (Accrolube Lubrication Teflon Grease or the equivalent).
Install the unloader cap.
Install the unloader spring.

M11 Series
Section 12 - Compressed Air System - Group 12

Lubricate the unloader screw threads and underhead with clean engine oil (SAE 15W40), before installation.

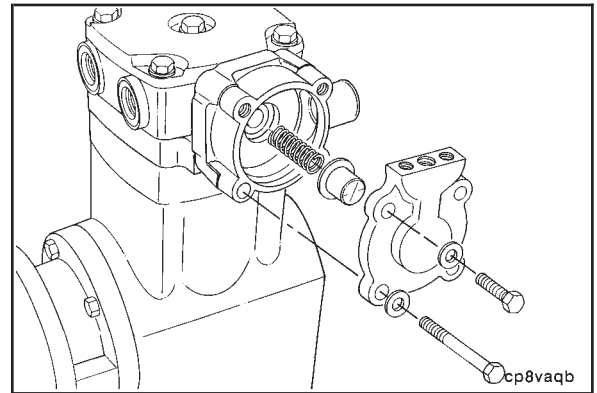
NOTE: The two unloader body screws **must not** be used to attach any brackets.



Assemble the unloader components and attach the unloader assembly to the valve plate with the four capscrews and washers.

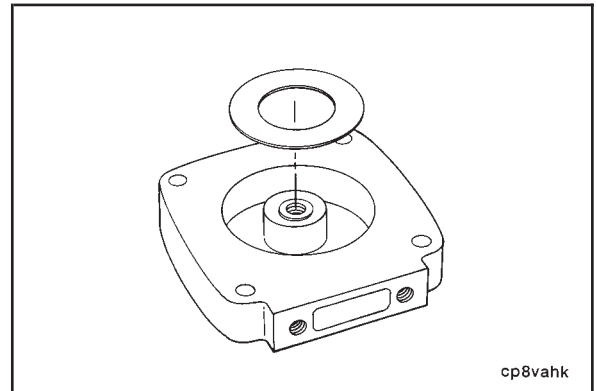
NOTE: The longer capscrews are used to mount the manifold to the air compressor.

Torque Value: 27 N•m [20 ft-lb]

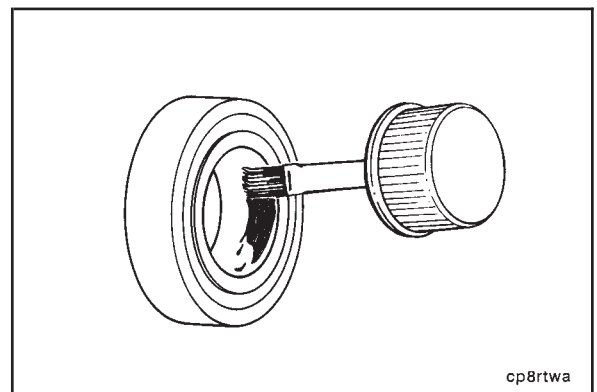


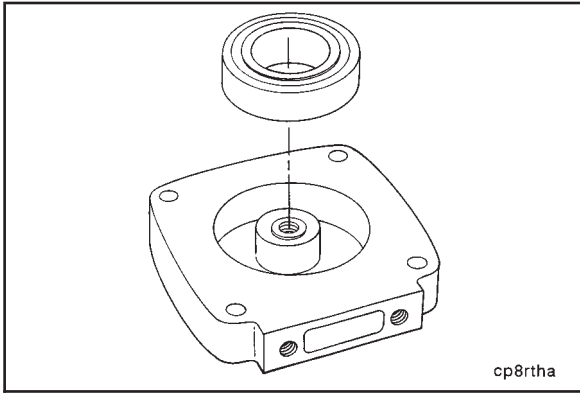
QE, European

Install the exhaust valve over the post in the valve plate.

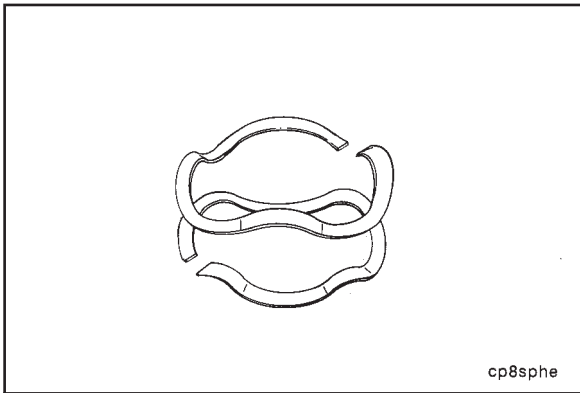


Apply a thin coating of anti-seize to the inside diameter of the exhaust valve retainer.

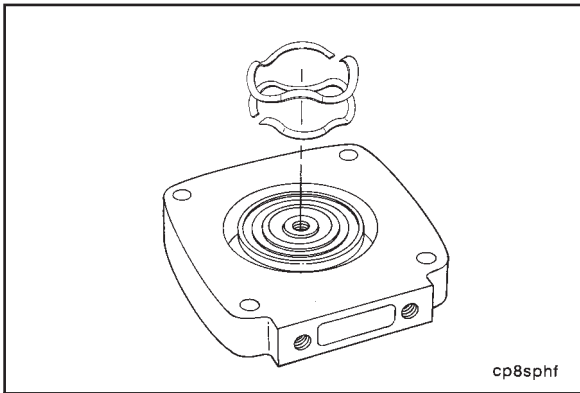




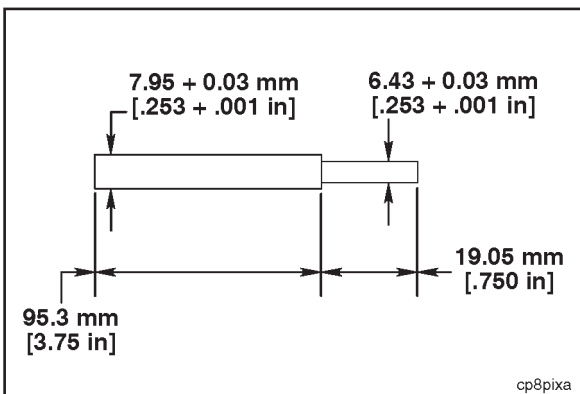
Slide the exhaust valve retainer over the valve plate. Make sure that the end of the retainer with the groove faces upward.



Align the wave spring gaps 180 degrees from each other so they do **not** overlap.

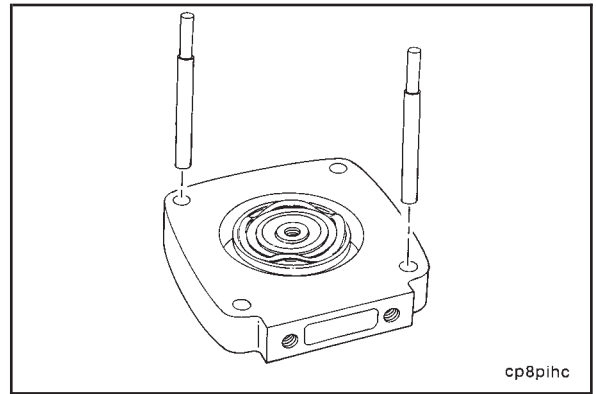


Place the wave springs in the retainer groove.

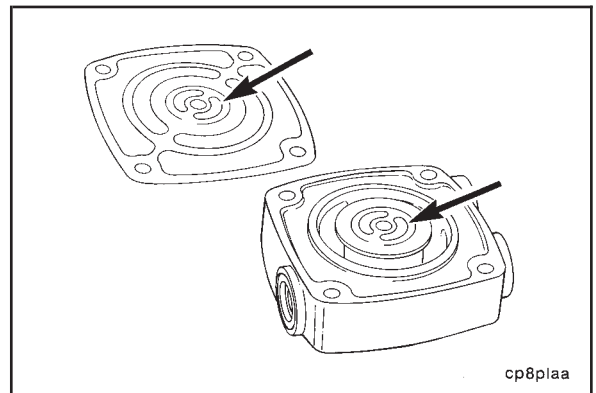


Fabricate or reuse the four guidepin tools.

Insert the larger end of two guide pins in opposite corner holes of the valve plate.

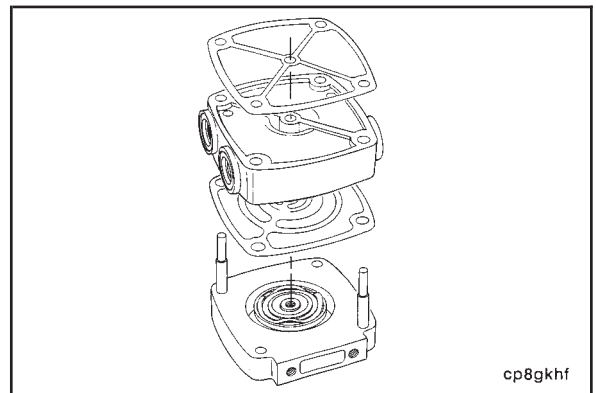


Determine the final orientation of the valve plate (air intake location) and the head (coolant ports with respect to air inlet or manifold location). Align the kidney-shaped slots in the head with the kidney shaped slots in the gasket.

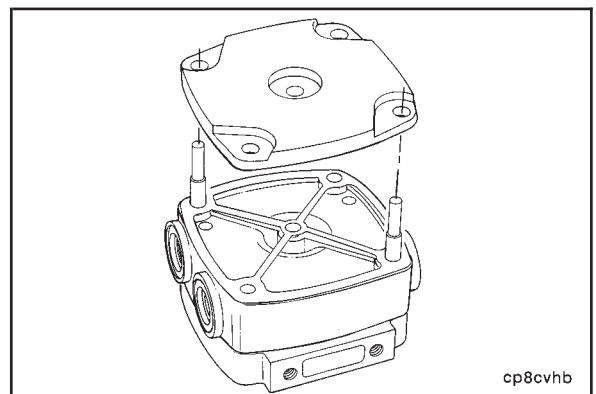


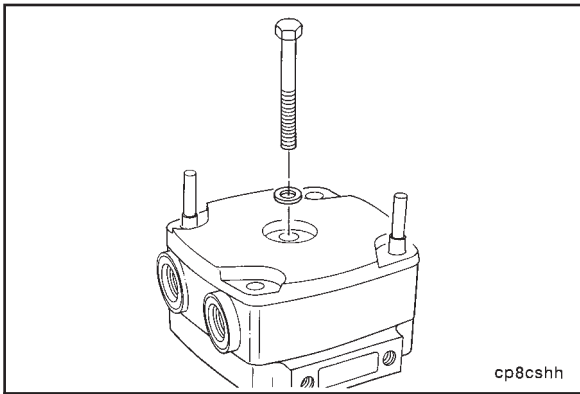
If orientation marks were made before disassembly, use them.

Install the head gasket onto the guide pins (either side up, but with correct slot orientation). Install the head onto the guide pins with the kidney-shaped slots aligned and toward the valve plate. Install the cover gasket over the guide pins.



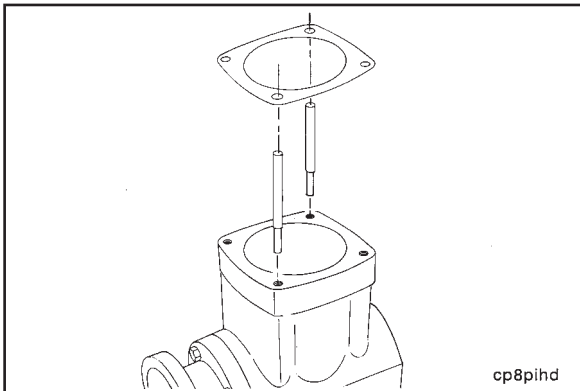
Assemble the cover.



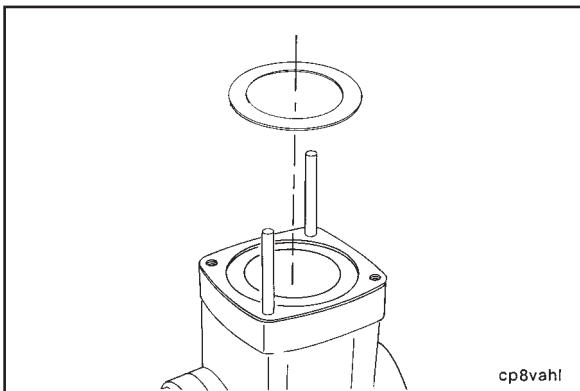


Install the shorter capscrew with washer, if initially installed, through the center hole.

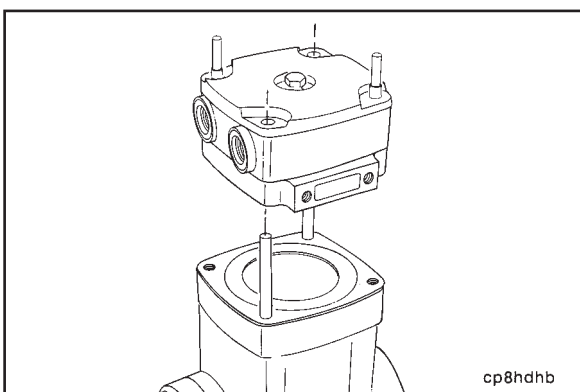
Torque Value: 14 N•m [120 in-lb]



Place the remaining two guide pins in the crankcase head capscrew holes (that will **not** interfere with the guide pins already in the head assembly). Install the valve plate gasket.

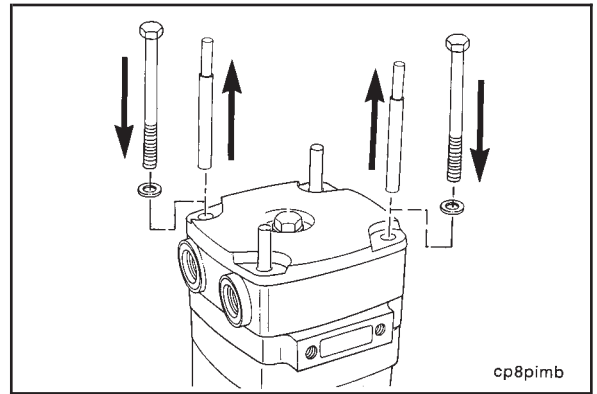


Carefully place the intake valve on the crankcase, located by the valve plate gasket. Do **not** allow the valve to overlap the gasket.



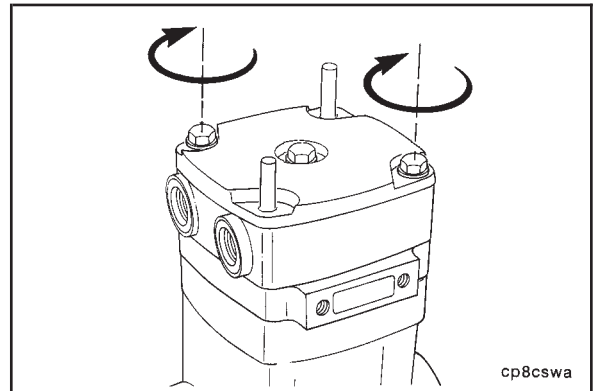
Install the head assembly over the guide pins. Be careful **notto** disturb the location of the intake valve. The compressor will **not** work if the valve overlaps the gasket and is pinched.

Carefully remove two of the guide pins and replace with two head capscrews and washers, if initially installed.

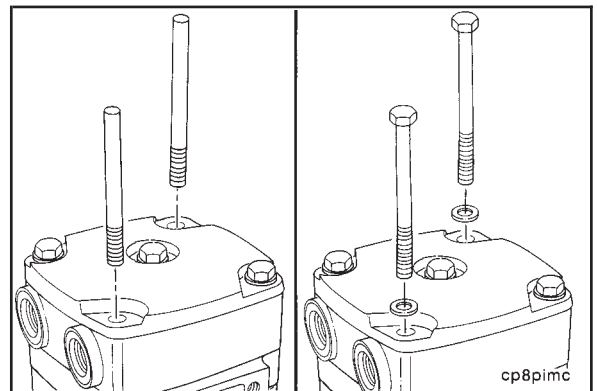


Tighten the two head capscrews.

Torque Value: 14 N•m [120 in-lb]

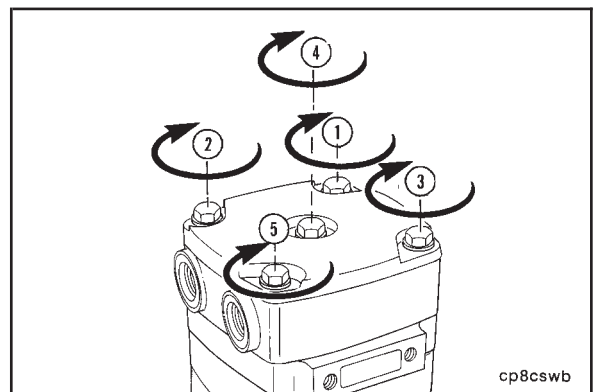


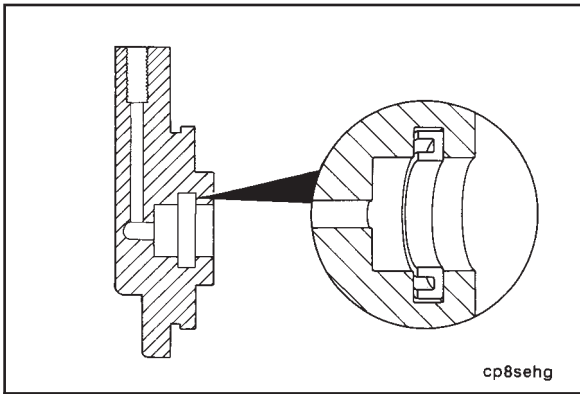
Remove the remaining two pins and replace with two head capscrews and washers if initially installed.



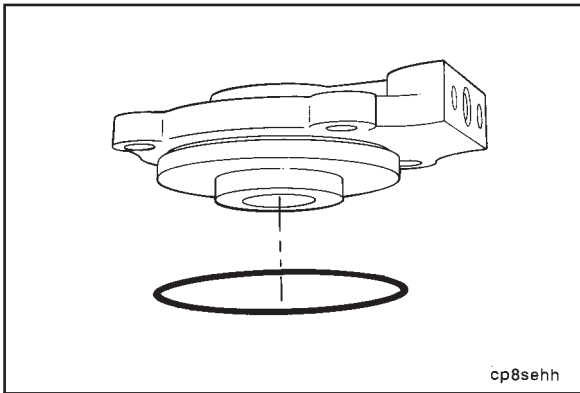
Tighten all five capscrews.

Torque Value: 28 N•m [250 in-lb]

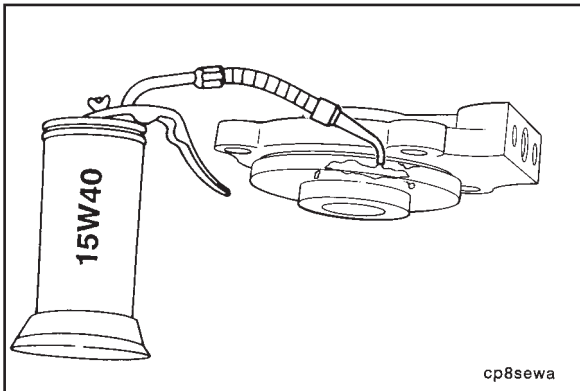




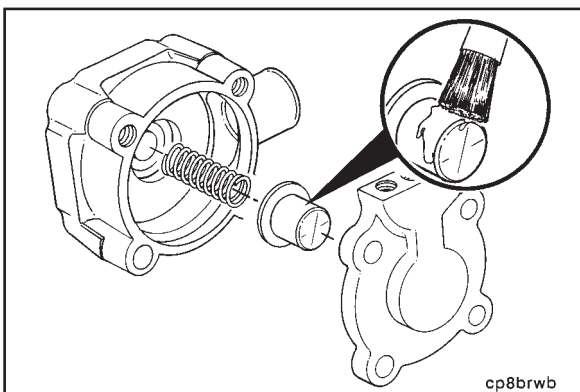
Install the new rectangular vee seal into the unloader body.
NOTE: The seal **must** be installed with the grooved side up.
Liberaly lubricate the unloader valve bore above and below the rectangular ring seal with high temperature grease (Accrolube Lubrication Teflon Grease or equivalent).



Install a new o-ring seal on the unloader valve body.



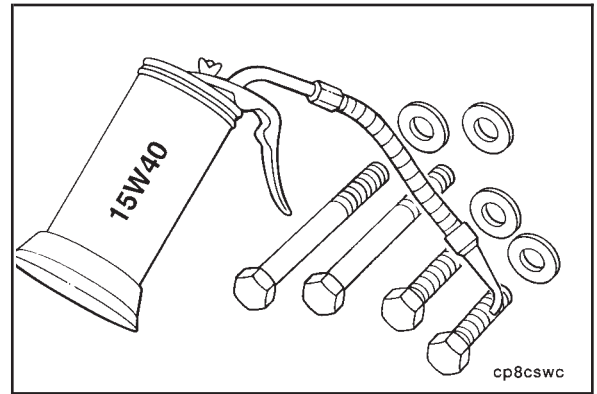
Use clean 15W-40 oil or Accrolube Lubrication Teflon Gease (or equivalent) to lubricate the seal.



Liberaly lubricate the unloader valve body bore and unloader cap with high temperature grease (Accrolube Lubrication Teflon Grease or the equivalent).
Install the unloader cap.
Install the unloader spring.

Lubricate the unloader screw threads and underhead with clean engine oil (SAE 15W-40) before installation.

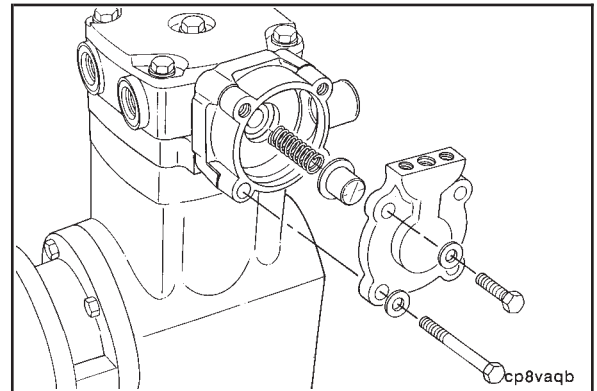
NOTE: The two unloader body screws **must not** be used to attach any brackets.



Assemble the unloader components and attach the unloader assembly to the valve plate with the four capscrews and washers.

NOTE: The longer capscrews are used to mount the manifold to the air compressor.

Torque Value: 27 N•m [20 ft-lb]

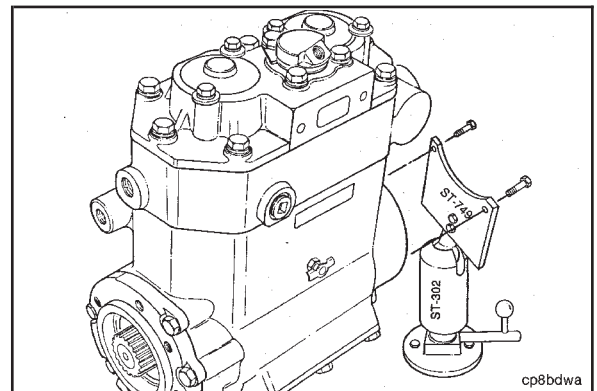


Air Compressor Cylinder Head (Holset ST Models) (012-106)

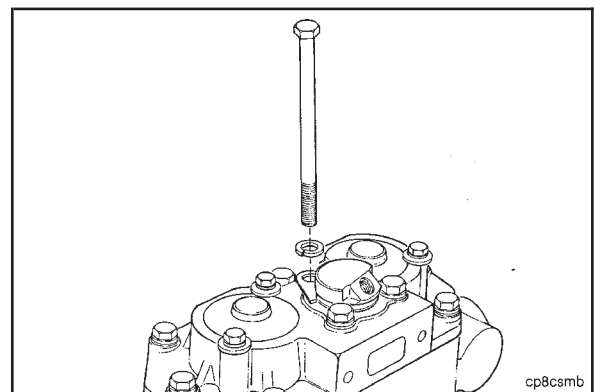
Disassemble (012-106-003)

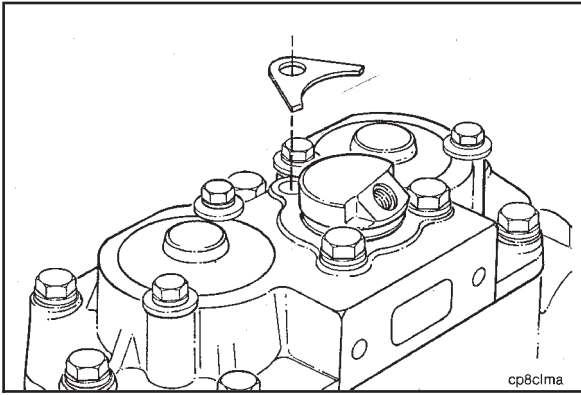
The component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

Use two 5/16 - 18 x 1 1/4 inch capscrews to mount the air compressor on the mounting plate, Part No. ST-749 which is used with the ball joint vise, Part No. ST-302.

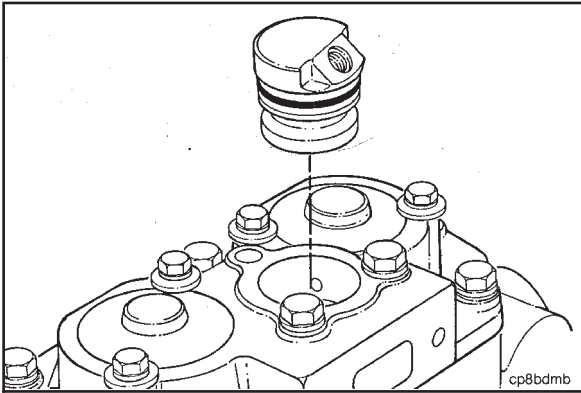


Remove the center unloader body hexagon head capscrew and lock washer.





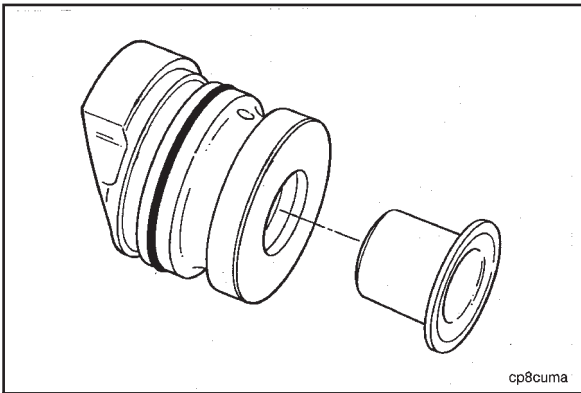
Remove the retaining clamp.



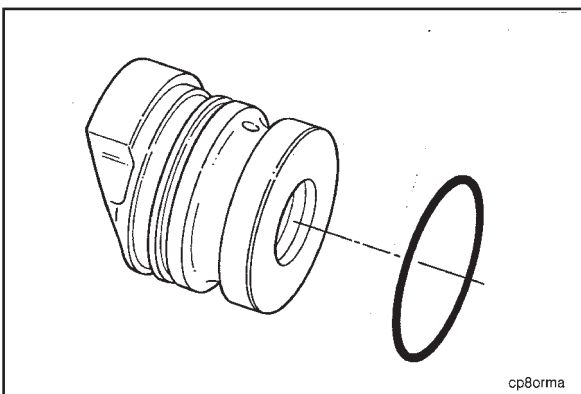
⚠ CAUTION ⚠

The unloader valve body is installed with spring tension. Carefully remove to avoid personal injury.

Remove the unloading valve body.



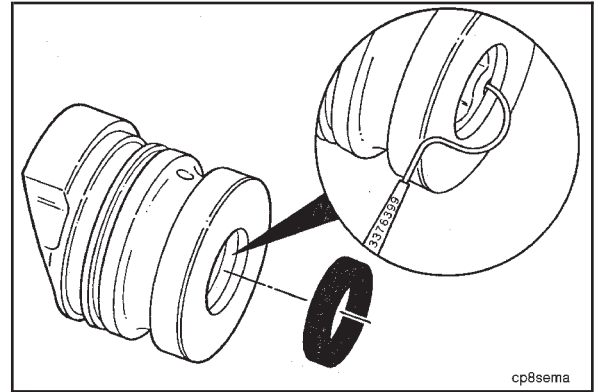
Remove the unloader valve cap, if installed.



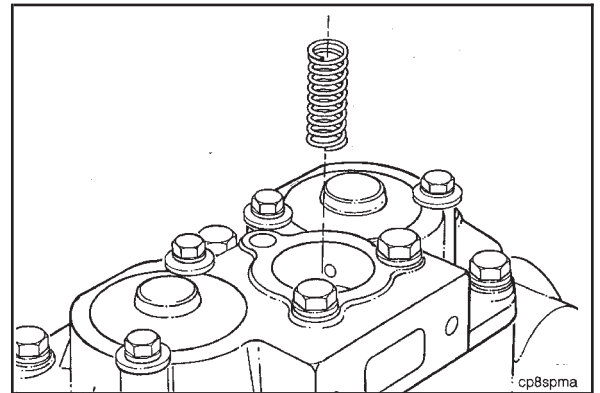
Remove and discard the o-ring seal.

Use a o-ring pick, Part No. 3376399, to remove the rectangular ring seal, if installed.

Discard the seal.

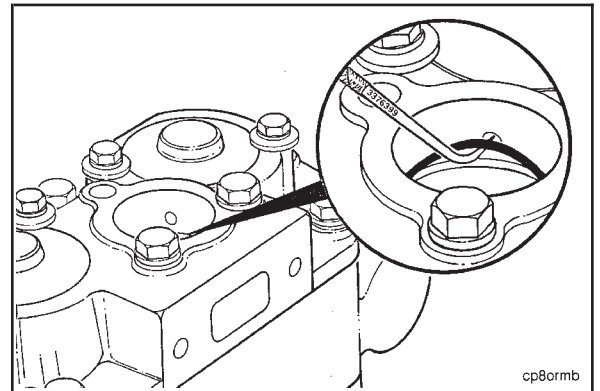


Remove the unloader valve cap spring.

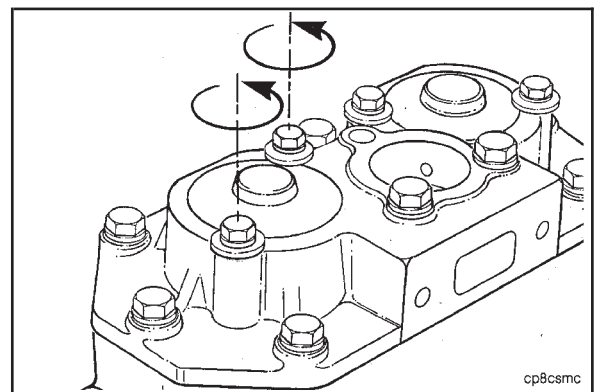


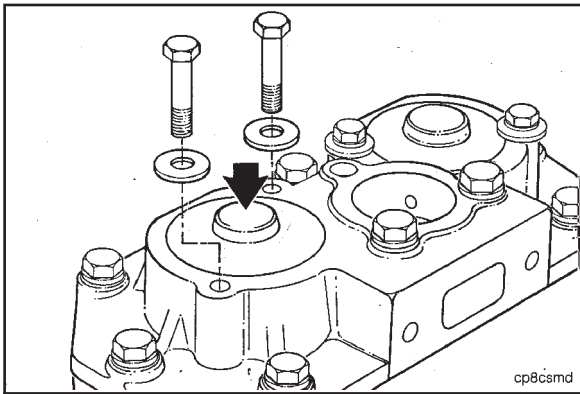
Use a o-ring pick, Part No. 3376399, to remove the o-ring seal.

Discard the seal.



Loosen the two unloader body hexagon head capscrews.

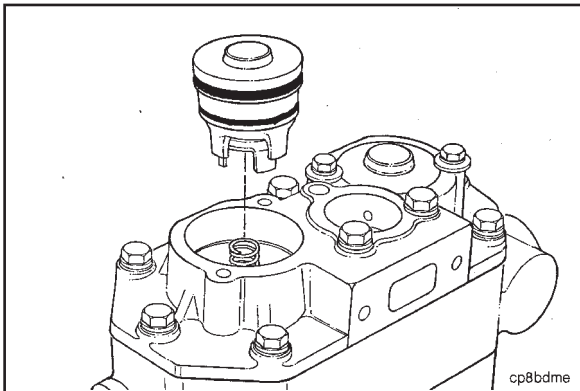




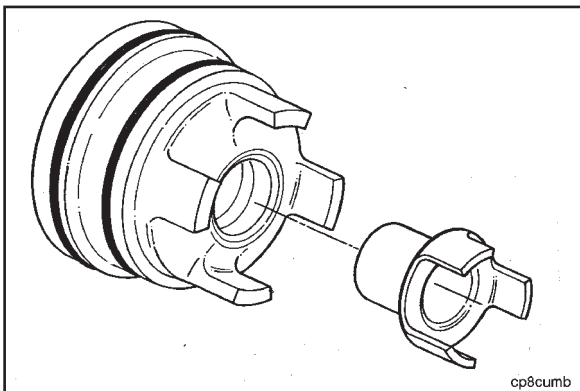
▲ WARNING ▲

The unloader body is installed with spring tension, it must be removed carefully to avoid personal injury. Always wear protective eye wear.

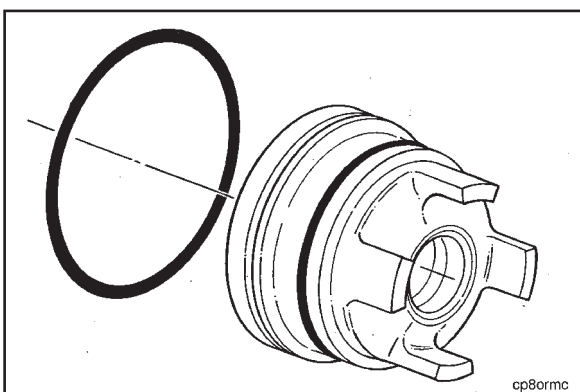
Hold down on the unloader body and slowly remove the two unloader body capscrews and the two plain washers so as to prevent the unloader body from being thrown free and causing personal injury.



Remove the unloader valve body.

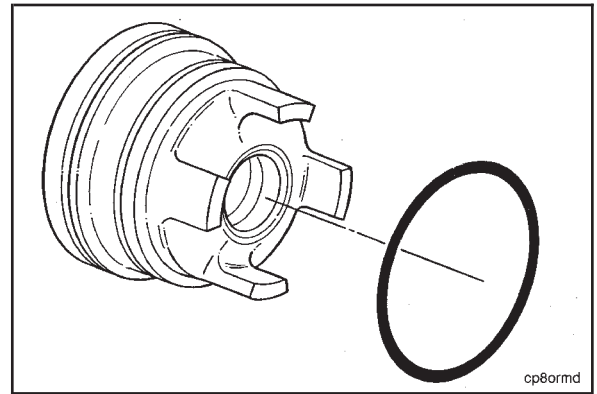


Remove the unloader cap.



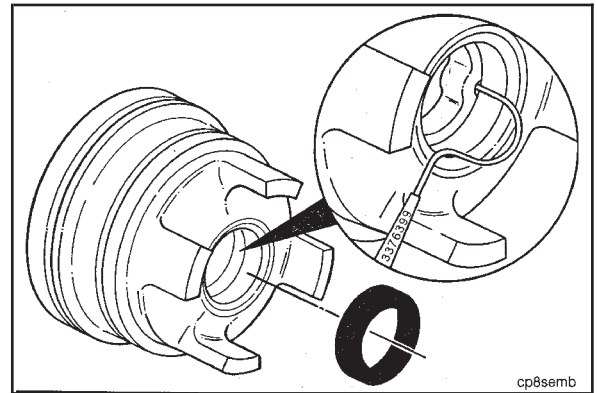
Remove and discard the top o-ring seal.

Remove and discard the bottom o-ring seal.



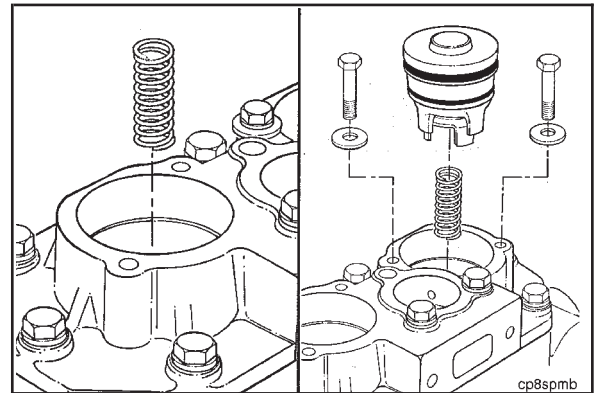
Use a o-ring pick, Part No. 3376399, to remove the rectangular ring seal.

Discard the seal.



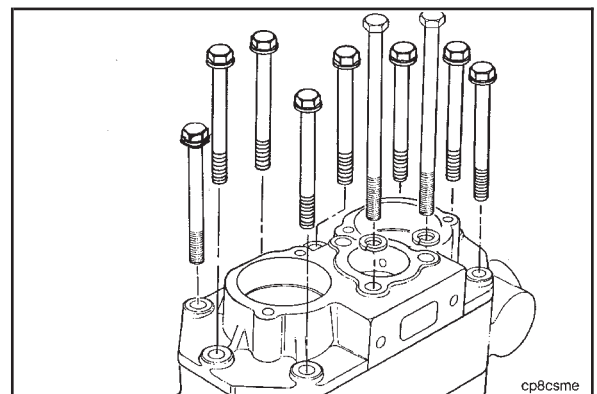
Remove the unloader cap spring.

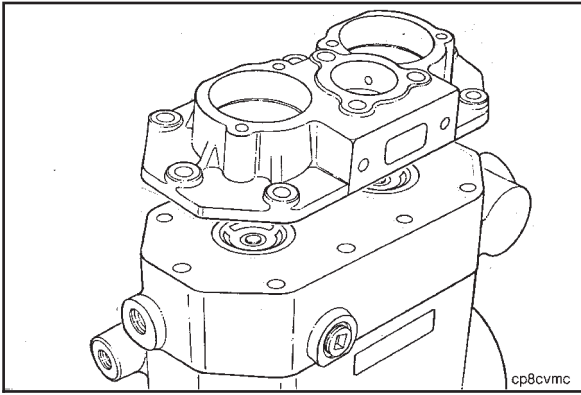
Repeat the last eight steps to remove the other unloader body assembly.



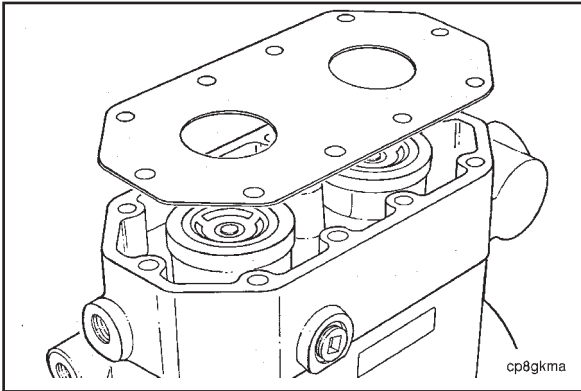
For the ST676, remove the ten remaining hexagon head capscrews and two lock washers.

For the ST773, remove the eight captive washer capscrews and the two hexagon head capscrews and lock washers.

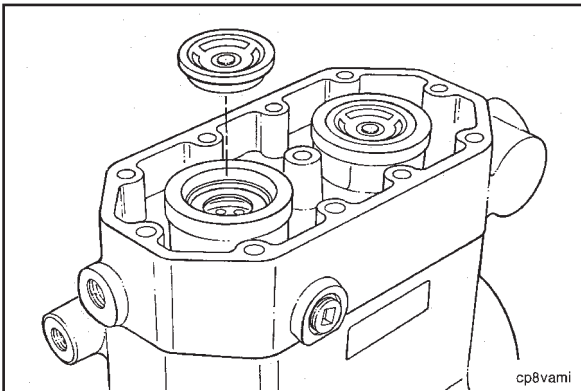




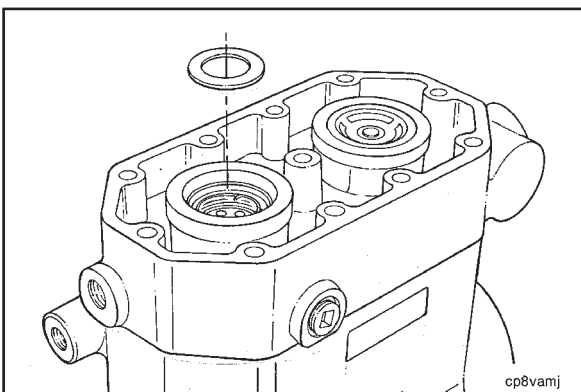
Remove the cover.



Remove and discard the cover gasket.



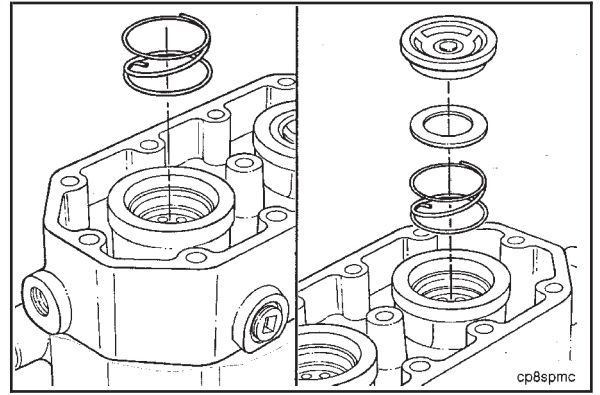
Remove the intake valve seat.



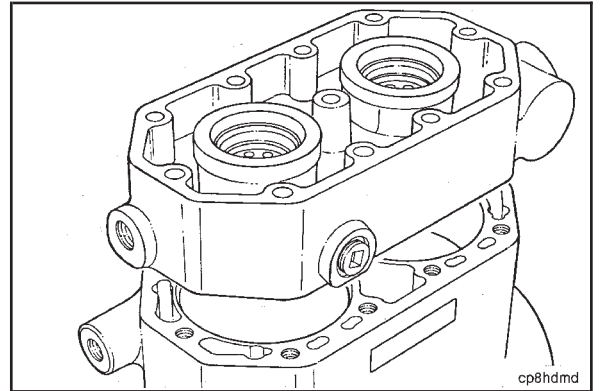
Remove the intake valve.

Remove the intake valve spring.

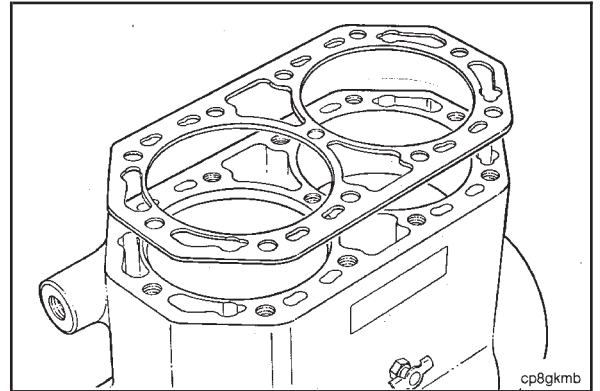
Repeat the last three steps to remove the other intake valve assembly.



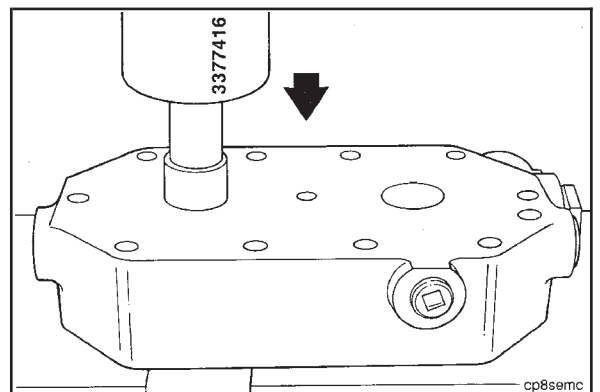
Remove the head.

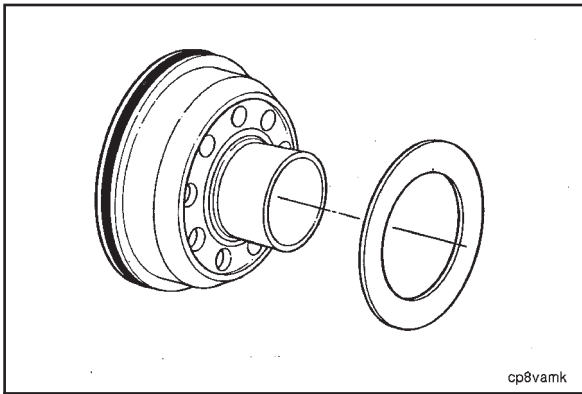


Remove and discard the head gasket.

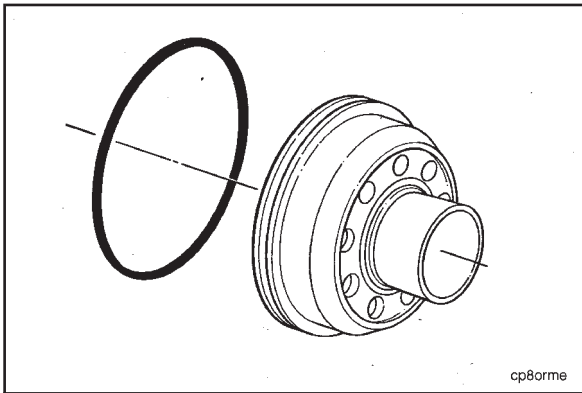


Use a press and a air compressor seat removal tool, Part No. 3377416, to remove the exhaust valve seat assembly from the head.

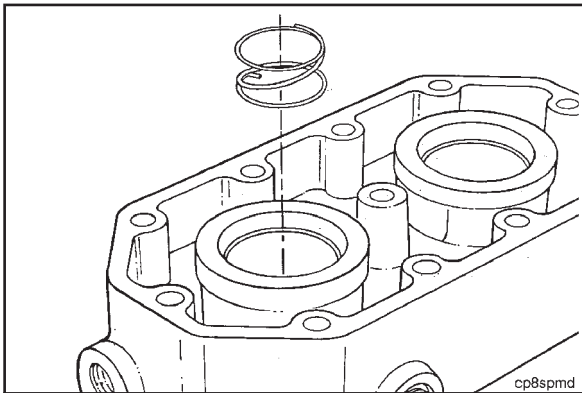




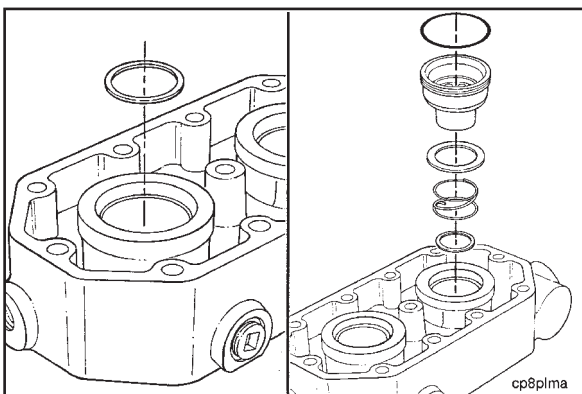
Remove the exhaust valve.



Remove and discard the o-ring seal.



Remove the exhaust valve spring.



Remove the wear plate.

Repeat the last five steps to disassemble the other exhaust valve seat assembly.

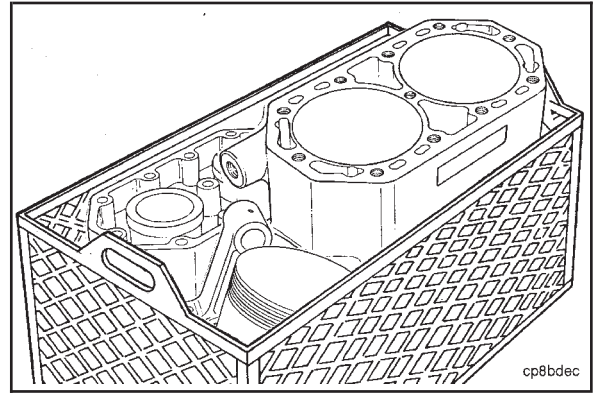
Clean (012-106-006)



WARNING

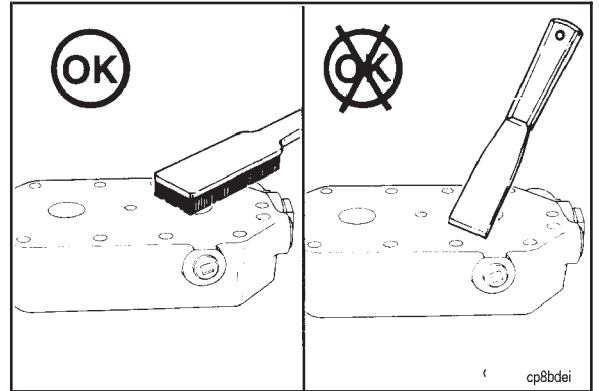
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturers recommendations for use. Wear goggles and protective clothing.

Soak the parts in a kerosene emulsion based cleaner designed to remove carbon. The cleaner **must** have a pH of 9.5 or less to avoid turning aluminum parts black. The cleaner manufacturer or supplier **must** be contacted about solution concentration, temperature and soak time.



NOTE: Do **not** use a scraper to remove carbon and scale, the sealing surfaces can be damaged.

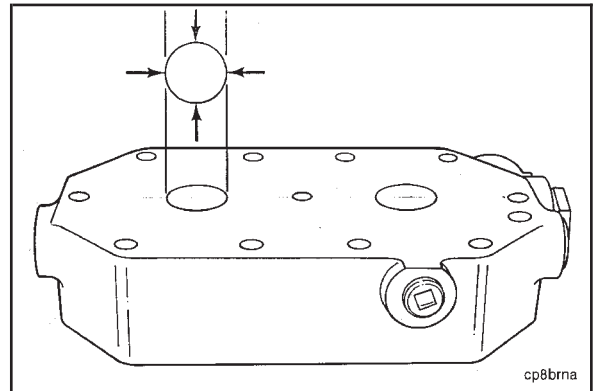
The parts can be scrubbed with a stiff non-metallic bristle brush.



Inspect for Reuse (012-106-007)

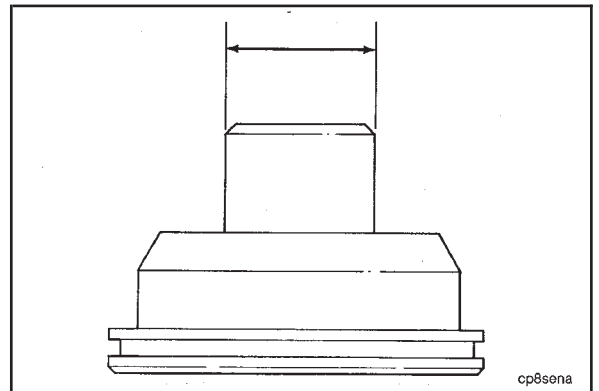
Measure the exhaust valve seat press fit diameter in the cylinder head.

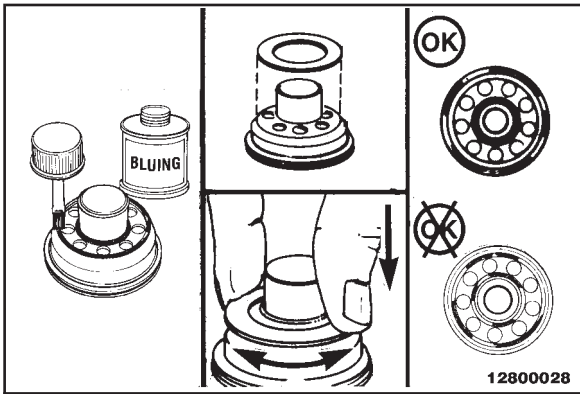
Replace if worn larger than 20.688 mm [0.8145-inch].



Measure the exhaust valve seat press fit diameter.

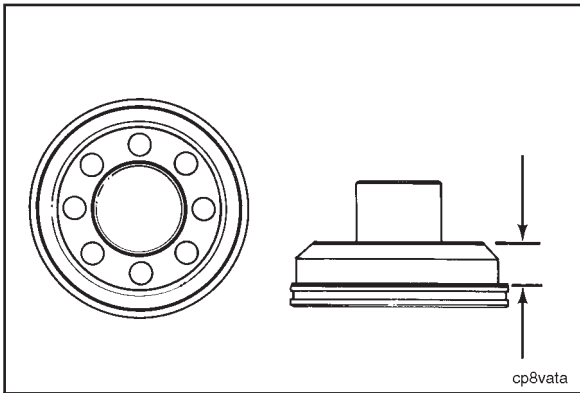
Replace if worn smaller than 20.714 mm [0.8155-inch].





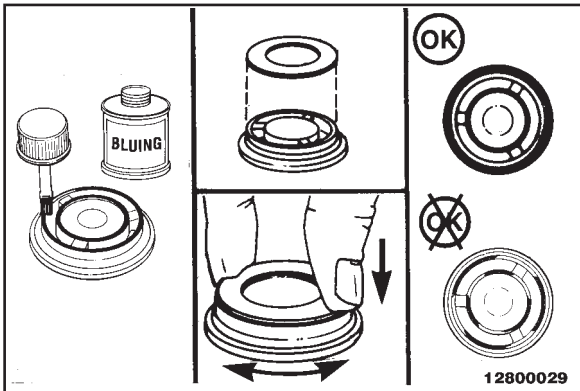
Apply "bluing" to the exhaust seating surface to check the seat.

If the seating surface is **not** 100 percent true discard and replace the valve seat.



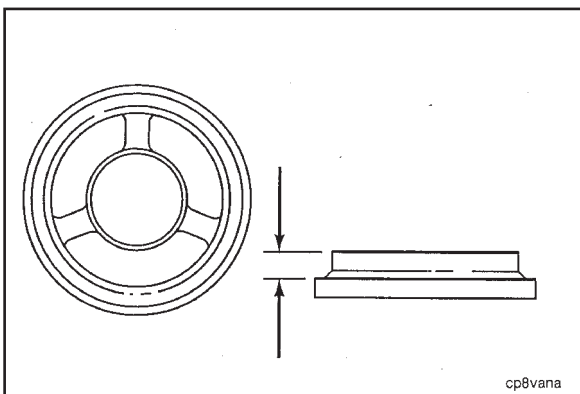
Measure the exhaust valve seat height.

If the height is less than 12.32 mm [0.485-inch] replace the exhaust valve seat.



Apply "bluing" to the intake valve seating surface.

If the seating surface is **not** 100 percent true replace the intake valve seat.



Measure the intake valve seat height.

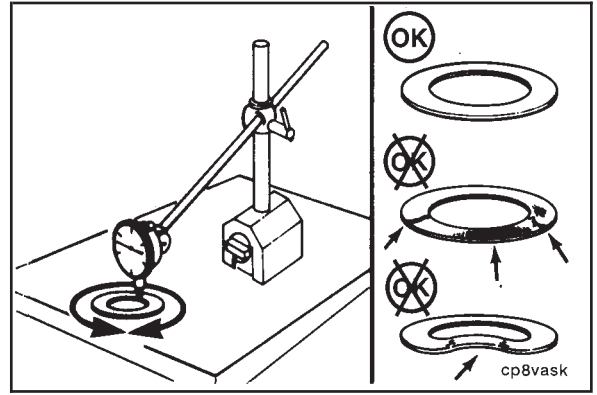
If the height is less than 6.86 mm [0.270-inch] replace the intake valve seat.

Inspect the exhaust and intake valves for cracks and damage.

Measure valves for flatness. The valves **must** be flat within 0.03 mm [0.001-inch].

Replace the valves if cracked, damaged, or not flat.

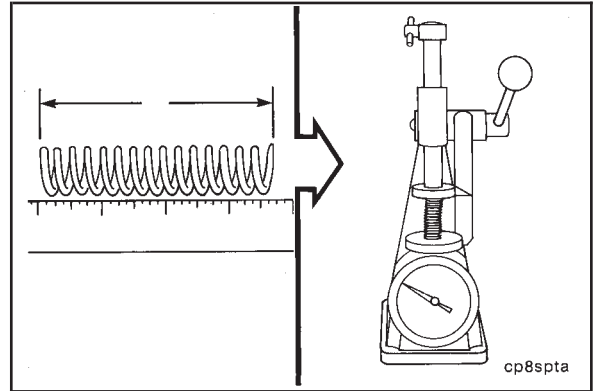
NOTE: Holset Engineering Co., Inc. recommends that new valves be installed during rebuild.



Use a valve spring tester, Part No. 3375182, to check the springs.

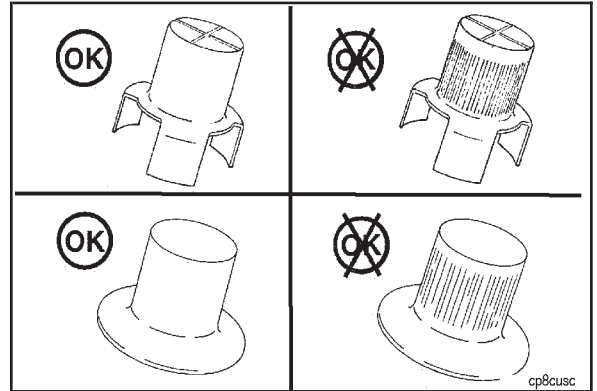
Replace if **not** within limits listed in the Compressor Spring Force Specifications Table at the front of this section.

NOTE: Holset Engineering Co., Inc. recommends that new springs be installed during rebuild.



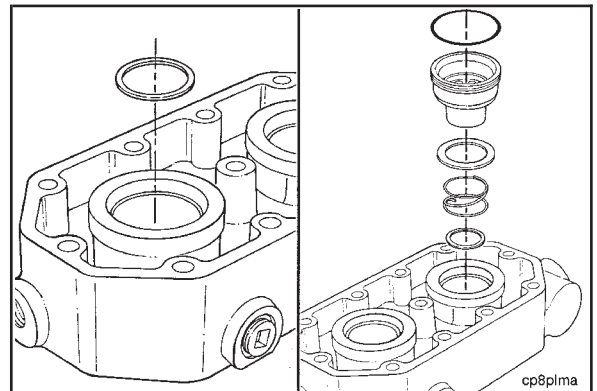
Inspect the upper part of the unloader cap where the rectangular ring seal seats for scoring.

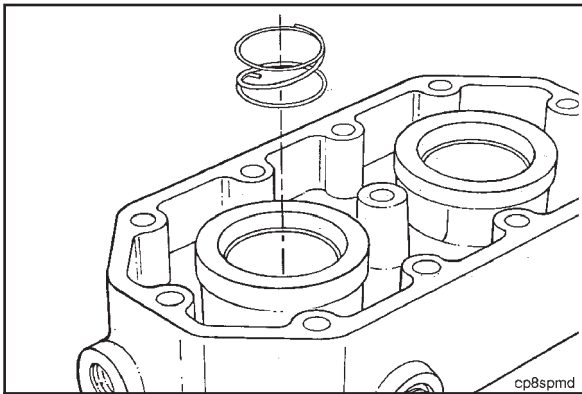
Replace if scored.



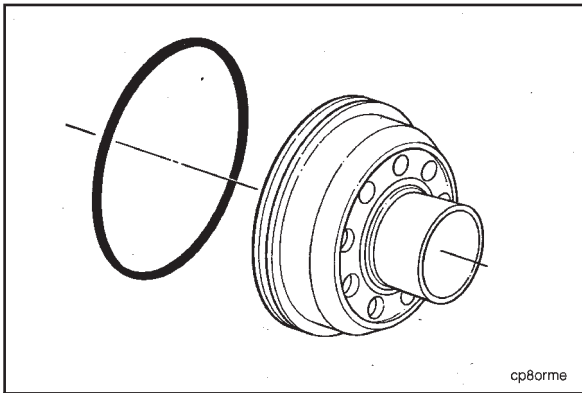
Assemble (012-106-025)

Install the wear plate.

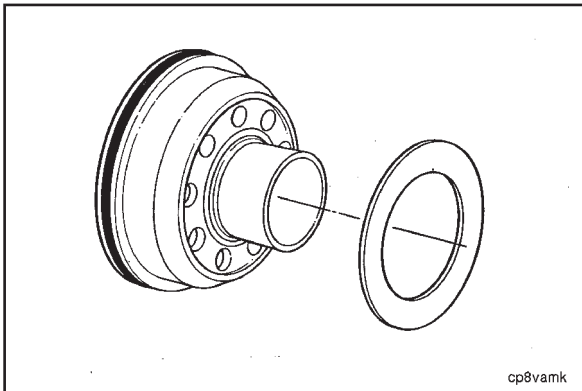




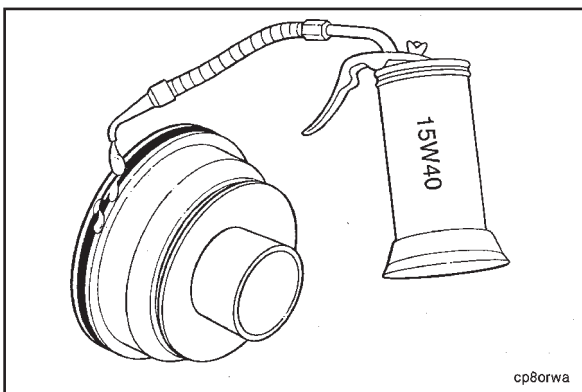
Install the exhaust valve spring with the tang end **down**.
NOTE: Holset Engineering Co., Inc. recommends that new springs be installed during rebuild.



Install a new o-ring seal.



Install the exhaust valve.
NOTE: Holset Engineering Co., Inc. recommends that new exhaust valves be installed during rebuild.

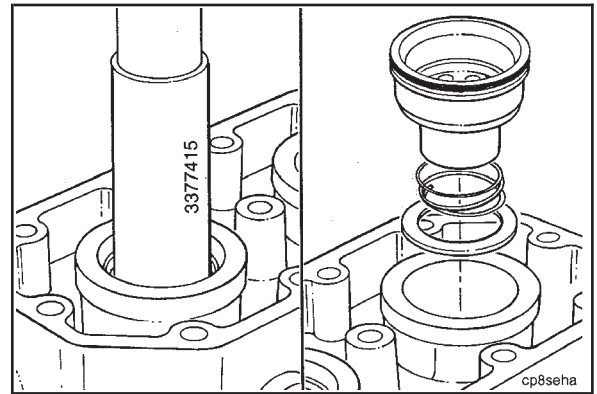


Use clean 15W-40 oil to lubricate the seal.

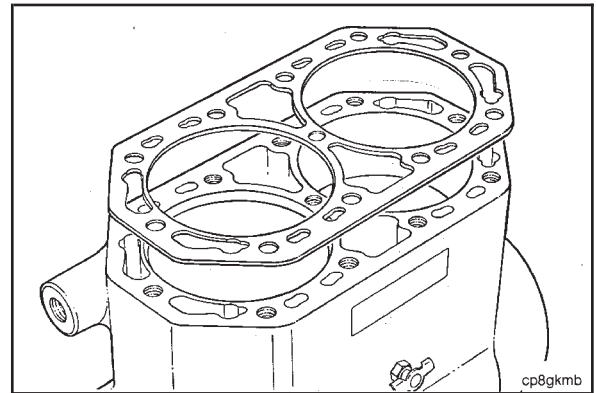
NOTE: Do **not** use excessive pressure on the exhaust valve seats, to do so can distort the valve.

Use a hand press and an air compressor seat installation tool, Part No. 3377415, to press the exhaust valve seat into the head.

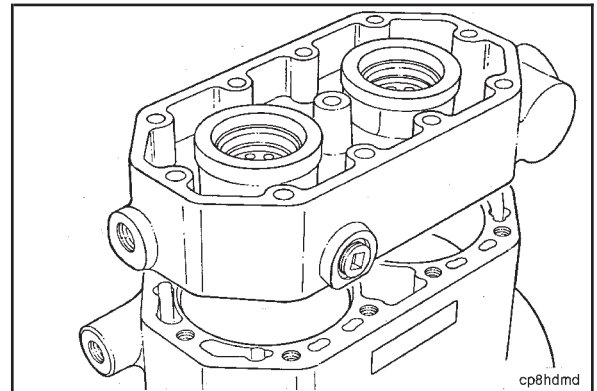
Repeat the last six steps to install the other exhaust valve assembly.



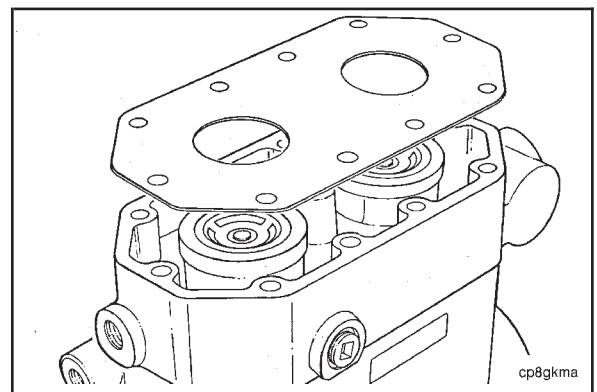
Install a new cylinder head gasket.

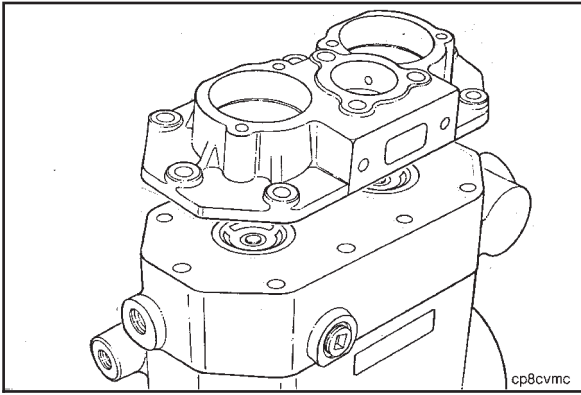


Install the head.

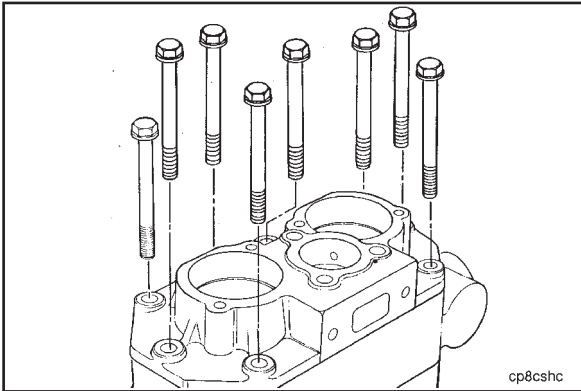


Install a new cover gasket.



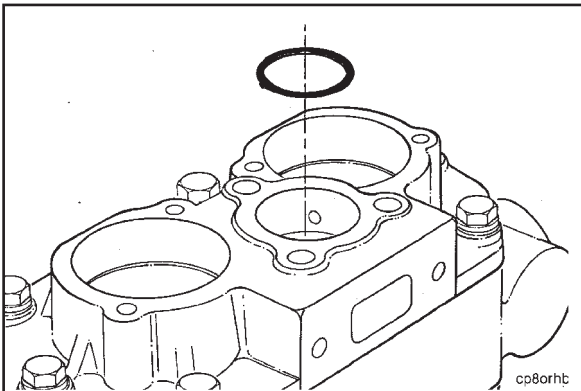


Install the cover.

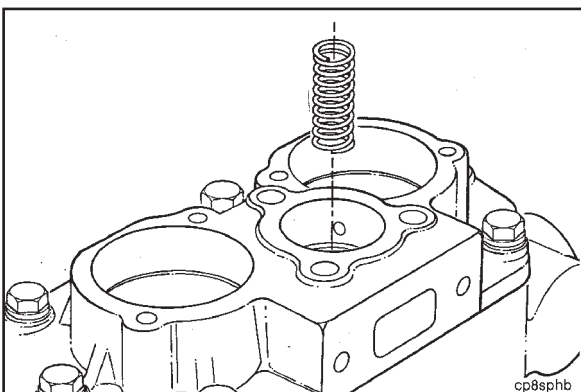


For the ST676, install the eight hexagon head capscrews and finger tighten.

For the ST773, install the eight captive washer capscrews.



Use an o-ring pick, Part No. 3376399, to correctly install the new o-ring seal.



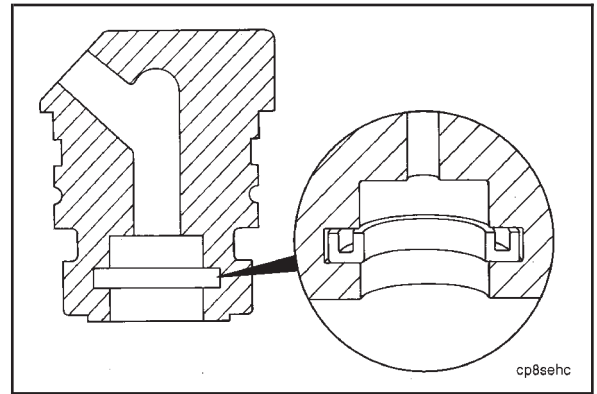
Install the unloading spring.

NOTE: Holset Engineering Co., Inc. recommends that new springs be installed during rebuild.

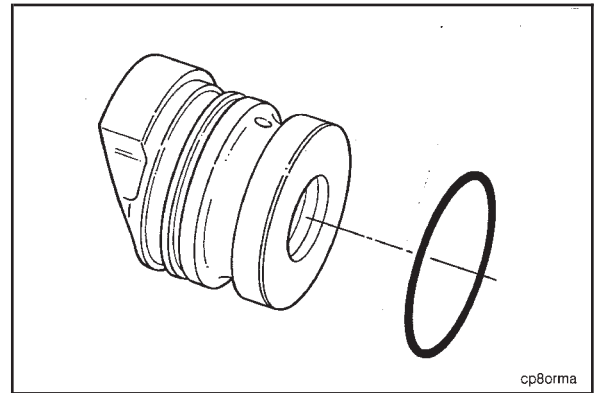
⚠ CAUTION ⚠

The rectangular ring seal must be installed with the grooved side up; failure to do so will result in air system damage and brake failure.

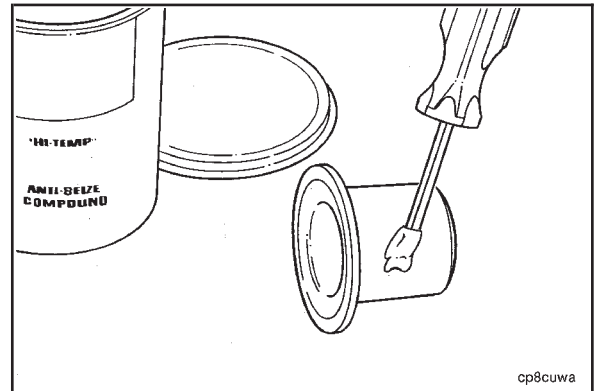
Use a o-ring pick, Part No. 3376399, to correctly install the new rectangular ring seal, if the unloader body has a cavity for this o-ring.



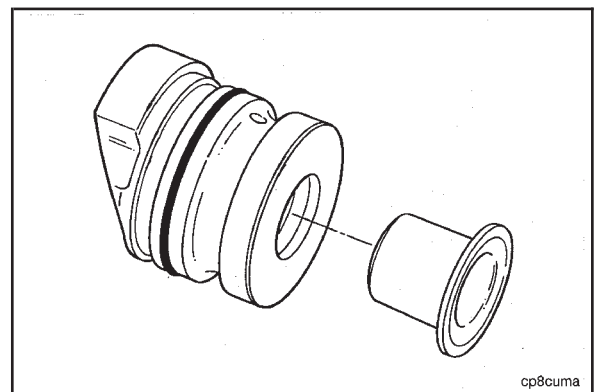
Install a new o-ring seal.

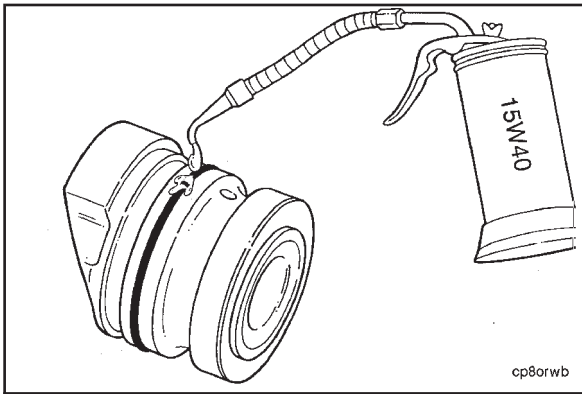


Use anti-seize compound to lubricate the outside diameter of the unloader valve cap.

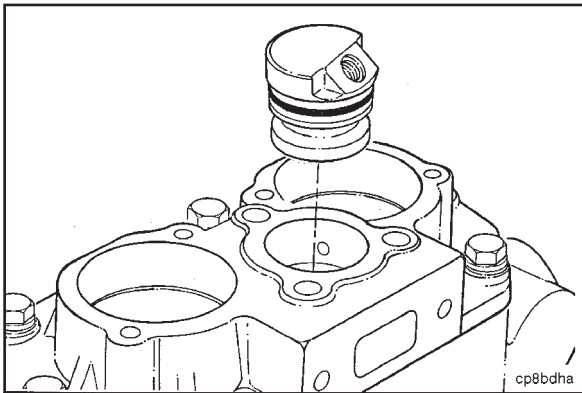


Install the cap into the unloading valve body.





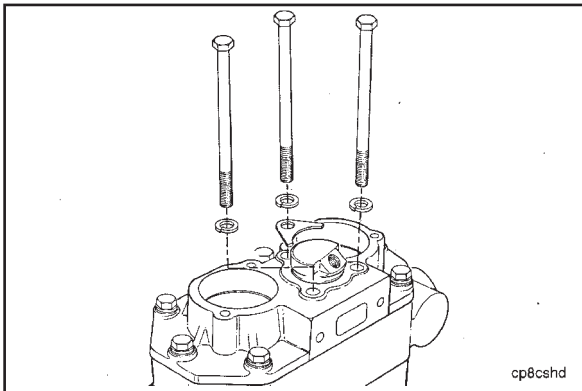
Use clean 15W-40 oil to lubricate the seal.



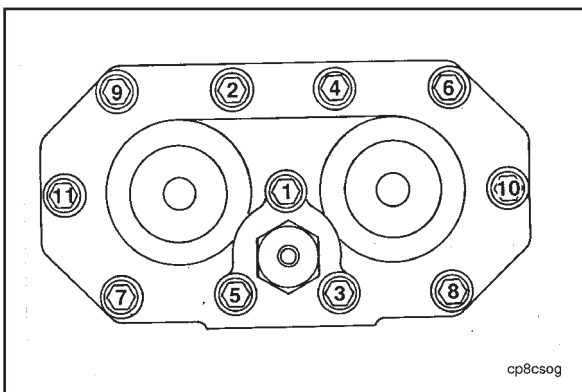
CAUTION

The unloader valve body is installed under spring tension. Carefully install to avoid personal injury.

Install the body into the cover.



Install the retaining clamp and the three lock washers and the three hex head capscrews.

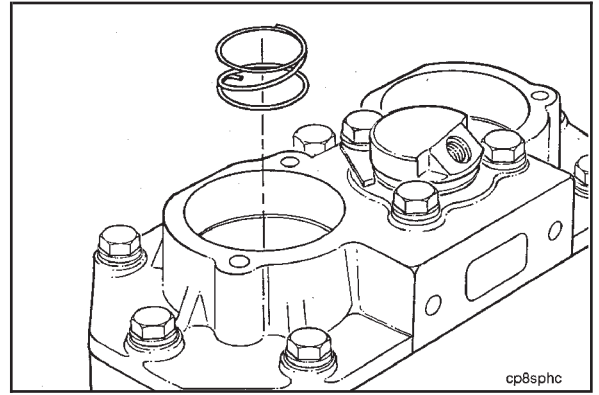


Tighten the capscrews in the sequence shown.

Torque Value: 41 N•m [30 ft-lb]

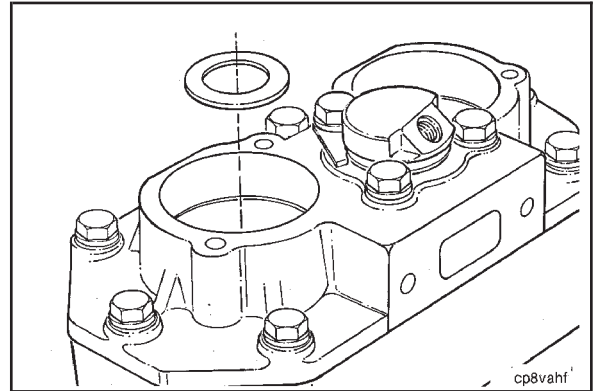
Install the intake valve spring with the tang end **down**.

NOTE: Holset Engineering Co., Inc. recommends that new springs be installed during rebuild.

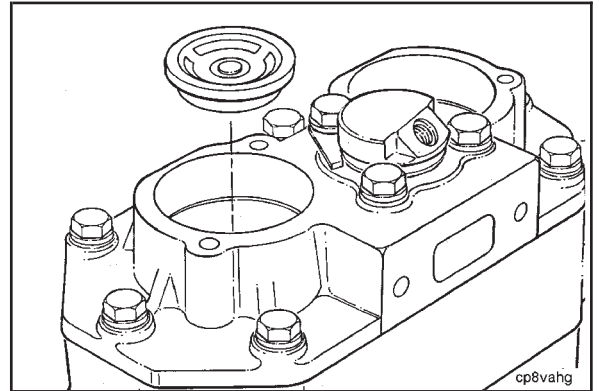


Install the intake valve.

NOTE: Holset Engineering Co., Inc. recommends that new intake valves be installed during rebuild.

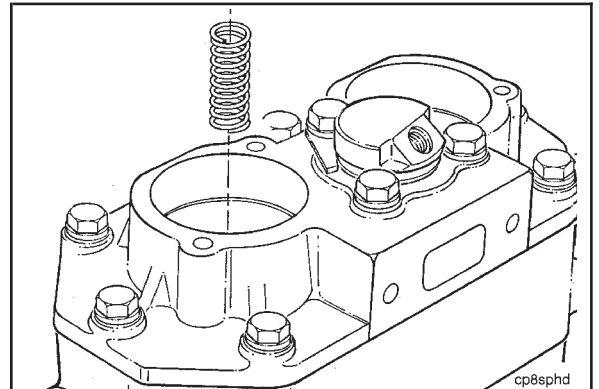


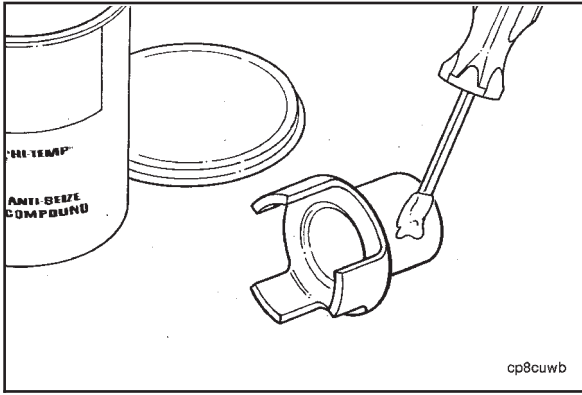
Install the intake valve seat with the flange end **up**.



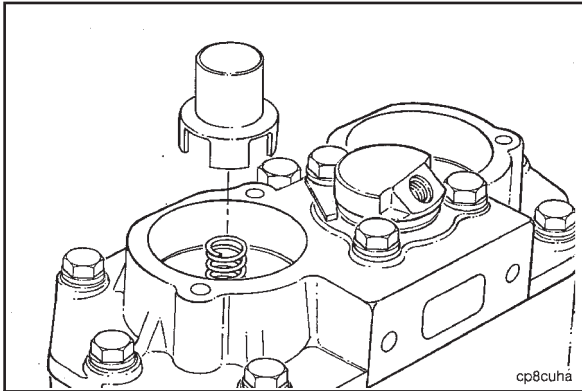
Install the unloader cap spring.

NOTE: Holset Engineering Co., Inc. recommends that new springs be installed during rebuild.

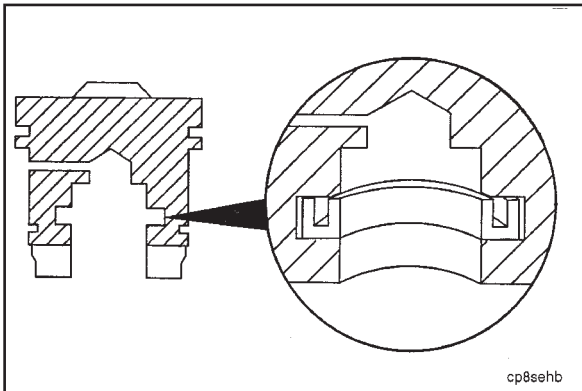




Use anti-seize compound to lubricate the outside diameter of the unloader valve cap.



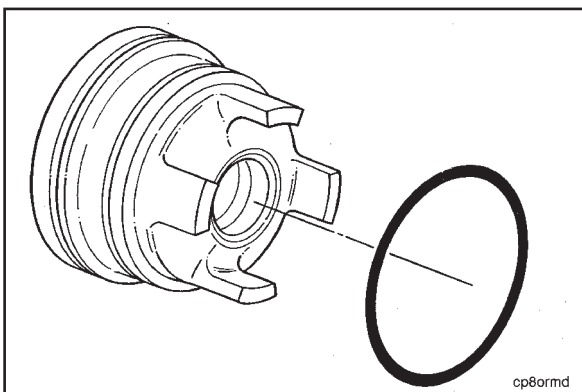
Install the cap into the cover and make sure the three tangs are in the three slots of the intake valve seat.



⚠ CAUTION ⚠

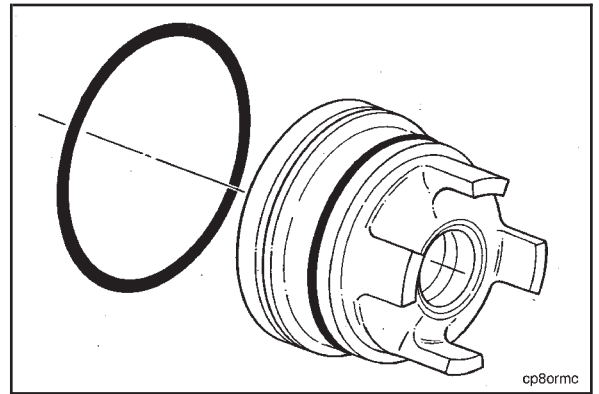
The rectangular ring seal must be installed with the grooved side up; failure to do so will result in air system damage and brake failure.

Use a o-ring pick, Part No. 3376399, to correctly install the new rectangular ring seal.

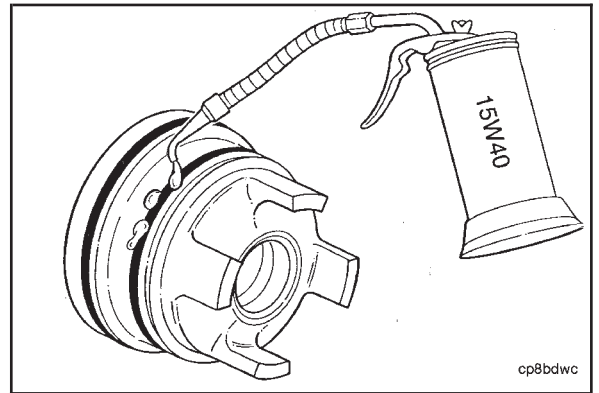


Install a new bottom o-ring seal.

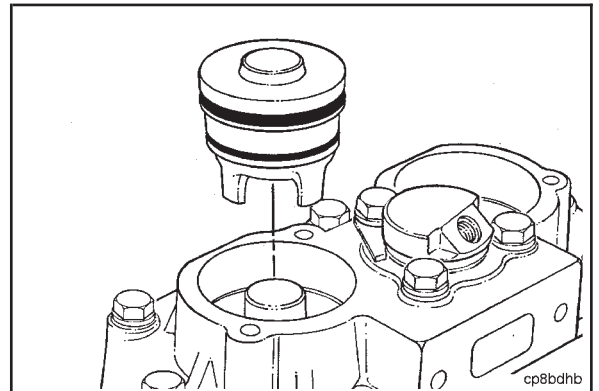
Install a new top o-ring seal.



Use clean 15W-40 oil to lubricate the seals.



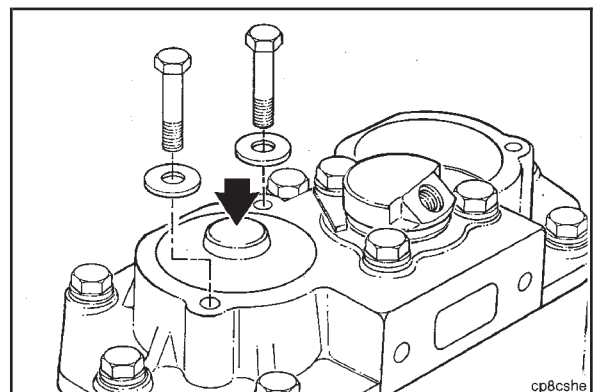
Install the unloading body into the cover.

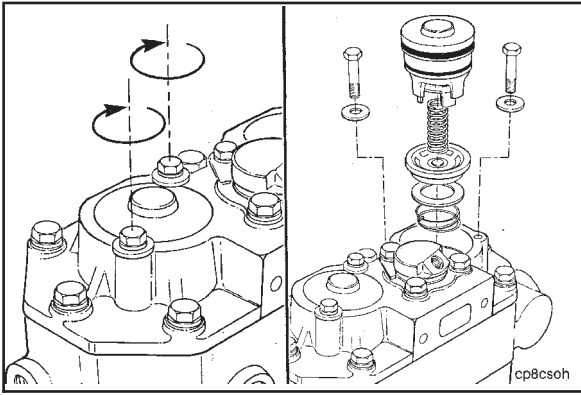


⚠ CAUTION ⚠

The unloader body is installed with spring tension, it must be carefully installed to prevent personal injury.

Hold down on the unloading body firmly and install the capscrews and plain washers so as to prevent the unloader body from being thrown free and causing personnel injury.





Tighten the capscrews.

Torque Value: 14 N•m [10 ft-lb]

Repeat the last thirteen steps to install the other unloading body assembly.

Section 13 - Electrical Equipment - Group 13

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Electrical Equipment - General Information

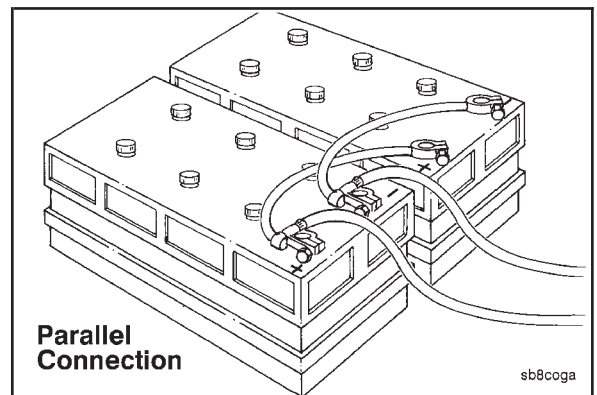
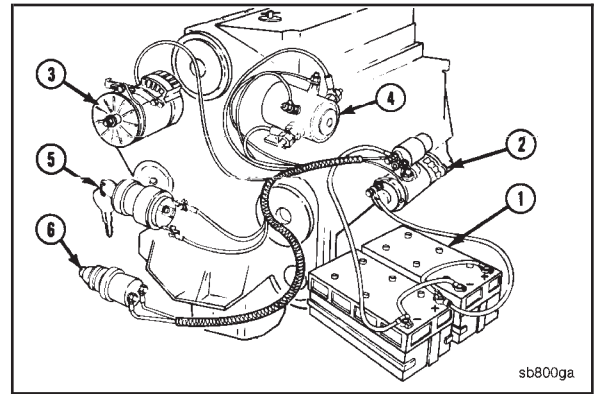
The basic heavy-duty electrical system consists of:

- Batteries (1) (usually three or four connected in parallel).
- A starting motor (2)
- An alternator (3)
- A magnetic switch (4)
- An ignition switch (5)
- A push button switch (6)
- All necessary wiring

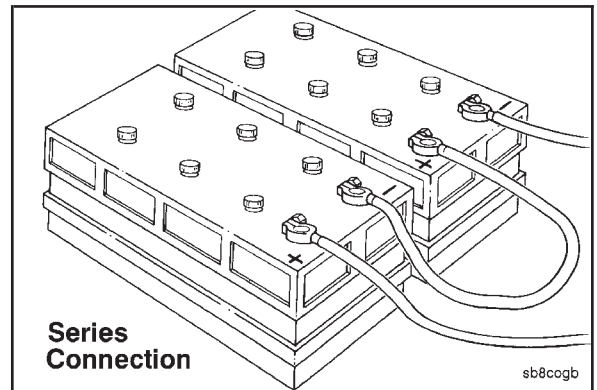
All components **must** be carefully matched.

The accompanying illustrations show typical parallel and series battery connections:

- Parallel connection



- Series connection



Specifications

Electrical System

Minimum Recommended Battery Capacity

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

1. The number of plates within a given battery size determines reserve capacity. Reserve capacity determines the length of time which sustained cranking can occur.
2. CCA ratings are based on two 12 volt batteries in series.

A minimum of 6.5 volts at the 3-pin power connector is required to power-up the ECM on CELECT™ and CELECT™ Plus engines.

A minimum of 9 volts at the ECM connector is required to power-up the ECM on CENTRY engines.

Minimum Battery Capacity @ -18 to 0°C [0 to 32°F] ambient temperature

12-volt starter	640 Reserve Capacity Amperes - 1800 cold cranking amps @ -18°C [0°F]
24-volt starter	320 Reserve Capacity Amperes - 900 cold cranking amps @ -18°C [0°F]

Minimum Battery Capacity above 0°C [32°F] ambient temperature

12-volt starter	480 Reserve Capacity Amperes - 1280 cold cranking amps @ -18°C [0°F]
24-volt starter	240 Reserve Capacity Amperes - 640 cold cranking amps @ -18°C [0°F]

Maximum Starting Circuit Resistance

12-volt starter	0.00075 OHMS
24-volt starter	0.00200 OHMS

Battery Cable Sizes - American Wire Gauge (Maximum length in cranking motor circuit)

12-Volt	
No. 00	3.7 Meters [12 Feet]
No. 000	4.9 Meters [16 Feet]
No. 0000 or Two No. 0*	6.1 Meters [20 Feet]
Two No. 00	7.6 Meters [25 Feet]
12-Volt High Output	
No. 00	2.1 Meters [7 Feet]
No. 000	2.7 Meters [9 Feet]
No. 0000 or Two No. 0*	3.7 Meters [12 Feet]
Two No. 00	4.3 Meters [14 Feet]
24 to 32-Volts	
No. 00	6.1 Meters [20 Feet]
No. 000	8.2 Meters [27 Feet]
No. 0000 or Two No. 0*	10.7 Meters [35 Feet]
Two No. 00	13.7 Meters [45 Feet]

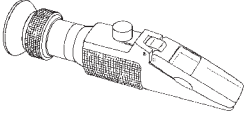
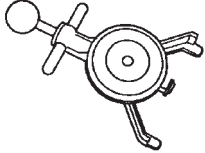
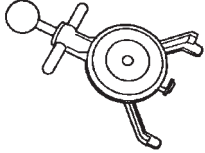
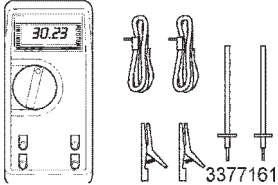
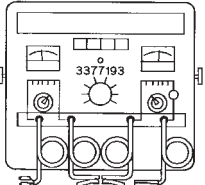
Minimum ambient temperature without starting aid -1°C [30°F]

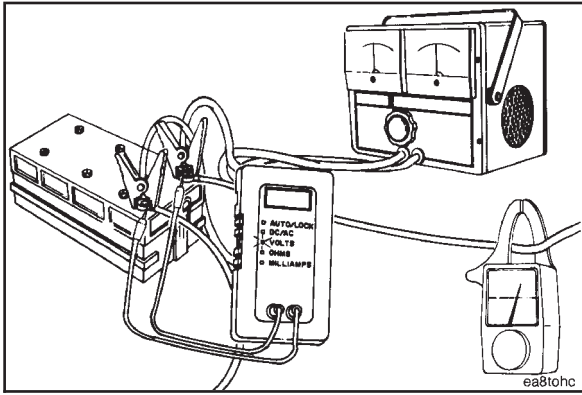
Minimum cranking speed without starting aid 170 rpm

* Two strands of No. 0 cable can be used in place of one No. 0000 cable providing all connections are carefully made to ensure equal current flow in each parallel cable.

Service Tools Electrical Equipment

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

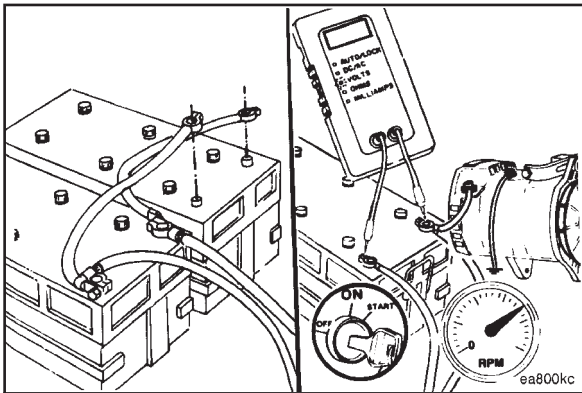
Tool No.	Tool Description	Tool Illustration
CC-2800	<p>Refractometer</p> <p>The Fleetguard® refractometer is used to check the charge condition of a conventional battery.</p>	 <p style="text-align: right; font-size: small;">ra80ds</p>
ST-1293	<p>Belt Tension Gauge</p> <p>Used to measure belt tension on 'K' type v-ribbed belt with six to nine ribs.</p>	 <p style="text-align: right; font-size: small;">fa8togc</p>
ST-1138	<p>Belt Tension Gauge</p> <p>Used to check the alternator v-belt tension</p>	 <p style="text-align: right; font-size: small;">fa8togc</p>
3377161	<p>Digital Multimeter</p> <p>Used to measure electrical circuits: voltage (volts), resistance (ohms) and current (amps). The digital multimeter is contained in compusave calibration kit, Part No. 3377151.</p>	 <p style="text-align: right; font-size: small;">3377161</p>
3377193	<p>Inductive Charging - Cranking Systems Analyzer</p> <p>Used to test generators, alternators, relays, starters, regulators, and batteries. Contains built-in voltmeter and ammeter.</p>	 <p style="text-align: right; font-size: small;">3377193</p>



Alternator (013-001) Initial Check (013-001-001)

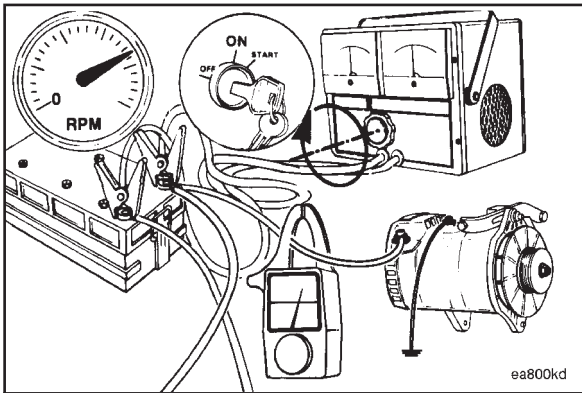
Connect a carbon pile load (battery tester) across the batteries in one of the battery boxes.

Clamp an induction pickup type ammeter around the battery cable, or use digital multimeter, Part No. 3377161, with clamp or current probe, Part No. 3823574.



Disconnect any cables that lead to any other battery boxes in the circuit.

Operate the engine at high idle and measure the alternator voltage output to the batteries with digital multimeter, Part No. 3377161. Refer to the equipment manufacturer's specifications.

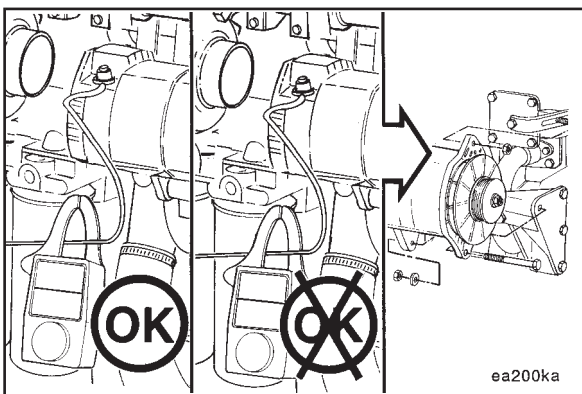


Operate the engine at high idle and adjust the battery tester to apply the maximum rated amperage load to the alternator. Refer to the manufacturer's specifications.



NOTE: The alternator maximum rated amperage output is normally stamped or labeled on the alternator.

Measure the alternator amperage output. Refer to the alternator manufacturer's specifications.

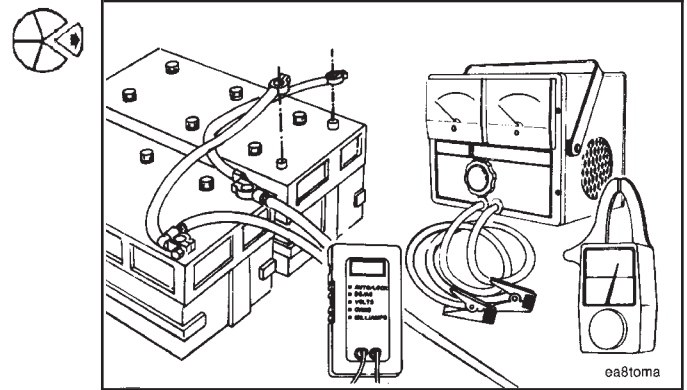


If the gauge on the carbon pile load testing equipment does **not** indicate approximately the same output as the induction-type ammeter, determine which is defective and replace it. Refer to the equipment manufacturer's instructions.



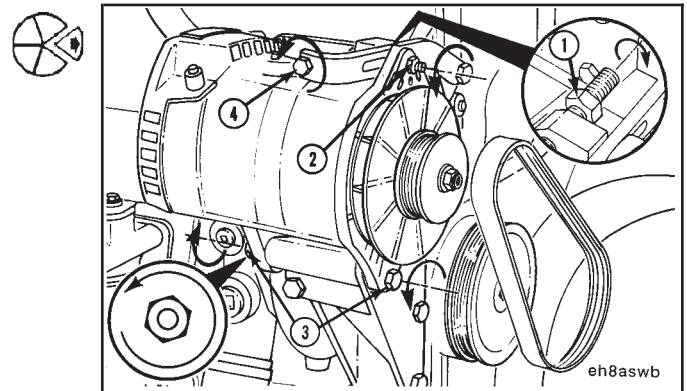
If the alternator output (amps) is **not** within 10 percent of rated output, repair or replace the alternator. Refer to the manufacturer's instructions for repair procedures.

Shut off the engine and remove the test equipment.

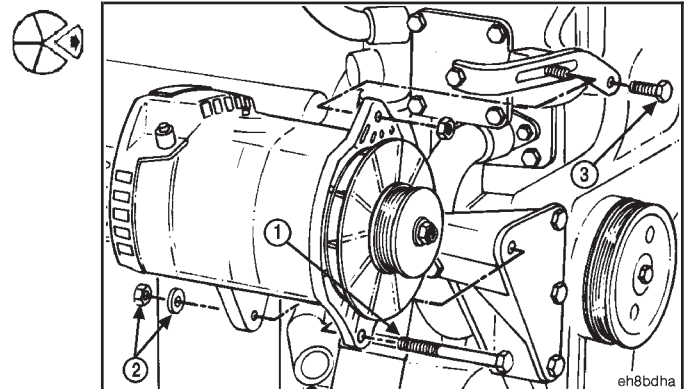


Remove (013-001-002)

- Loosen the adjusting screw locknut (1).
- Loosen the retaining nut (2).
- Loosen the alternator mounting capscrew (3).
- Turn the adjusting screw **counterclockwise** to release tension.
- Remove the alternator belt.

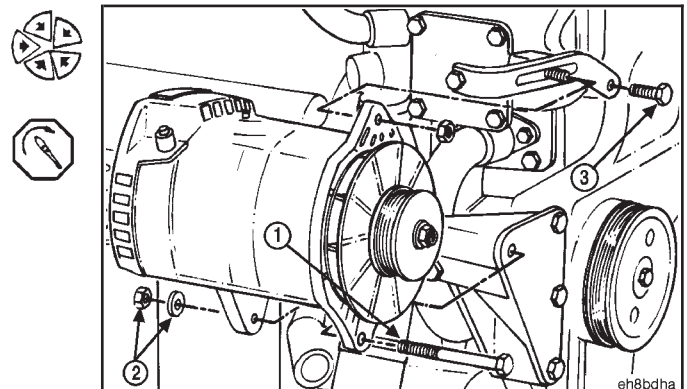


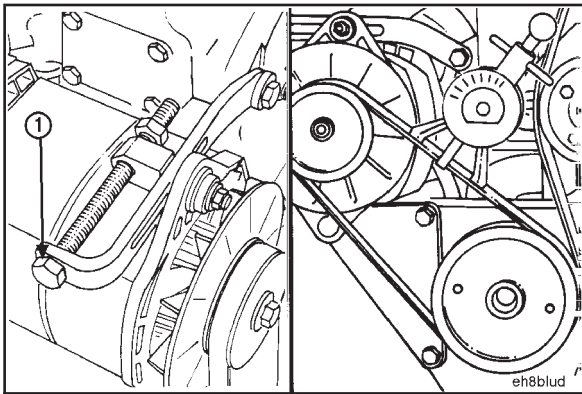
- Remove the adjusting link mounting capscrew and the adjusting link.
- Remove the alternator mounting capscrew, nut, washer and the alternator.



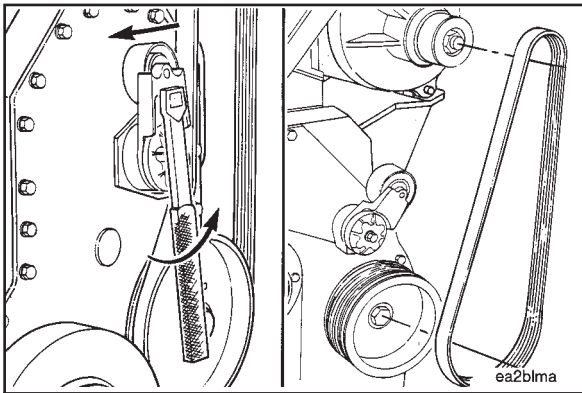
Install (013-001-026)

- Install the adjusting link and mounting capscrew.
- Torque Value:** 47 N•m [35 ft-lb]
- Install the alternator, capscrew, washer and nut to the mounting bracket and adjusting link.
- NOTE:** Do **not** tighten the capscrews and nuts until the alternator belt is installed and adjusted.





Install and adjust the alternator belt. Refer to Procedure 013-005-026.



Drive Belt, Alternator (013-005)

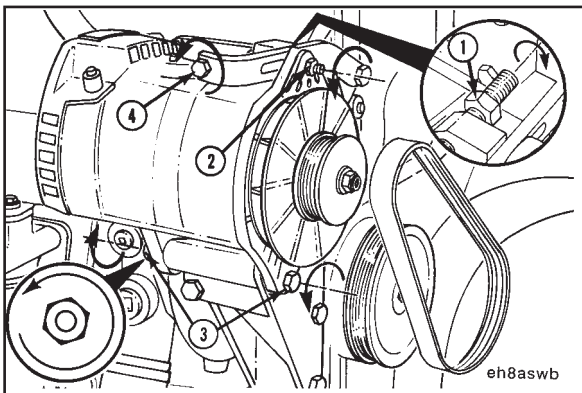
Remove (013-005-002)

Automatic Belt Tensioner

Insert a 3/8 inch breaker bar into the space provided on the tensioner.

Rotate the tensioner away from the belt until it stops.

Remove the alternator belt while holding the tensioner back.



Adjustment Link Type

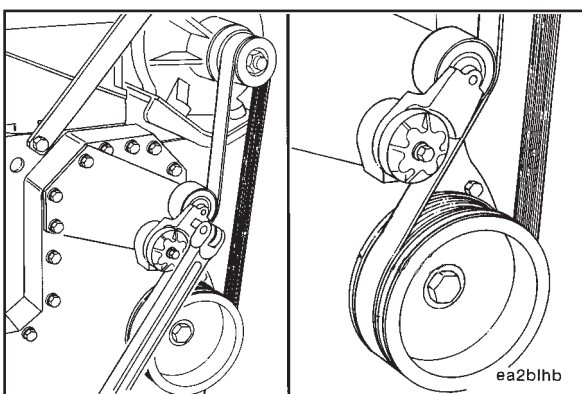
Loosen the adjusting screw locknut (1).

Loosen the adjustment link locking capscrew (2).

Loosen the alternator mounting capscrew (3).

Turn the adjusting screw (4) **counterclockwise** to release tension.

Remove the alternator belt.



Install (013-005-026)

Automatic Belt Tensioner

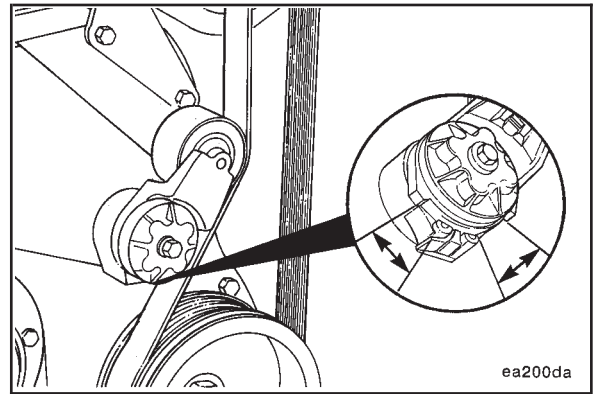
Install a new belt over the pulleys while holding the tensioner back. Be careful **not** to damage the belt while working it over the flanged pulleys.

Release the tensioner and remove the breaker bar.

Belt drive systems equipped with an automatic belt tensioner **cannot** be adjusted. A belt tension gauge will **not** give an accurate measure of the belt tension. The automatic belt tensioner is designed to maintain proper belt tension over the life of the belt. Only visual inspection of the tensioner is required.

The belt tensioner is designed to operate within the limit of arm movement provided by the cast stops when the belt length and geometry are correct.

If the tensioner is hitting either of the limits during operation, check the mounting brackets and the belt length. Loose brackets, bracket failure, alternator movement, incorrect belt length or belt failure can cause the tensioner to hit the limits.



ea200da

Adjustment Link Type

Install a new belt on the water pump and alternator pulleys. To prevent damage, do **not** roll a belt over the pulley or pry it on with a tool.

Turn the adjusting screw (1) **clockwise** to increase the belt tension.

Use belt tension gauge, Part No. ST-1293, to measure the belt tension. Refer to Drive Belt Tension in Section V for the correct tension value for the belt you are installing.

NOTE: A belt is considered used if it has been in operation for 10 minutes or longer.

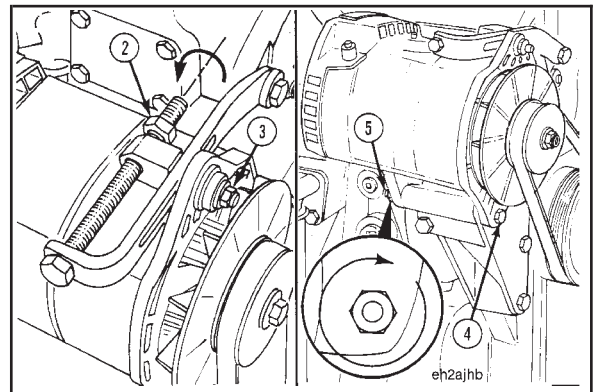
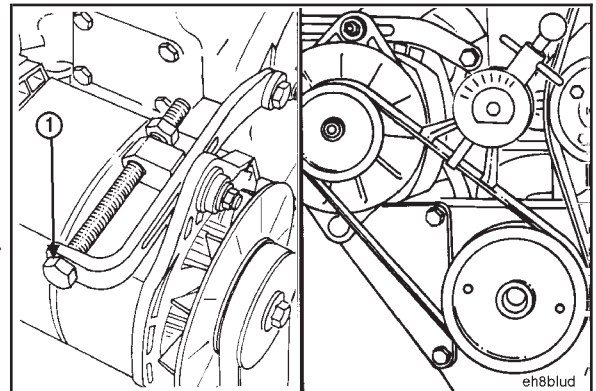
NOTE: If the alternator drive belt has more than five ribs, refer to the belt tension chart in Section V for correct belt adjustment.

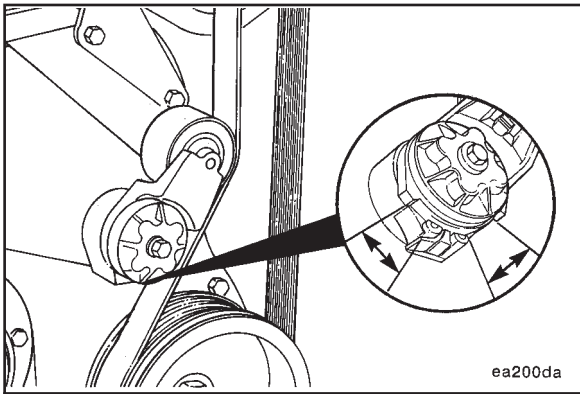
Tighten the adjusting screw locknut (2) against the retainer. Tighten the adjustment link locking capscrew (3).

Torque Value: 80 N•m [60 ft-lb]

Tighten the pivot capscrew (4) and nut (5).

Torque Value: 47 N•m [35 ft-lb]





Adjust (013-005-029)

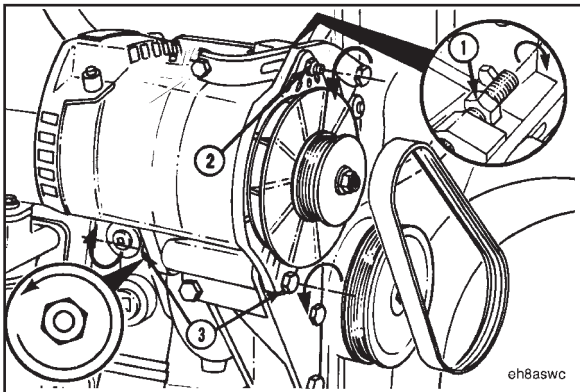
Automatic Belt Tensioner

Belt drive systems equipped with an automatic belt tensioner **cannot** be adjusted. A belt tension gauge will **not** give an accurate measure of the belt tension. The automatic belt tensioner is designed to maintain proper belt tension over the life of the belt. Only visual inspection of the tensioner is required.

The belt tensioner is designed to operate within the limit of arm movement provided by the cast stops when the belt length and geometry are correct.

If the tensioner is hitting either of the limits during operation, check the mounting brackets and the belt length. Loose brackets, bracket failure, alternator movement, incorrect belt length or belt failure can cause the tensioner to hit the limits.

NOTE: If the engine is equipped with a secondary alternator, refer to the vehicle manufacturer for the secondary alternator belt adjustment procedure.

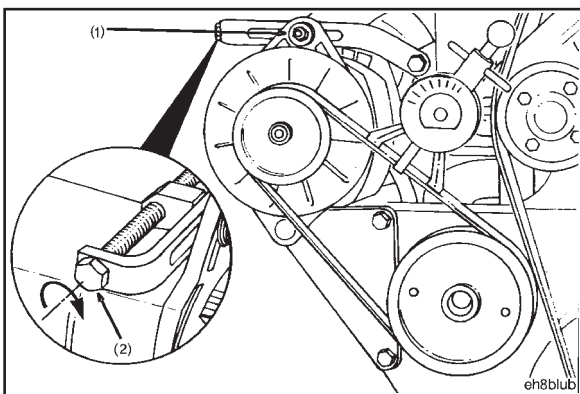


Adjustment Link Type

Loosen the adjusting screw locknut (1).

Loosen the adjustment link locking capscrew (2).

Loosen the pivot capscrew and nut (3).



Use belt tension gauge, Part No. ST-1293, to measure belt tension.



Turn the alternator adjusting screw **clockwise** to tighten the belt. Refer to Drive Belt Tension in Section V for the correct belt tension for the belt you are adjusting.

NOTE: A belt is considered used if it has been in operation for 10 minutes or longer.

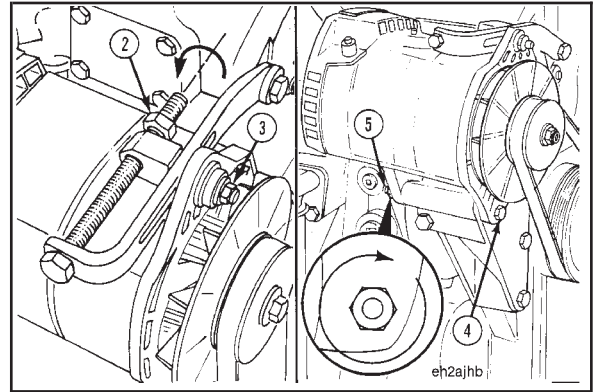
NOTE: If the alternator drive belt has more than five ribs, refer to the belt tension chart in Section V for correct belt adjustment.

Tighten the adjusting screw locknut (2) against the retainer.
Tighten the adjustment link locking capscrew (3).

Torque Value: 80 N•m [60 ft-lb]

Tighten the pivot capscrew (4) and nut (5).

Torque Value: 47 N•m [35 ft-lb]



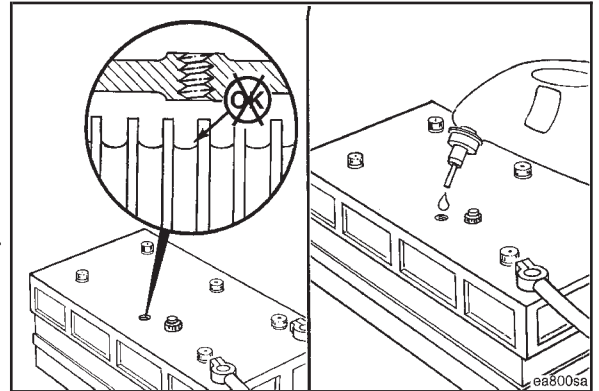
Batteries (013-007)

Initial Check (013-007-001)

If conventional batteries are used, remove the cell caps or covers and check the electrolyte level.

NOTE: Maintenance-free batteries are sealed and do **not** require the addition of water.

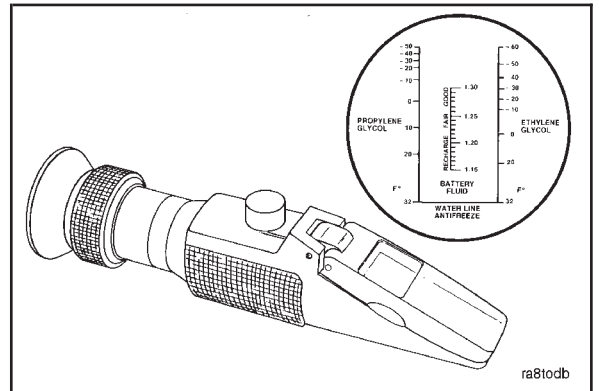
Fill each battery cell with distilled water. Refer to the manufacturer's specifications.



Use the Fleetguard® refractometer, Part No. CC-2800, to check the specific gravity of the battery electrolyte.

Refer to the battery fluid column in the refractometer to determine the state-of-charge of each battery cell.

If water has been added to a dry cell, recharge the battery to mix the added water with the existing battery electrolyte to prevent incorrect readings.



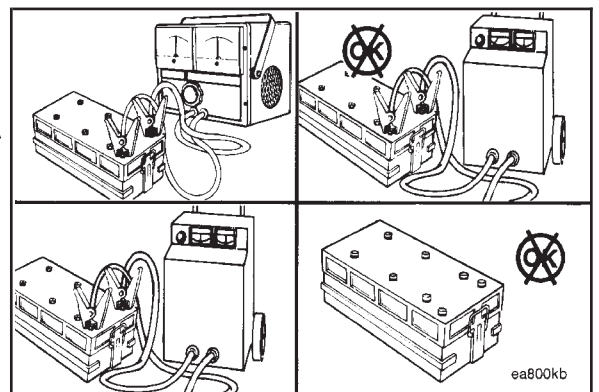
⚠ CAUTION ⚠

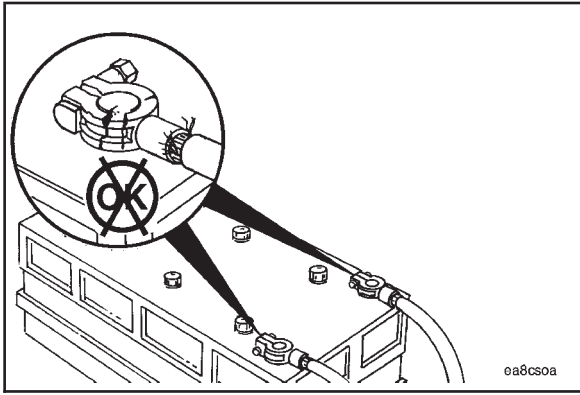
Do not connect battery charging cables to any CELECT™ part. This can damage the CELECT™ parts.

Use battery tester, Part No. 3377193, 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.



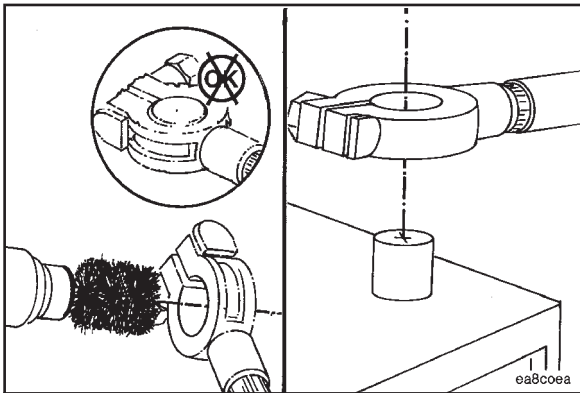


Battery Cables and Connections (013-009)

Initial Check (013-009-001)

Visually inspect the battery terminals for loose, broken or corroded connections.

Repair or replace broken cables or terminals.

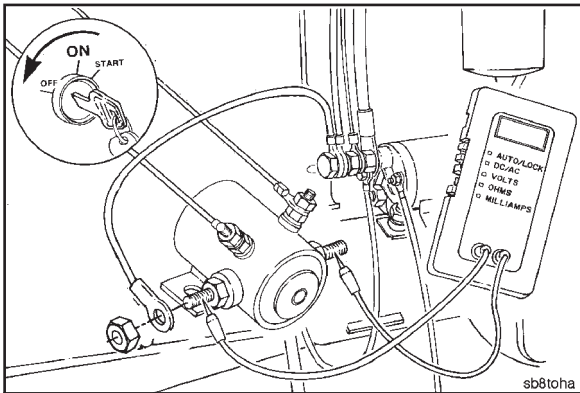


If the connections are corroded, remove the cables and use a battery brush to clean the cable and battery terminals.

Install and tighten the battery cables.



Use grease to coat the battery terminals to prevent corrosion.



Starter Magnetic Switch (013-017)

Current Check (013-017-042)

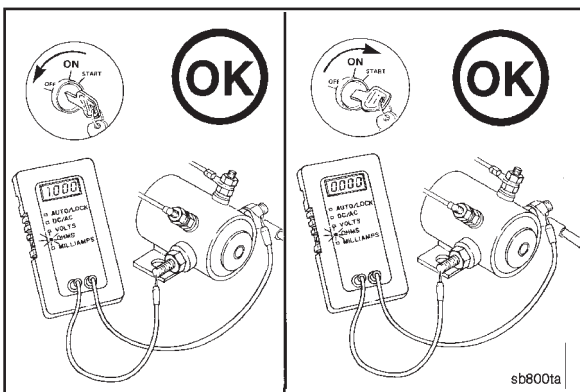


WARNING

Be sure the starter switch is in the "OFF" position to prevent electrical shock.

Remove the cable connecting the magnetic switch to the starter solenoid from the magnetic switch terminal.

Connect the leads of the digital multimeter, Part No. 3377161, to the two large switch terminals.



Set the multimeter to measure resistance (OHMS).

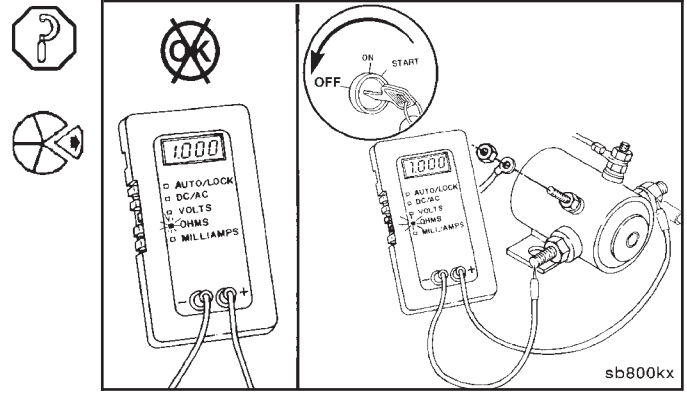
With the starter switch off, the multimeter **must** indicate resistance at infinity, open circuit.

Turn the starter switch to the "START" position.

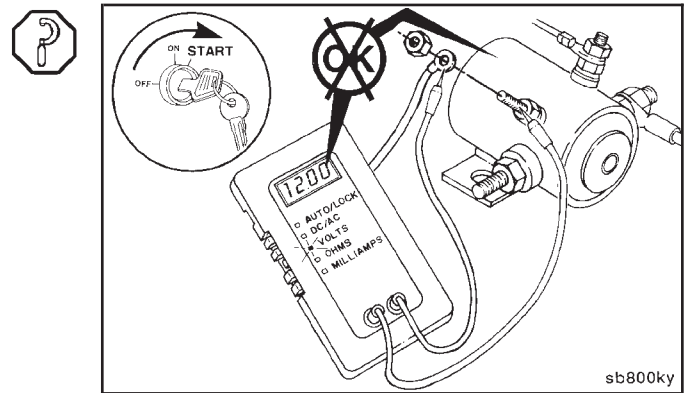
The multimeter **must** indicate zero (0) resistance, closed circuit.

If the multimeter indicates resistance at infinity with the starter switch in the "START" position:

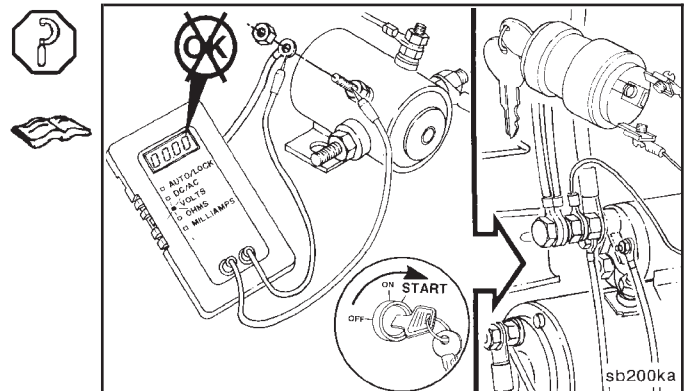
- Turn the starter switch off
- Remove the ground wire which is connected to one of the small magnetic switch terminals



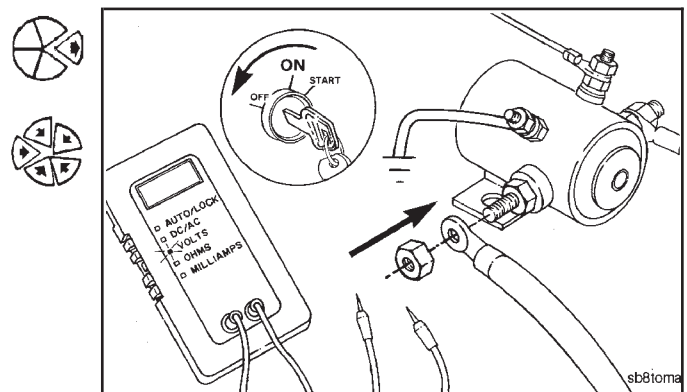
- Set the multimeter scale to indicate volts, 24 volts or more.
- Connect the positive lead of the multimeter to the magnetic switch ground terminal and the other lead to the ground wire
- Turn the starter switch to the "START" position
- The multimeter **must** indicate vehicle electrical system voltage.

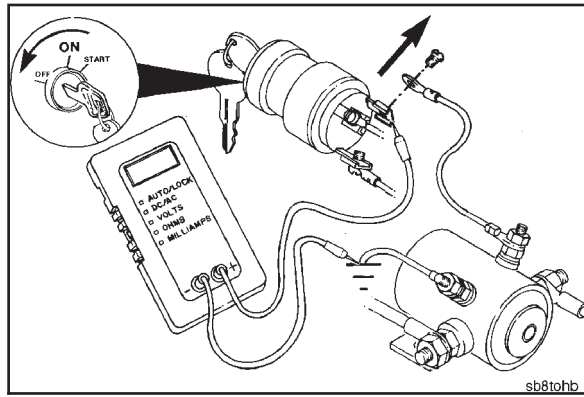


- If the multimeter does **not** indicate voltage, refer to "Starter Switch - Check" in this section



- Turn the starter switch to the "OFF" position
- Remove the multimeter leads
- Connect the starter solenoid cable to the magnetic switch terminal, and the ground wire to its corresponding terminal on the magnetic switch





Starter Switch (013-018)

Voltage Check (013-018-041)

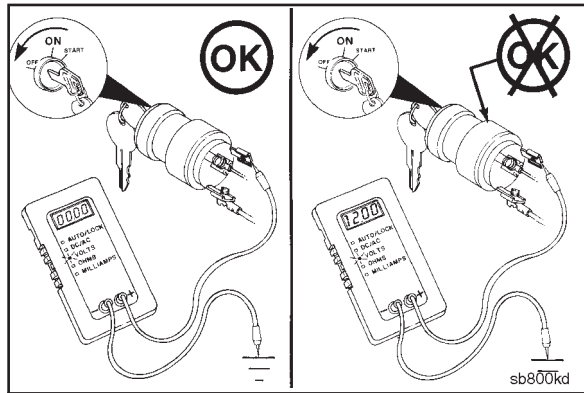


WARNING

Be sure the starter switch is in the "OFF" position to prevent electrical shock.

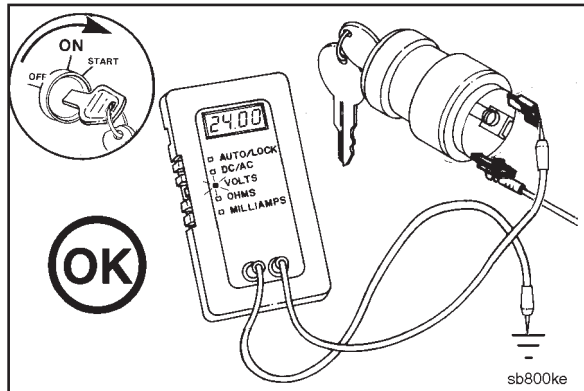
Remove the wire connecting the starter switch to the magnetic switch from the starter switch terminal.

Connect the positive lead of digital multimeter, Part No. 3377161, to the starter switch terminal and the negative lead to the chassis or an engine ground location.



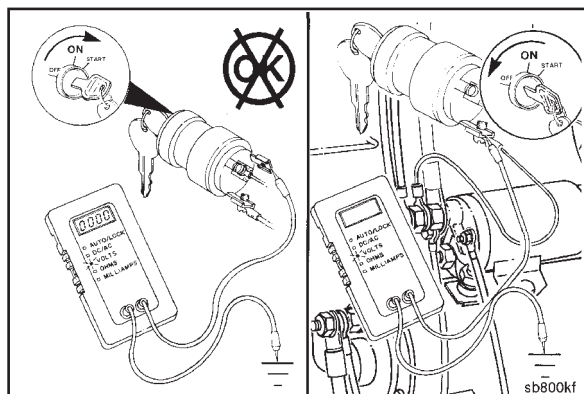
- Set the multimeter to indicate D.C. volts

With the starter switch in the "OFF" position, there **must not** be a voltage reading. If the meter indicates a voltage, the starter switch is malfunctioning and **must** be replaced.



Turn the starter switch to the "START" position.

The multimeter **must** indicate a voltage in order for this check to be normal.

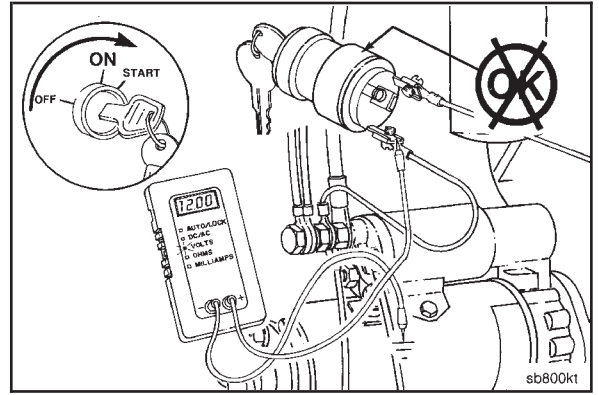


If there is **not** a voltage:



- Turn the starter switch to the "OFF" position
- Check the cable from the positive voltage terminal of the starter solenoid to the starter switch for breaks. Also check for loose or corroded connections.

- If the cable is good and the connections are clean and tight, the starter switch is malfunctioning and **must** be replaced.



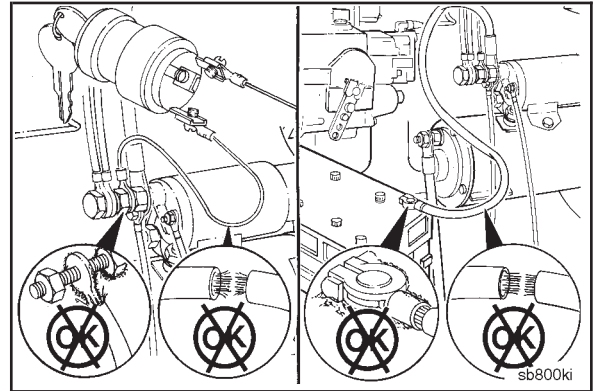
Starter Solenoid (013-019)

Voltage Check (013-019-041)

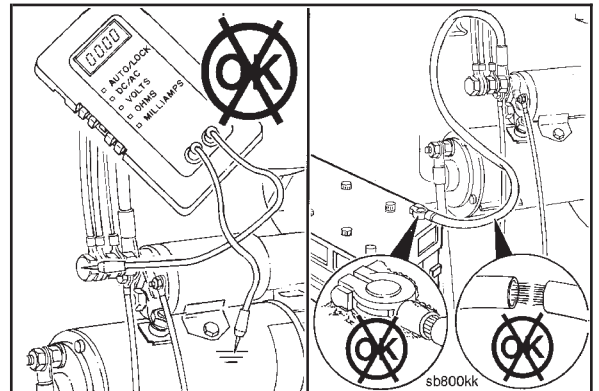
Use digital multimeter, Part No. 3377161, with the switch set to indicate D.C. volts.

Connect the multimeter positive lead to the starter solenoid positive cable terminal and the negative lead to a chassis or engine ground location.

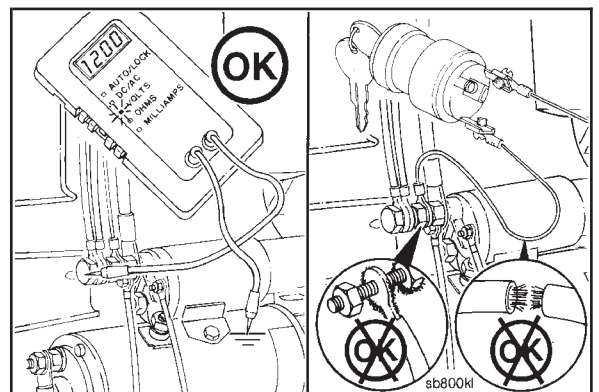
The multimeter **must** show a voltage with the starter switch off to be normal.

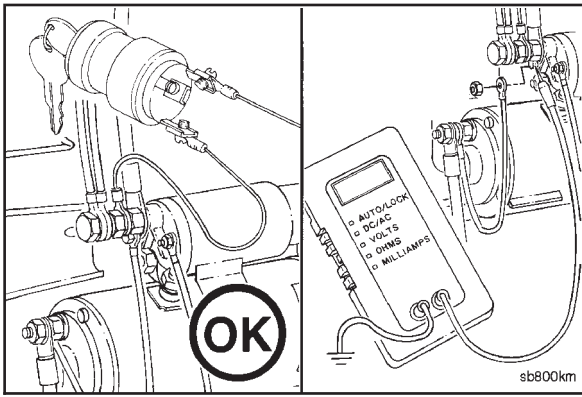


If the multimeter does **not** indicate a voltage, check the cable connecting the starter solenoid and battery for breaks. Also check for loose or corroded connections.



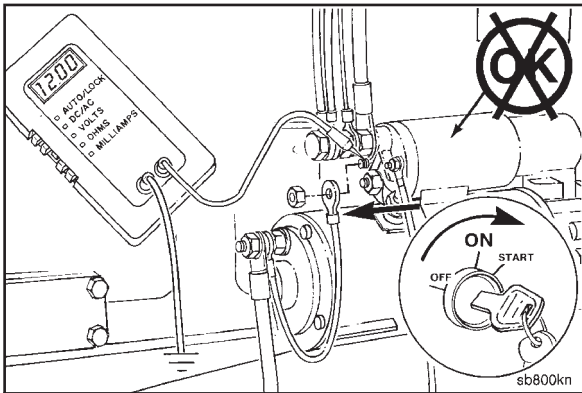
If the multimeter indicates a voltage, but the starter will **not** operate, check the wire connecting the starter solenoid to the starter switch for breaks, and also check for loose or corroded connections.



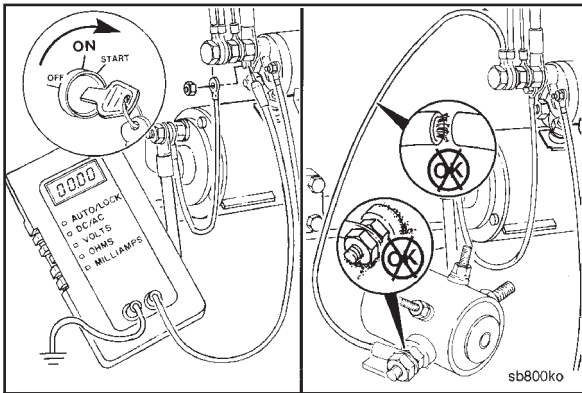


If the wire connecting the starter solenoid and starter switch is **not** loose or damaged, and the starter will **not** operate:

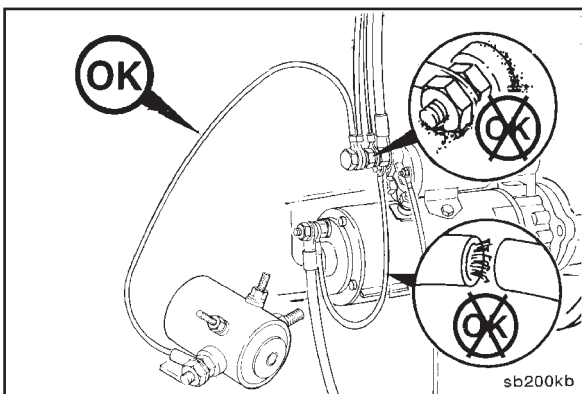
- Remove the cable connecting the starter and starter solenoid from the solenoid terminal
- Connect the multimeter positive lead to the solenoid positive terminal and the negative lead to the chassis or an engine ground location



- Turn the starter switch to the "START" position
- If the multimeter indicates a voltage, the starter solenoid is malfunctioning and **must** be replaced



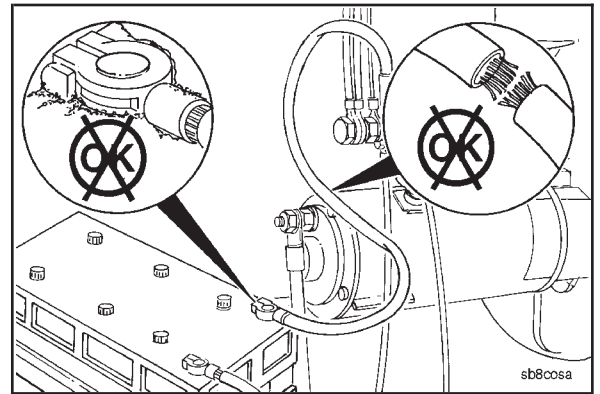
- If the multimeter does **not** indicate a voltage, check the wire connecting the starter solenoid to the magnetic switch for breaks, and for loose or corroded connections



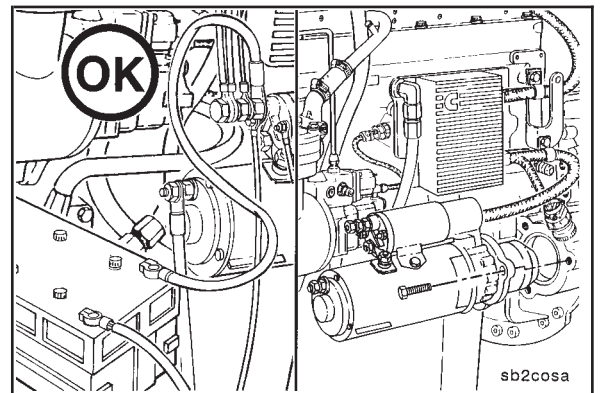
If the wire connecting the starter solenoid to the magnetic switch is **not** loose or damaged and the starter will **not** operate:

- Check the cable connecting the starter solenoid to the starting motor for breaks, and for loose or corroded connections

- Check the cable connecting the starting motor to the battery for breaks, and for loose or corroded connections



- If the cables are **not** loose or damaged, the starting motor is defective and **must** be replaced



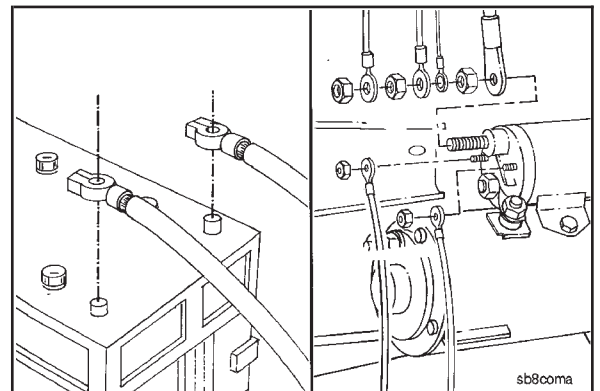
Starting Motor (013-020)

Remove (013-020-002)

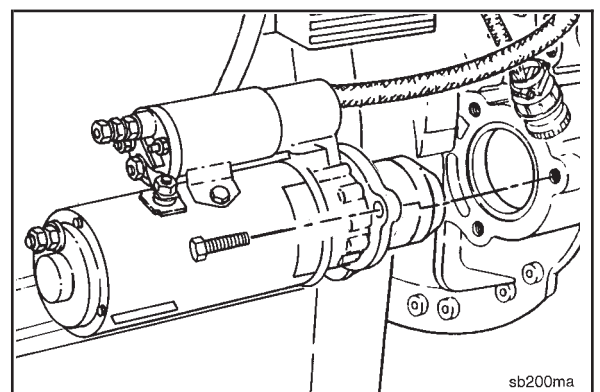
The starting motor mounting capscrews can be metric or standard thread sizes. Be sure to install the same size capscrews which were removed.

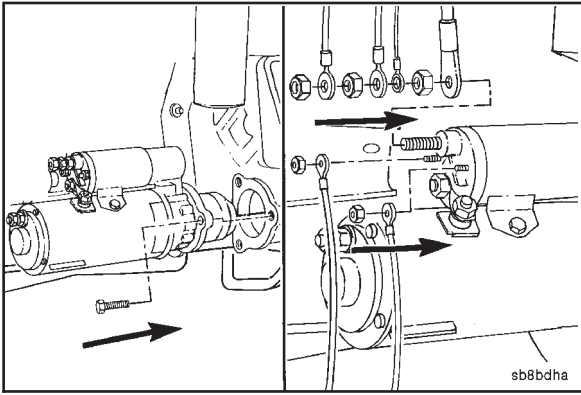
Remove the electrical connections from the batteries.

Remove the electrical connections from the starting motor and mark their locations.



Remove the three capscrews and the starting motor.





Install (013-020-026)

Before installing the starting motor, be sure the capscrews are the correct size and grade.

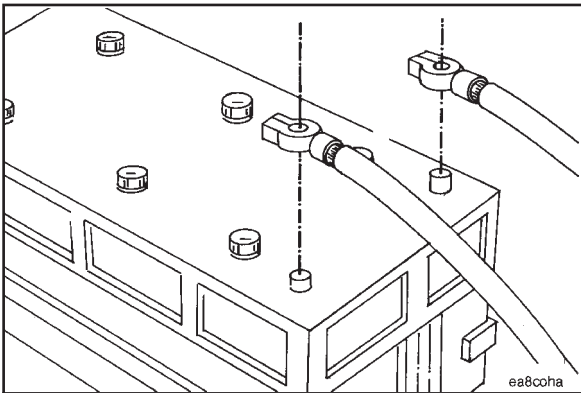


Install the starting motor and the three mounting capscrews.

Tighten the capscrews.

Torque Value: 90 N•m [140 ft-lb]

Install and tighten the electrical connection to the starting motor.



Install and tighten the battery electrical connections.

Section 14 - Engine Testing - Group 14

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Engine Testing - General Information

This section outlines engine testing and engine run-in recommendations for M11 engines. All engines **must** be run-in after a rebuild or a repair involving the replacement of one or more piston ring sets, cylinder liners or cylinder kits.

Incorrect or insufficient break-in of the piston rings will lead to early oil consumption or high blowby complaints. Adherence to these run-in guidelines will allow the full durability of new pistons, liners, and rings to be realized.

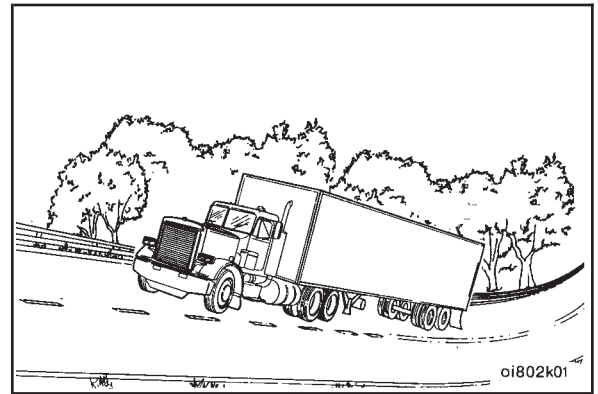
Before running the engine, make sure the engine is filled with the proper coolant. Also, be sure the lubricating oil system is filled and primed.

In-Service Run-In

The majority of heavy duty diesel applications will provide sufficient run-in under normal **loaded** operations. However, light load/high rpm operation **must** be avoided during the run-in period. The following in-service run-in guidelines are recommended for M11 engines after a repair involving replacement of one or more of the piston ring sets, cylinder liners or cylinder kits where engine or an engine dynamometer and/or chassis dynamometer run-in **cannot** be performed.

Engine Dynamometer Run-In

This is the preferred method of run-in for engines that have been rebuilt **out-of-chassis**. It is **not** practical, nor recommended that an engine be removed from the application to conduct the run-in after a rebuild or cylinder repair has been performed in-chassis. There is no requirement, nor is it recommended for an engine that has been run-in and tested on an engine dynamometer to be run-in again after it has been reinstalled in the vehicle or equipment.



DEFINITION OF TERMS ON ENGINE PERFORMANCE CURVE

Cummins M11 Heavy Duty Engine Operating Curve Definitions:

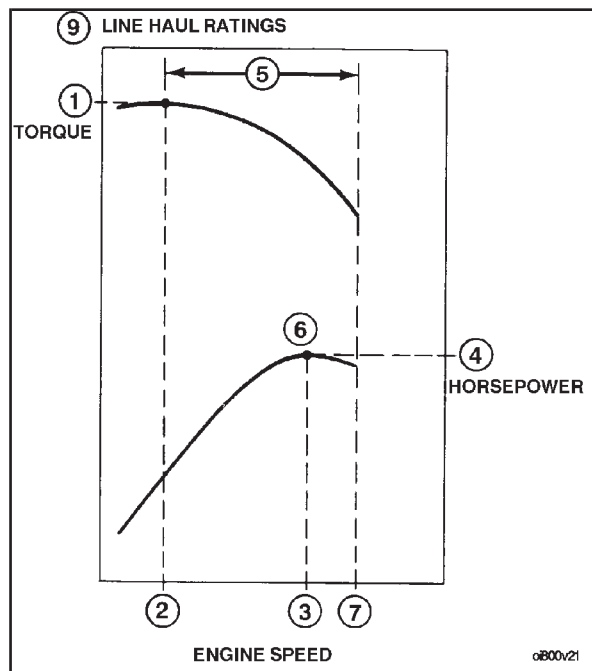


Fig. 1

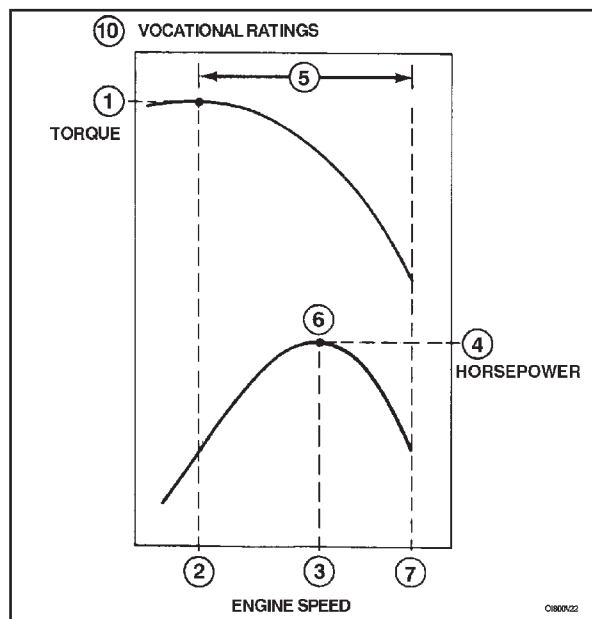


Fig. 2

1. **Peak Torque (N•m [ft-lb])** - Maximum torque that the engine will produce. Also, sometimes referred to as **COMMAND TORQUE**. This is listed on the engine data plate.
2. **Peak Torque rpm** - Engine speed at which peak torque is generated. This is listed on the engine data plate.
3. **Maximum HP rpm** - Engine speed at which maximum power is developed. This is listed with Advertised Horsepower on the engine data plate.
4. **Advertised Horsepower (HP)** - Maximum power that the engine will develop. This is provided on the engine data plate with its corresponding engine speed.
5. **Command Range** - The engine's operating range from **COMMAND TORQUE** or **Peak Torque** up to the engine's governed speed.
6. **COMMAND Point** - The point on the performance curve where maximum horsepower and optimum fuel economy come together. This is the point where Advertised Horsepower occurs.
7. **Full Load Governed Speed** - Defined as the upper end of the engine's full load operating range. This is listed on the engine data plate.
8. **No-Load Governed Speed** - (not shown) Maximum unloaded engine speed. This value is listed on the engine data sheet and in the FPEPS publications.
9. **Line Haul Rating** - An engine that has a line haul rating has a narrow operating range (rpm). A line haul rating is typically used for on-highway applications. These engines are used with larger (more gears, 13 speed, etc.) transmissions with close ratio splits between gear shifts.
10. **Vocational Rating** - A vocational rated engine has a wider operating range (rpm). This rating is typically used for on and off, or off-highway applications. These engines are used with smaller (fewer gears, 9 speeds, etc.) transmissions with large ratio splits between gear shifts.

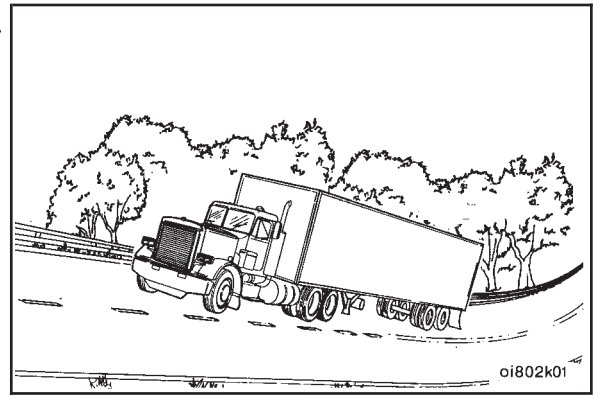
General Run-In Procedures



Refer to General Engine Test Specifications in this section before operating the engine to avoid internal component damage.

The amount of time specified for the following engine run-in phases are minimums.

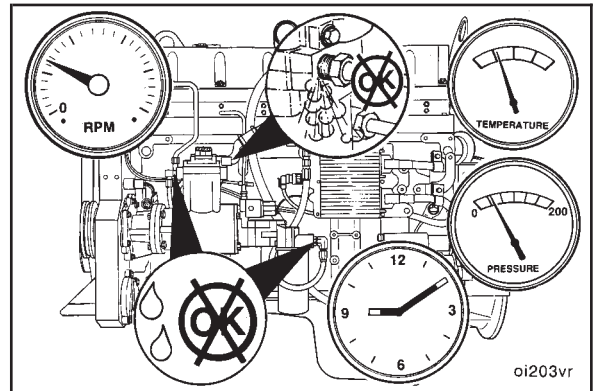
The engine can be operated for longer periods of time at each operating range or phase with the exception of engine idling which **must** be kept to 5 minutes or less.



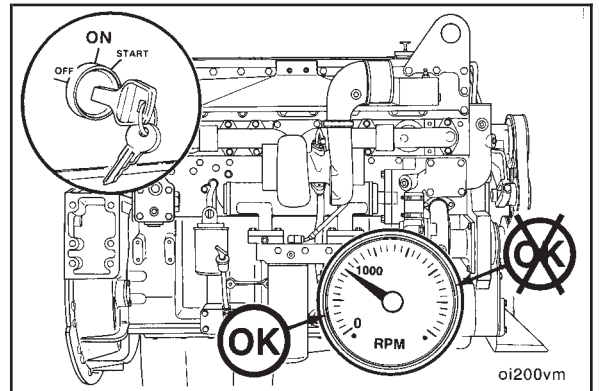
Start the engine and idle for initial check.

Avoid long idle periods. Operate the engine at low idle only long enough (5 minutes maximum) to check for correct oil pressure and any fuel, oil, water, or air leaks.

Do **not** operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation will occur and cause damage to the engine.

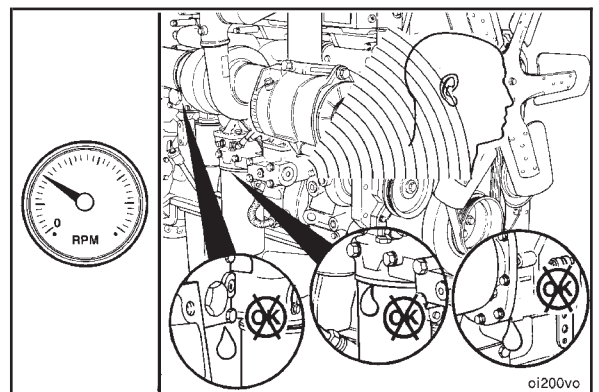


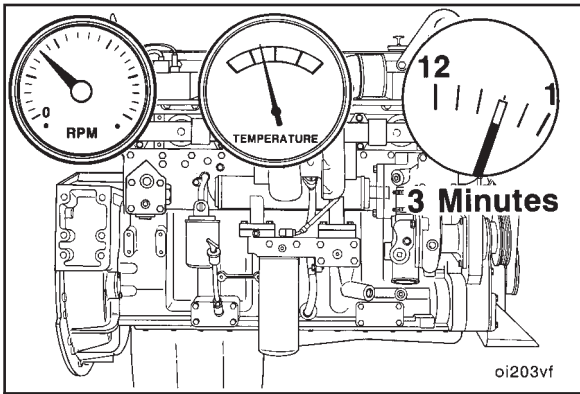
To avoid internal component damage, do **not** allow the engine speed to exceed 1,000 rpm before run-in.



While the engine is idling, listen for unusual noises; watch for coolant, fuel, and lubricating oil leaks; and check for correct engine operation in general.

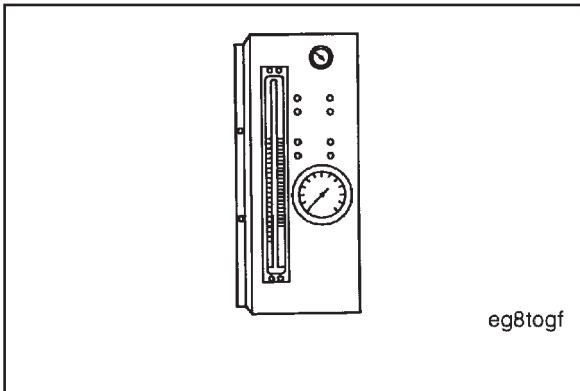
Repair all leaks or component problems before continuing the engine run-in.





△ CAUTION △

Do not shut off the engine immediately after the run-in is completed. Allow the engine to cool by operating at low idle for a minimum of 3 minutes to avoid internal component damage.



Fuel Flow Measurement on Engine or Chassis Dynamometer

Accurate fuel flow measurement is important for evaluation of engine performance and troubleshooting on an engine or chassis dynamometer. The only way accurate fuel flow measurement can be obtained is through proper use of the available equipment. Below is a description of the fuel measuring device, available from Cummins Engine Company, along with installation and operation recommendations. The fuel measuring device, Part No. 3376375, can be used with either a chassis or engine dynamometer.

Installation

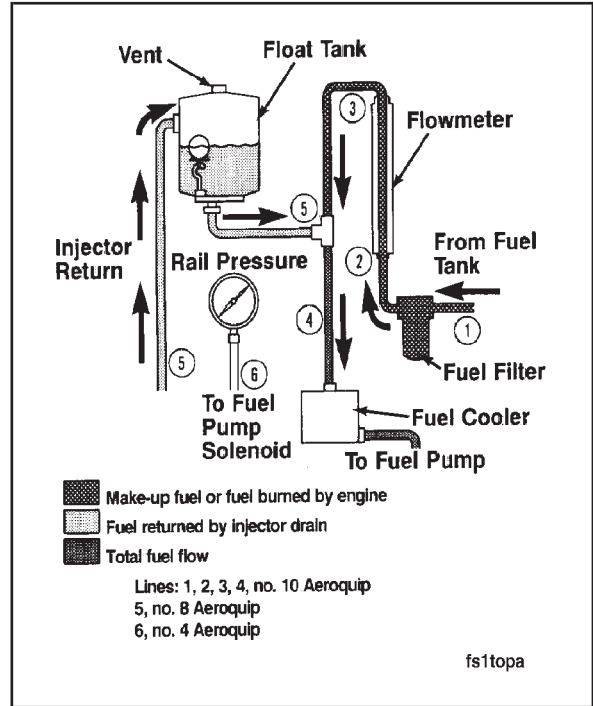
When installing the fuel measuring device, it is important to reduce the amount of air that can be introduced into the system when the device is **not** in use. Therefore, the plumbing used **must** include non-restrictive shutoff valves, such as ballcock valves, to contain fuel in the device after each use. Additional installation considerations are:

- The fuel measuring device, Part No. 3376375, **must** be mounted vertically to ensure accuracy and proper operation.
- A separate fuel supply for use on the dynamometer is recommended. All fuel used in the measuring device **must** be clean for consistent operation.
- Care **must** be taken to reduce fuel line restriction to and from the engine. Minimum recommended hose sizes are No. 10 for the engine fuel inlet, and No. 8 for the engine fuel drain. The length of either hose **must not** exceed 15 feet.
- For accurate fuel consumption or flow measurement while testing on a chassis dynamometer, it is recommended to use a fuel cooler to maintain inlet temperature to the fuel gear pump at 49°C [120°F] or below.

Operation

This is a schematic of the fuel measuring device, Part No. 3376375. The device consists of the following components:

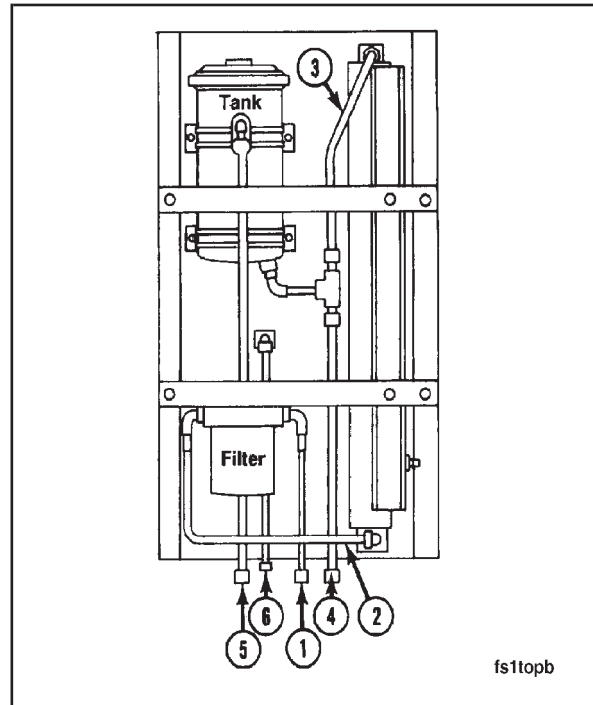
- Fuel filter
- Flowmeter
- Float tank
- Fuel rail pressure gauge
- Fuel cooler is not a part of fuel measuring device, Part No. 3376375; however, **must** be used when conducting test with the flow meter.



The fuel measuring device recirculates return fuel to the engine fuel inlet by routing the return fuel to the top side of the float tank. The fuel is deaerated as it passes through the baffling in the float tank. A ball float valve at the bottom of the float tank maintains an adequate volume in the tank for deaeration. The fuel is then returned to the engine fuel inlet. Refer to the sketch for fuel line connection points on the fuel measuring device.

1. Fuel supply from tank
2. Fuel flow to fuel meter
3. Fuel flow from fuel meter
4. Fuel flow to fuel cooler
5. Injector return fuel
6. Fuel rail pressure

NOTE: The fuel supply tank **must** be below the level of the fuel measuring device to prevent overflow of the float tank. If an overhead fuel supply tank is used, a float controlled reservoir **must** be installed between the fuel supply tank and the fuel measuring device, and below the level of the device.

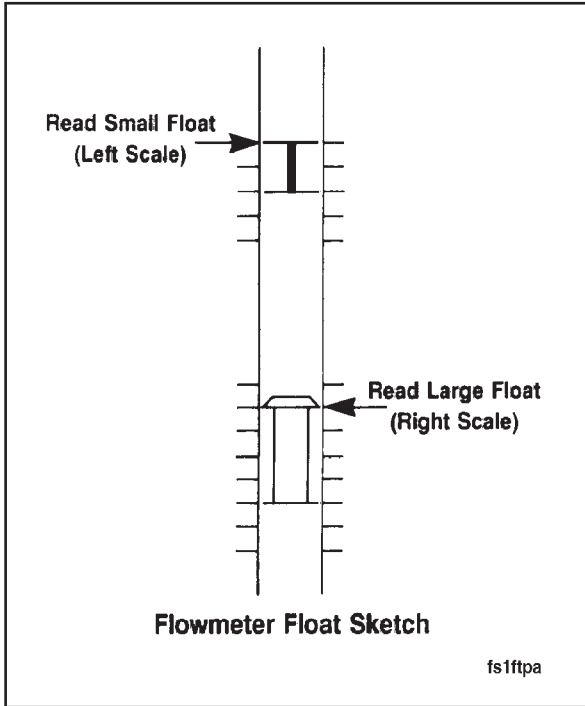


NOTE: On CELECT™ and CELECT™ Plus engines, the engine fuel inlet line **must** flow through the ECM cooling plate to ensure proper cooling of the ECM during engine operation.

The fuel measuring device is installed in series between the fuel supply tank and the engine fuel inlet. The quantity of fuel being drawn through the flowmeter is known as “make up” fuel or the amount of fuel being burned by the engine.

The flowmeter is graduated to read fuel flow in pounds per hour. The flowmeter contains two floats with respective scales on either side of the flowmeter. The small float is used to measure lower flows and **must** be read on the left scale, as shown. The larger float is for measuring higher flows and **must** be read on the right scale.

To obtain an accurate fuel rate measurement, the flowmeter reading **must** be corrected based on the fuel temperature. There is a fuel temperature gauge on the front panel of the fuel measuring device. The gauge is graduated in percent of error by which the reading requires correction. An example is: The fuel of an engine reads 125 lbs/hr on the flowmeter, and the temperature gauge reads +2 percent; the corrected fuel flow rate will be 125 plus 2 percent, or 127.5 lbs/hr.



Specifications

Engine Testing

Maintain the following limits during the engine test/run-in procedures:

Due to variations in ratings of different engine models, refer to the specific "Engine Data Sheet" for the particular engine model being tested.

Charge Air Cooler Restriction (Maximum)

Mercury	152 mm Hg [6 in. Hg]
Pounds Force	21 kPa [3 psi]

Intake Restriction (Maximum at Advertised Horsepower)

Clean Air Filter	254 mm H ₂ O [10 in. H ₂ O]
Dirty Air Filter	635 mm H ₂ O [25 in. H ₂ O]

Maximum Exhaust Back Pressure 75 mm Hg [3 in. Hg]

Oil Pressure

Low Idle (minimum allowable)	69 kPa [10 psi]
At 1200 rpm or Torque Peak (minimum allowable)	207 kPa [30 psi]

Maximum Cylinder Block Coolant Pressure (Closed Thermostat) 275 kPa [40 psi]

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

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

Fuel Inlet Maximum Restriction

CELECT™ and CELECT™ Plus

Clean Fuel Filter	152 mm [6 in Hg]
Dirty Fuel Filter	254 mm [10 in Hg]

STC

Clean Fuel Filter	102 mm [4 in Hg]
Dirty Fuel Filter	204 mm [8 in Hg]

Fuel Drain Line Maximum Restriction

CELECT™ and CELECT™ Plus 89 mm Hg [3.5 in Hg]

STC

Without Check Valves	63 mm Hg [2.5 in Hg]
With Check Valves	165 mm Hg [6.5 in Hg]

Blowby* (Maximum at Advertised Horsepower)

New or rebuilt engines (maximum)

(less than 160,000 km [100,000 miles] or 3600 hours) 305 mm H₂O [12 in. H₂O]

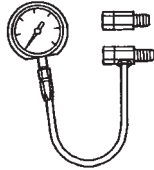

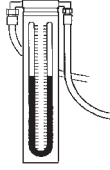

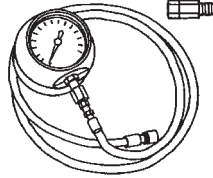
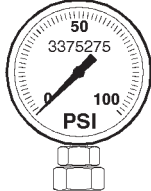
Used Engines (maximum)



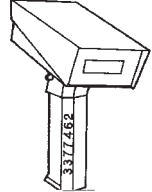
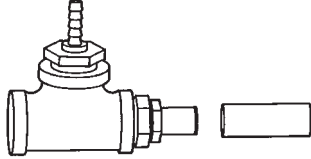
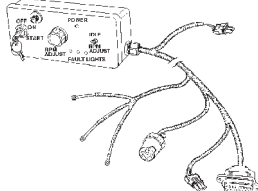
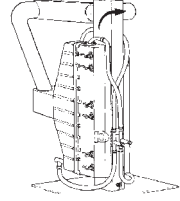
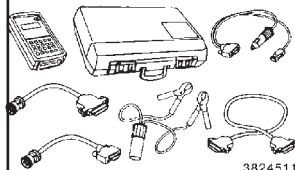
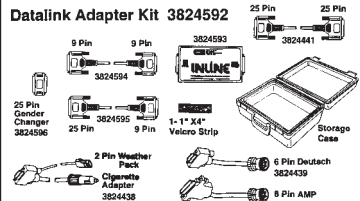
(over 160,000 km [100,000 miles] or 3600 hours) 460 mm H₂O [18 in. H₂O]

Blowby checking tool, Part No. 3822566, has a special 7.67 mm [0.302-inch] orifice that **must** be used to be certain an accurate reading is obtained.

Service Tools Engine Testing

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

Tool No.	Tool Description	Tool Illustration
ST-434	Vacuum Gauge Used to check fuel filter or intake air restriction.	 eg8togc
ST-435-6	Pressure Gauge Included in snap rail pressure gauge, Part No. 3375932. Used to measure fuel pressure.	 eg8togh
ST-1111-3	Manometer Used with tool, Part No. 3375150, for measuring blowby.	 eg1009a
ST-1135	Lubricating Oil Sampling Filter Used to monitor oil contamination.	 st-1135
ST-1273	Pressure Gauge Used to measure intake manifold pressure.	 eg8togi
3375275	Pressure Gauge (0-160 psi) Used to measure lubricating oil pressure.	 3375275

Tool No.	Tool Description	Tool Illustration
3375932	<p>Pressure Gauge (0-300 psi)</p> <p>Used to measure fuel pressure. Includes necessary hoses and hardware to attach to a fuel pump. Part No. ST-435-1 is the hose and Part No. ST-435-6 is the pressure gauge.</p>	 <p>eg8togh</p>
3376375	<p>Fuel Measuring Device</p> <p>Measure the rate of fuel consumption of a Cummins diesel engine.</p>	 <p>eg8togf</p>
3377462	<p>Digital Optical Tachometer</p> <p>Used to measure engine speed (rpm).</p>	 <p>3377462</p>
3822566	<p>Blowby Check Tool</p> <p>Used with manometer, Part No. ST-1111-3, to measure the engine crankcase pressure.</p>	 <p>eg8toge</p>
3823948	<p>CELECT™/CELECT™ Plus Engine Dyno Control</p> <p>Used on an engine dyno to control the CELECT™/CELECT™ Plus engine.</p>	 <p>wr8000</p>
3823978	<p>Dyno-Room Charge Air Cooler</p> <p>Used to cool intake air when an air to air engine is used on a engine dyno.</p>	 <p>3823978</p>
3824511	<p>Echek™ Tool Kit</p> <p>Used to troubleshoot and adjust CELECT™ or CELECT™ Plus system. Kit includes Echek™ tool, and all necessary power cords and cables. Requires the correct cartridge for whichever application being used.</p>	 <p>3824511</p>
3824592	<p>Data Link Adapter Kit</p> <p>Inline adapter and associated cables are used to connect a computer to an engine data link.</p>	<p>DataLink Adapter Kit 3824592</p>  <p>25 Pin Gender Changer 3824596 25 Pin 3824595 9 Pin 3824594 9 Pin 3824593 1-1" X4" Velcro Strip Storage Case 2 Pin Weather Pack Connector Adapter 3824438 6 Pin Deutsch 3824439 8 Pin AMP 3824441</p> <p>3824592</p>

Dynamometer Worksheet (014-001)

Date:	Repair Order No:	Operator:
ESN:	CPL:	Fuel Pump Code:
Complaint:		SC Code:

PARAMETER	CODE SPECIFICATIONS	ACTUAL READING
Fuel Pressure (psi @ rpm)	Refer to Specifications - Engine Testing	
Fuel Rate (lb/hr)		
Intake Mfd. Pressure (in.Hg)	See Fuel Pump Code	
Intake Mfd. Temperature		
* Intake Air Restriction	25 in. H ₂ O, Maximum	
* Exhaust Air Restriction	3 in. Hg, Maximum	
* Fuel Inlet Restriction	Refer to Specifications - Engine Testing	
* Fuel Drain Line Restriction	3.5 in. Hg	
Engine Blowby	12 in. H ₂ O New Engines, Max. 18 in. H ₂ O Used Engines, Max.	
* Recorded at maximum horsepower speed and full load		

Road Speed Limit				Engine High Speed Limit		
Check Oil Level	Low	High	OK	Fuel Quality	OK	Not OK

Engine Speed	Fuel *Rate/Press	Fuel Temp	Turbo Inlet Air Temp	Intake Manifold Temp/Press	Coolant Temp/Press	Engine Blowby	Lube Oil Press	HP or Torque

* Be sure that the fuel rate is corrected for temperature.

Fuel Temperature	Correction for Flow Rate
Less than 7°C[45°F]	Flow meter not accurate
7 to 13°C[45 to 55°F]	Subtract 2% from flow rate reading
13.0 to 20.0°C[55 to 68°F]	Subtract 1% from flow rate reading
20.0 to 29°C[68 to 85°F]	No Correction
29 to 42°C[85 to 108°F]	Add 1% to flow rate reading
42 to 56°C[108 to 132°F]	Add 2% to flow rate reading
56°C above [132°F]	Flow meter not accurate.

Pressure Conversions
1 in. H ₂ O = 0.074 in. Hg = 0.036 psi
1 in. Hg = 13.514 in. H ₂ O = 0.491 psi
1 psi = 2.036 in. Hg = 27.7 in. H ₂ O

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Engine Testing (Chassis Dynamometer) (014-002)

Setup (014-002-011)

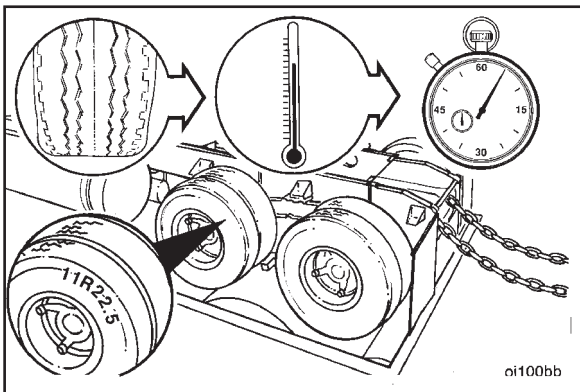
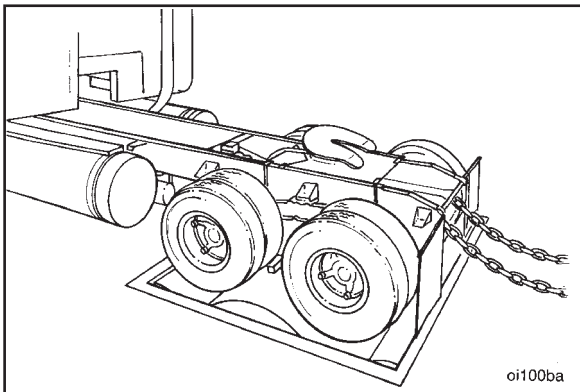
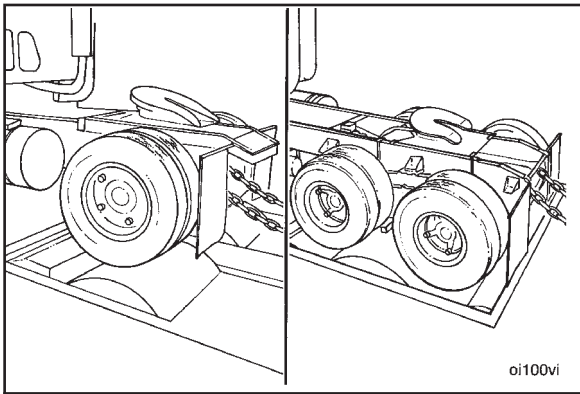
The performance of an engine installed in “on-highway” vehicles can be tested on a chassis dynamometer.

NOTE: Due to driveline inefficiencies and engine-driven accessories, the rated horsepower will be reduced by approximately:

- 20 percent for single axle vehicles
- 25 percent for tandem axle vehicles

The net horsepower available is called wheel horsepower (WHP).

NOTE: These percentages are used for engine run-in only and are **not** to be used as absolute figures.



⚠ CAUTION ⚠

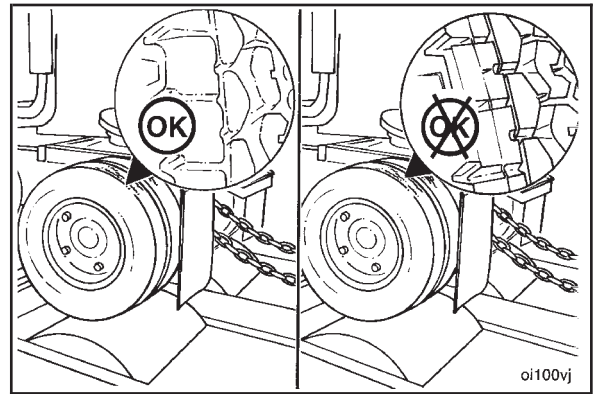
Before installing or operating a vehicle on a chassis dynamometer, follow all the vehicle manufacturer's safety precautions.

⚠ CAUTION ⚠

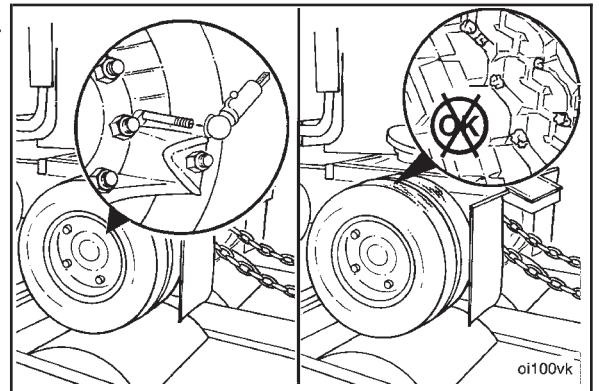
Low profile radial tires are more sensitive to heat than bias ply tires. Excessive operating time at full load can damage tires due to overheating. Check the tire manufacturer's recommendations for the maximum allowable chassis dynamometer operating time.

The following are general safety precautions to be observed while operating the chassis dynamometer.

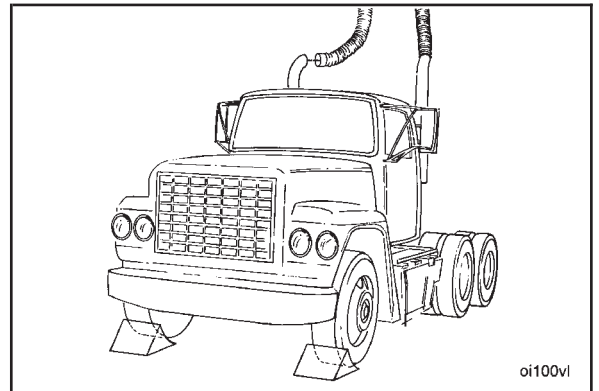
- Use tires that have more than 160 kilometers [100 miles] on them. Do **not** use new tires.
- Do **not** use recapped tires or tires of different sizes or designs.



- Make sure the tires are inflated to the manufacturer's specifications.
- Remove all rocks or other material from the tread of all tires that will be rotating on the dynamometer rollers.



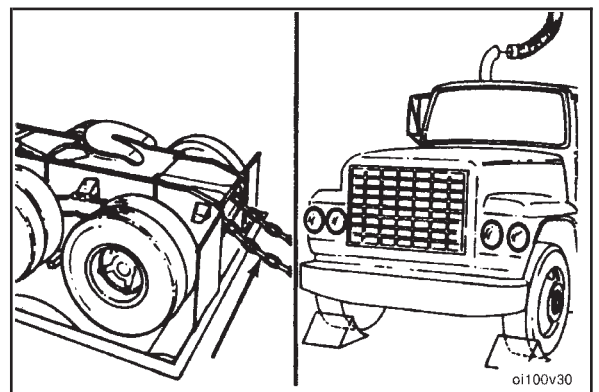
- Make sure there is correct overhead clearance for exhaust stacks, air deflectors, or other attachments above the cab.

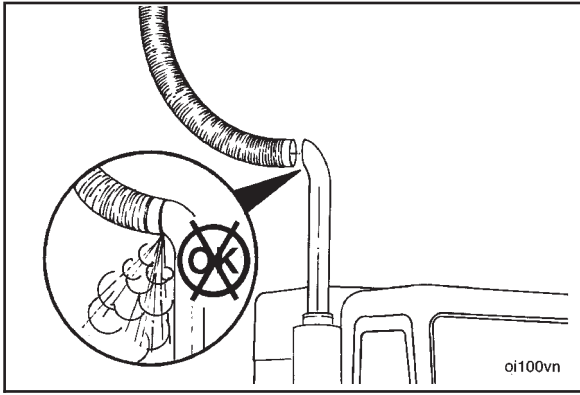


▲ CAUTION ▲

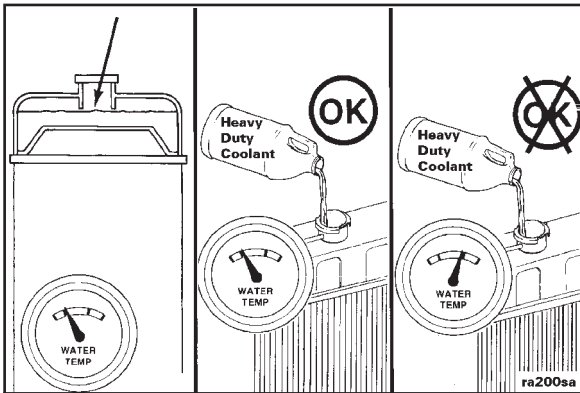
The "tie down" chains must have slack to prevent damage to the chassis dynamometer.

- Carefully position the vehicle on the rollers.
- Attach the "tie down" chains to the rear of the vehicle, and put wheel chocks in front of the front wheels.





- Adjust the vehicle and dynamometer room exhaust system to make sure all exhaust gases are removed from the room.
- Refer to the chassis dynamometer and vehicle manufacturer's recommendations and specifications for testing procedures.



Test (014-002-012)

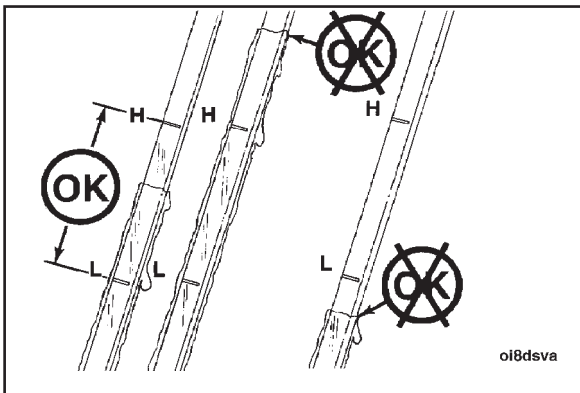
Check the engine coolant level to be sure it is filled to the proper level.

⚠ WARNING ⚠

Check the coolant level only when the engine is stopped. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.

⚠ CAUTION ⚠

Do not add cold coolant to a hot engine. This can cause engine casting damage. Allow the engine to cool to below 50°C [120°F] before adding coolant.

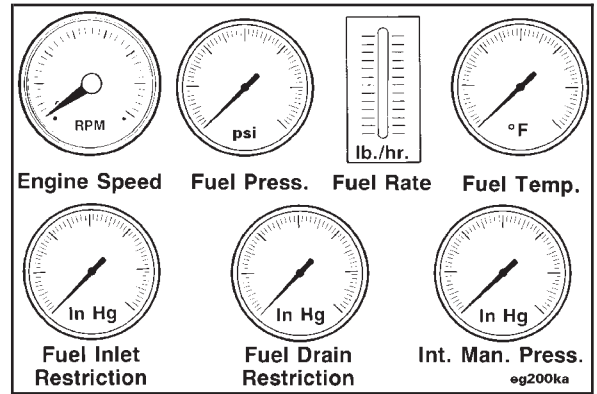


Check the engine lubricating oil level to be sure it is filled to the proper level.

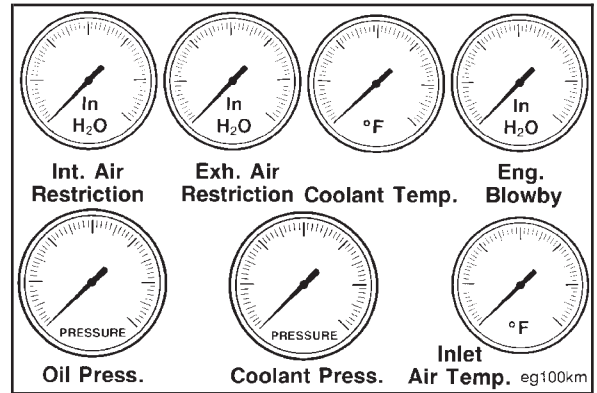
NOTE: Use a known source of "good" quality No. 2 diesel fuel. This is very important since No. 1 diesel fuels, along with most other alternate fuels, are lighter (lower specific gravity, higher API gravity) than No. 2 diesel fuel. The lighter the fuel, the lower the energy content (BTU) per gallon (liter, etc.).

To properly monitor engine performance, record the following parameters. To limit dynamometer operating time, instrument the engine to make as many checks as possible.

- Engine speed rpm with a verified tachometer
- Fuel pressure
- Fuel rate (Use Service Tool, Part No. 3376375)
- Fuel temperature (if needed to correct fuel rate)
- Fuel inlet restriction
- Fuel drain line restriction
- Intake manifold pressure

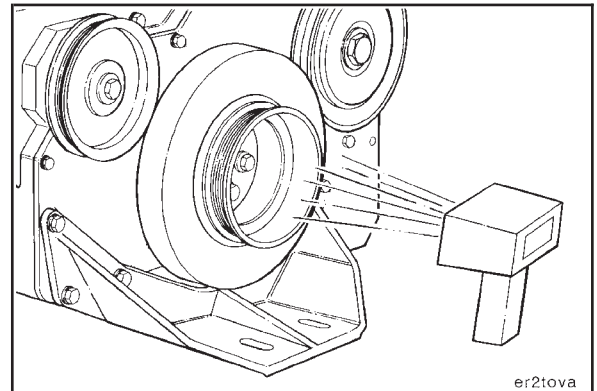


- Intake air restriction
- Exhaust air restriction
- Coolant temperature
- Engine blowby
- Lubricating oil pressure
- Coolant pressure
- Inlet manifold air temperature
- Turbocharger inlet air temperature
- Oil temperature



Engine Speed (rpm) With a Verified Tachometer

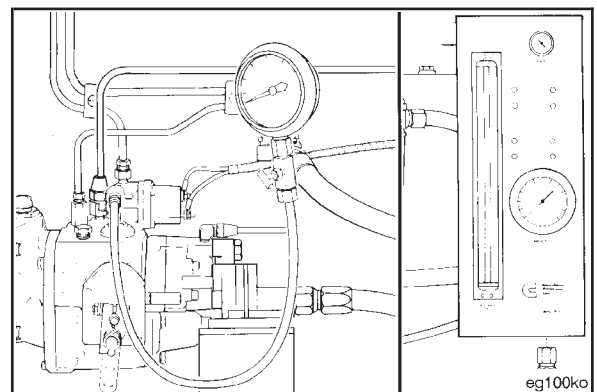
Use digital optical tachometer, Part No. 3377462, to check and verify engine speed.

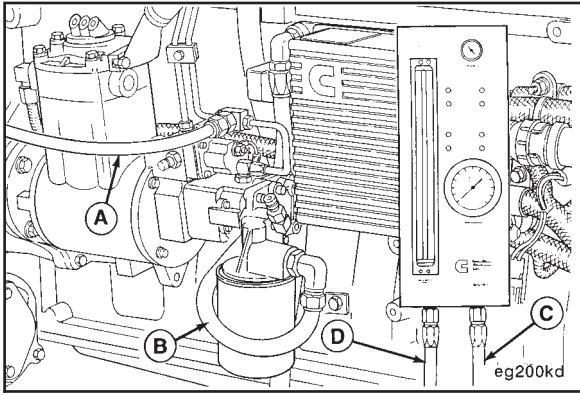


Fuel Pressure

Measure the fuel pressure. Install the pressure gauge, Part No. ST-435-6, or the pressure gauge in the fuel measuring device, Part No. 3376375, to the fitting on the fuel shutoff valve.

NOTE: Pressure gauge, Part No. ST-435-6, is included with snap rail pressure gauge, Part No. 3375932.





Fuel Rate

Use fuel measuring device, Part No. 3376375, to measure the rate of fuel consumption. For more information, refer to "Engine Testing - General Information".

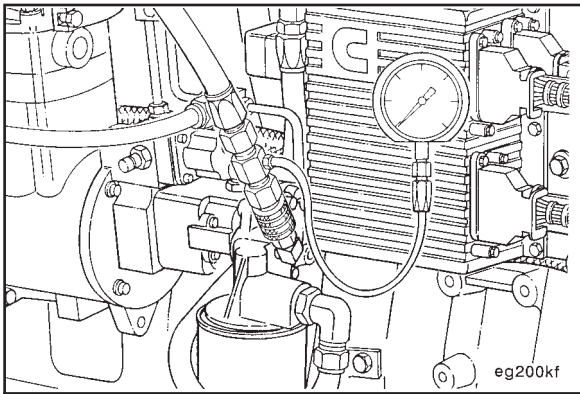


Install the fuel measuring device as follows:

- The fuel return hose from the engine to the fuel measuring device (A).
- The fuel inlet hose to the fuel filter inlet (B).
- The return hose from the device (C) to the fuel tank.
- The fuel inlet hose to the device from the fuel tank suction line (D).

NOTE: Adjust the fuel rate to compensate for temperature variation if required.

Inlet Fuel Temperature		
°C		°F
15.5°	MIN	60°
48.9°	MAX	120°

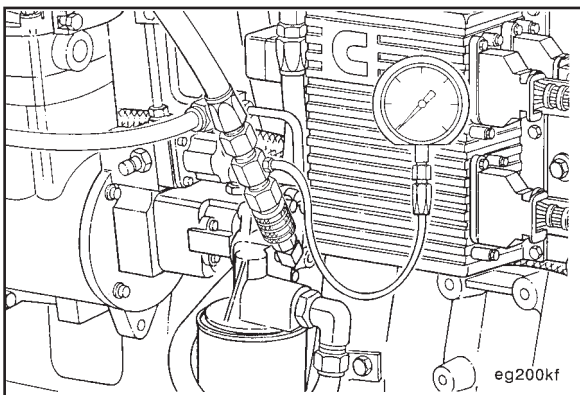


Fuel Inlet Restriction

Measure the fuel inlet restriction. Install a vacuum gauge, Part No. ST-434, between the fuel filter and the gear pump inlet.



NOTE: Do **not** measure fuel inlet restriction with the fuel measuring device installed. This will **not** measure the inlet restriction of the vehicle's supply plumbing.



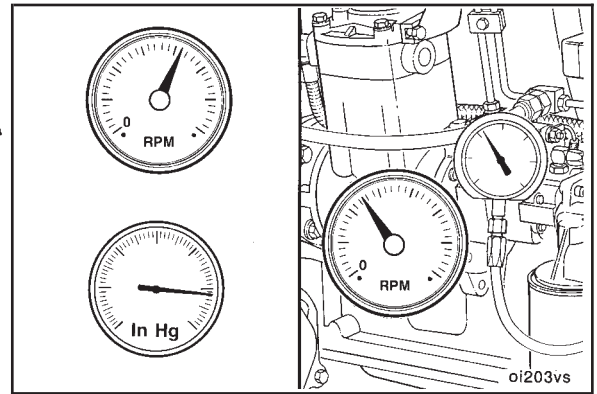
Hold the gauge at the same level as the gear pump.

NOTE: The gauge will **not** measure the correct vacuum if the gauge is **not** held at the same level as the gear pump.

Operate the engine at maximum horsepower rpm on STC engines.

NOTE: On CELECT™ and CELECT™ Plus, it is **not** necessary to operate the engine to maximum horsepower, only high idle.

Observe the reading on the gauge.



Fuel Inlet Restriction CELECT™ and CELECT™ Plus			
	mm Hg		in Hg
Clean Filter	152	MIN	6
Dirty Filter	254	MAX	10

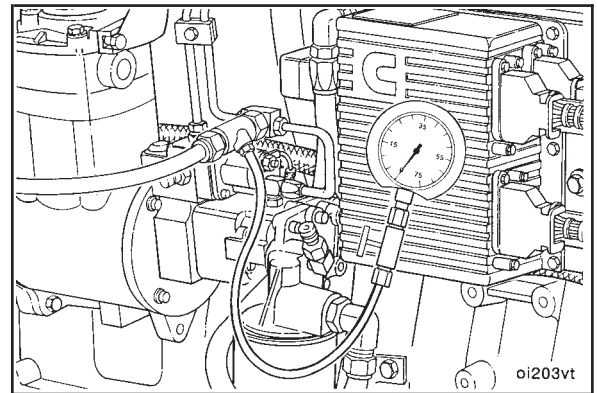
Fuel Inlet Restriction STC Engines			
	mm Hg		in Hg
Clean Filter	102	MIN	4
Dirty Filter	204	MAX	8

Correct the restriction or replace the fuel filter.

Fuel Drain Line Restriction

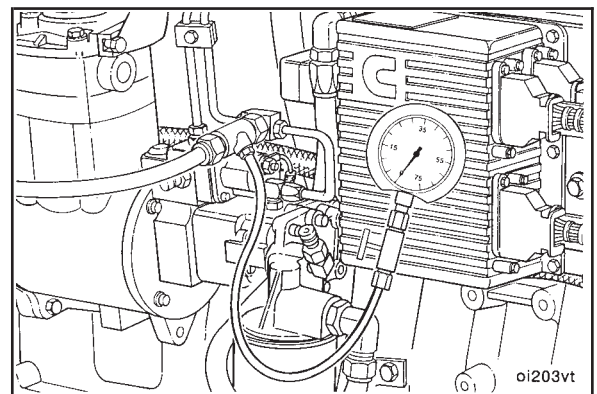
Use Pressure Gauge, Part No. ST-1273, to measure fuel drain line restriction.

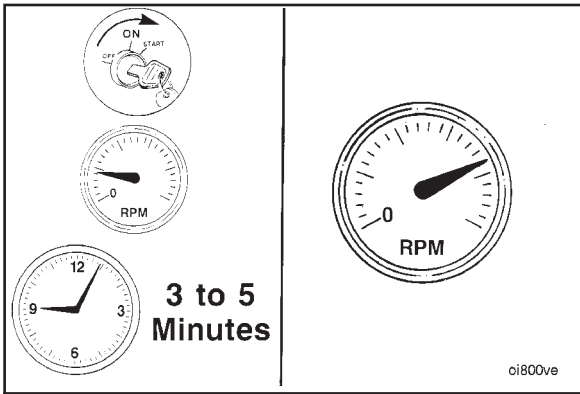
NOTE: Do **not** measure fuel drain line restriction with the fuel measuring device installed. This will **not** measure the drain line restriction of the vehicle's return plumbing.



Hold the gauge at the same level as the connection.

NOTE: The gauge will **not** measure the correct pressure if the gauge is **not** held at the same level as the connection.





Operate the engine at maximum horsepower rpm on STC engines.



NOTE: On CELECT™ and CELECT™ Plus, it is **not** necessary to operate the engine to maximum horsepower, only high idle.

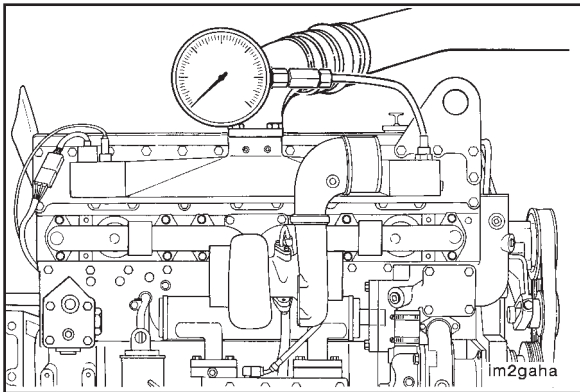
Observe the reading on the gauge.

**Fuel Drain Line Restriction
CELECT™ and CELECT™ Plus**

mm Hg		in Hg
89	MAX	3.5

**Fuel Drain Line Restriction
STC Engines**

	mm Hg		in Hg
Without Check Valves	63	MAX	2.5
With Check Valves	165	MAX	6.5

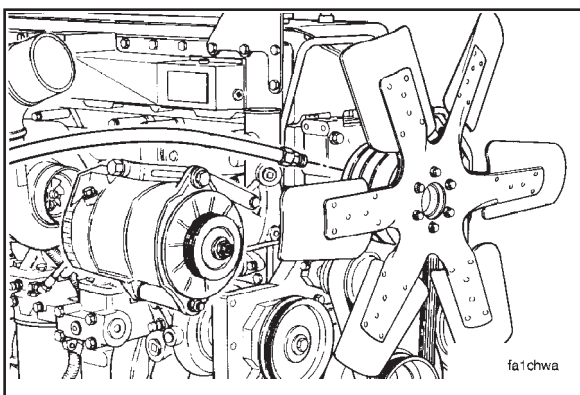


Intake Manifold Pressure

Measure the intake manifold pressure (turbocharger boost). Install pressure gauge, Part No. ST-1273, in the intake manifold as shown.



Observe the reading on the pressure gauge.



Intake Air Temperature Control - Chassis Dynamometer Test

When operating an engine on a chassis dynamometer, follow these steps for best results and safe operation.

CELECT™ and CELECT™ Plus Engines

Lock the cooling fan in the "ON" mode. This can be done by installing a jumper across the temperature switch, or by supplying shop air to the control valve. Refer to the fan drive manufacturer for the recommended procedure.

Monitor the intake manifold air temperature using INSITE™ in the monitor mode, or install Fluke digital thermometer, Part No. 3822666, and thermocouple wire kit, Part No. 3822988, into the intake manifold.

The intake manifold air temperature **must not** exceed the maximum allowable temperature. The engine protection system will disrupt performance if the temperatures exceeds this level. Maintain intake manifold air temperature at the nominal level or below during chassis dynamometer operation.

Intake Manifold Air Temperature		
°C		°F
66°	NOMINAL	150°
77°	MAX	170°

If the intake manifold temperature exceeds 77°C [170°F], shut off the engine. Allow the engine to cool.

Inspect the CAC fins for obstructions to the air flow.

Check the fan drive. Make sure the fan is locked in the “ON” mode.

Remove any obstructions such as a winterfront or debris. Manually lock the shutters in the “OPEN” position if equipped.

Inspect the dynamometer room for adequate supply of suitably cool or outside air. Make sure that dynamometer room recirculation is **not** an issue.

Resume the test.

STC Engines

Lock the cooling fan in the “ON” mode. This can be done by installing a jumper across the temperature switch or by supplying shop air to the control valve. Refer to the fan drive manufacturer for the recommended procedure.

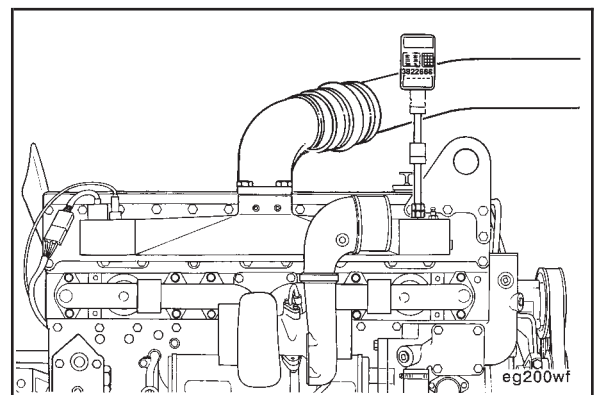
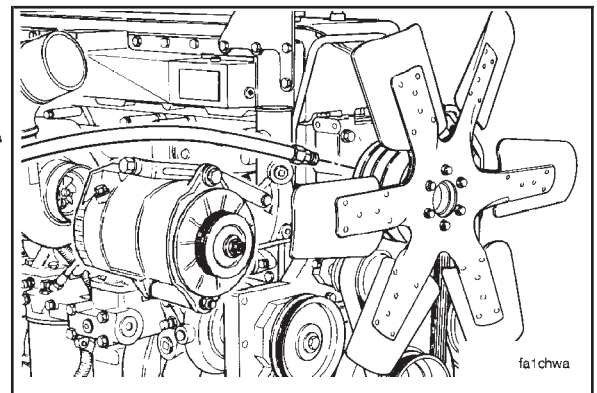
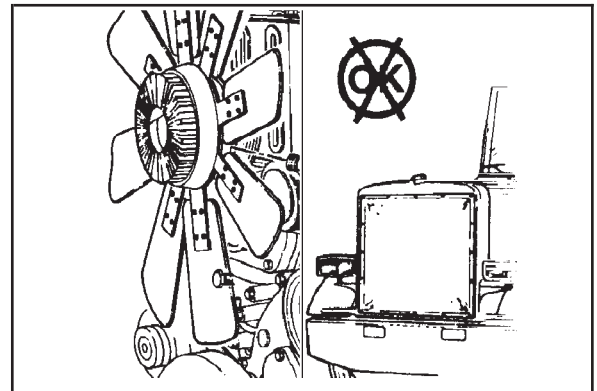
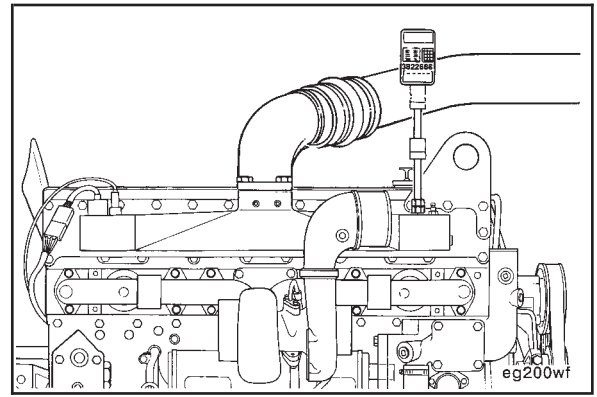
Remove any obstructions to the air flow across the radiator such as a winterfront. Manually lock the shutters in the “OPEN” position, if equipped.

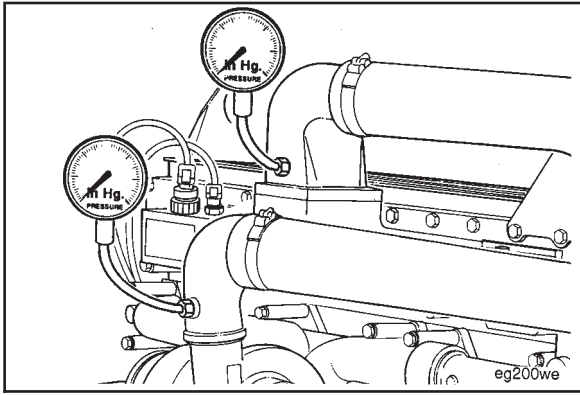
Install a Fluke digital thermometer, Part No. 3822666, and attach thermocouple wire kit, Part No. 3822988, into the intake manifold. Monitor the intake manifold temperature. The temperature **must not** exceed 77°C [170°F].

If the intake manifold temperature exceeds the above limits, shut off the engine. Allow the engine to cool.

Inspect the radiator fins for obstructions to the air flow. Check the fan drive to make sure it is locked in the “ON” mode.

Resume the test.





Charge Air Cooler Restriction

Measure the intake pressure drop across the charge air cooler, if applicable.

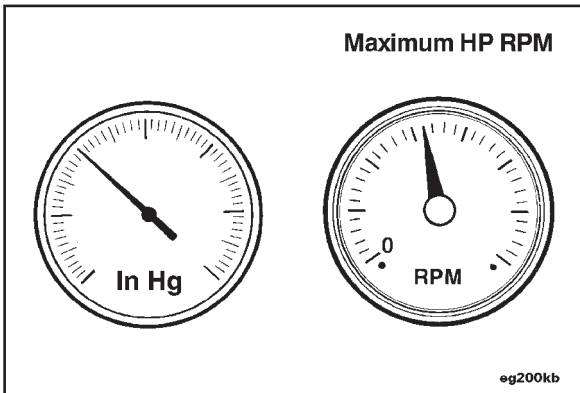


This test can be done with a mercury manometer or two separate gauges, Part No. ST-1273. If two gauges are being used, calibrate both gauges on a common pressure source to ensure consistency.

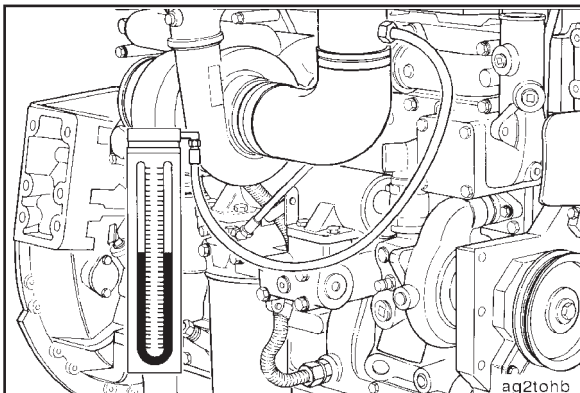
Install one pressure gauge, Part No. ST-1273, in the fitting in the turbocharger compressor outlet elbow. Install the other pressure gauge in the fitting in the intake manifold.

CAC Restriction

mm Hg		in Hg
152	MAX	6



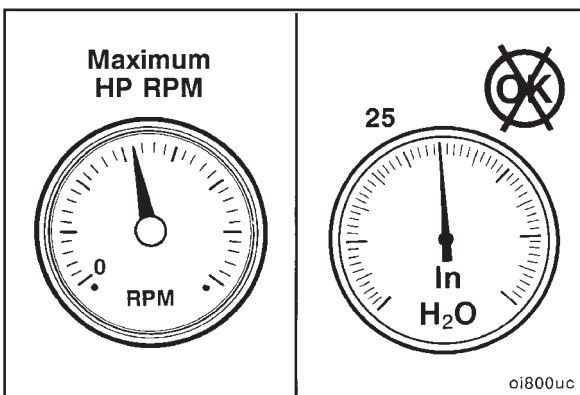
When measuring the pressure drop, operate a dynamometer at the rpm that delivers the maximum horsepower of engine tested. Engine speed will be 1600-1700 rpm on most engines.



Intake Air Restriction

Measure the inlet air restriction. Install the vacuum gauge, Part No. ST-434, or a manometer in the intake air piping.

NOTE: The gauge adapter **must** be installed at a 90 degree angle to the air flow in a straight section of pipe at a minimum of one pipe diameter before the turbocharger.



Operate the engine at maximum horsepower rpm and advertised horsepower.

Observe the reading on the gauge or manometer.

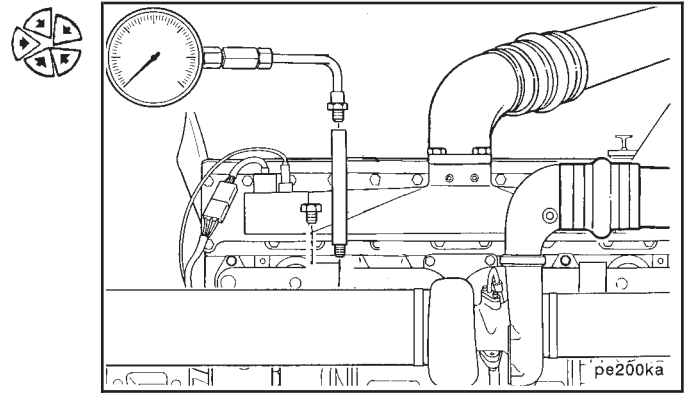
Intake Air Restriction

mm H ₂ O		in H ₂ O
635	MAX	25

Exhaust Air Restriction

Measure the exhaust air restriction. Install the pressure gauge, Part No. ST-1273, or a manometer in the exhaust air piping.

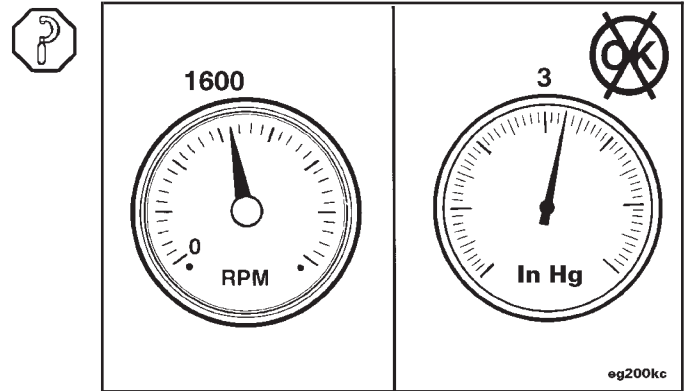
The gauge adapter **must** be installed near the turbocharger in a straight section of pipe at the turbine outlet.



Operate the engine at maximum horsepower rpm and advertised horsepower.

Observe the gauge or manometer.

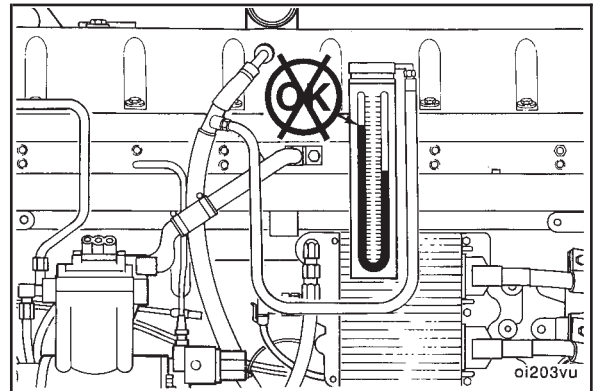
Exhaust Air Restriction		
mm Hg		in Hg
76	MAX	3.0



Engine Blowby

Measure the engine crankcase pressure.

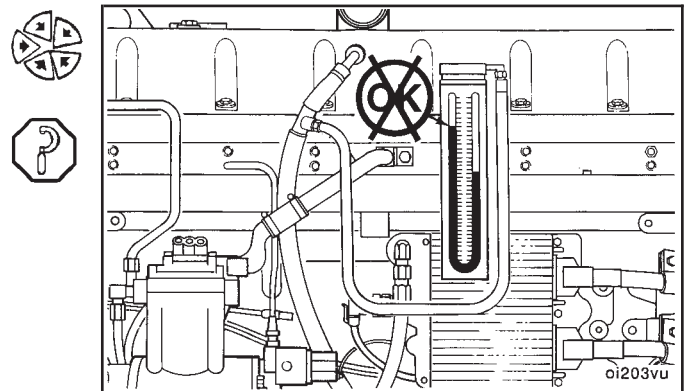
Use blowby checking tool, Part No. 3375150, and water manometer, Part No. ST-1111-3.

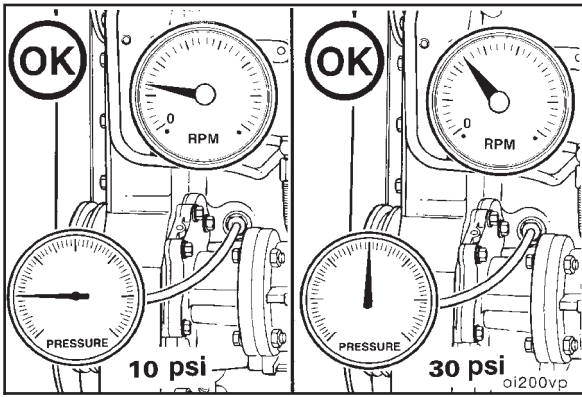


Install the water manometer to the blowby checking tool. Observe the engine blowby.

Engine blowby **must not** exceed the following specifications:

Blowby Specifications	
New, Rebuilt Engines*	30.5 cm H ₂ O [12.0 in H ₂ O]
Used Engines**	46.0 cm H ₂ O [18.0 in H ₂ O]
* Less than 160,000 km [100,000 miles] or 3600 hours.	
** Over 160,000 km [100,000 miles] or 3600 hours.	





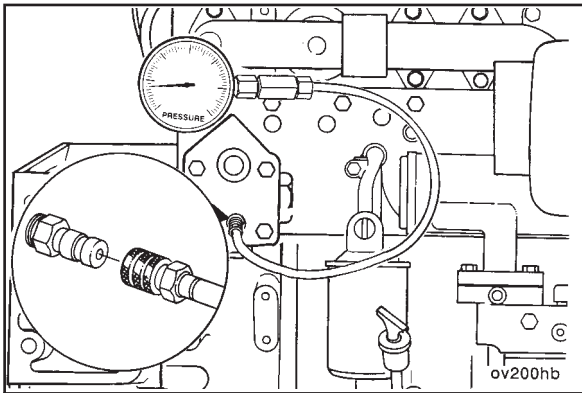
Lubricating Oil Pressure

Use Pressure Gauge, Part No. 3375275, to measure lubricating oil pressure.



Install the pressure gauge to the main oil rifle and observe the oil pressure.

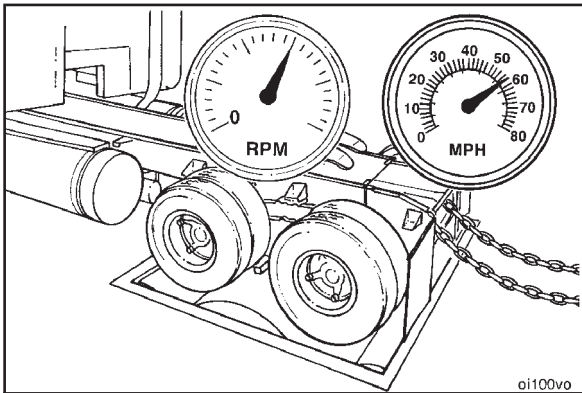
Lubricating Oil Pressure			
	kPa		psi
Low idle	70	MIN	10
At 1200 rpm	207	MIN	30



Coolant Pressure

Use coolant pressure/temperature/flow analyzer kit, Part No. 3822994, to measure engine coolant pressure.

Coolant Pressure		
kPa		psi
275	MAX	40



Engine Run-in (Chassis Dynamometer) (014-003)

Run-In Instructions (014-003-276)

Refer to Chassis Dynamometer - Operation, Procedure 014-002, for general operating procedures and safety precautions.

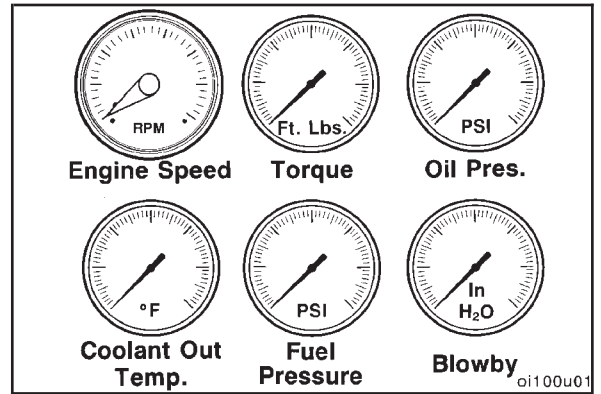
Operate the vehicle in a gear that produces a road speed of 90 to 100 km/h [55 to 60 m.p.h.] at maximum horsepower rpm.

M11 Series
Section 14 - Engine Testing - Group 14

Install a Cummins Electronic Service Tool on CELECT™ and CELECT™ Plus engines for monitoring engine performance variables, system pressures, temperatures etc.

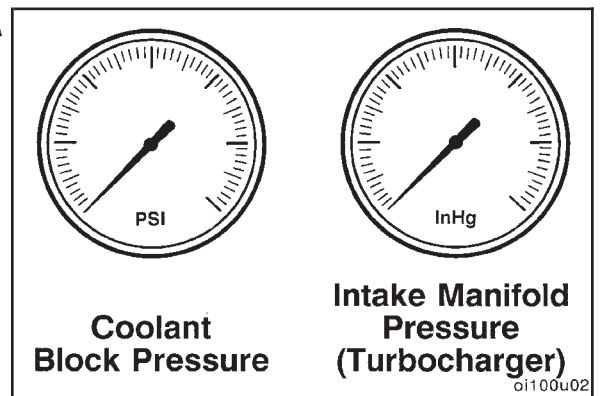
Monitor and record the following measurements during run-in:

- Lubricating oil pressure
- Coolant temperature
- Fuel pressure
- Wheel Horsepower
- Crankcase blowby
- Engine speed (rpm)
- Fuel rate (Use service tool, Part No. 3376375)
- Intake manifold air temperature
- Intake manifold pressure
- Turbocharger inlet air temperature
- Oil temperature



Refer to the Engine Dynamometer Worksheet in this section.

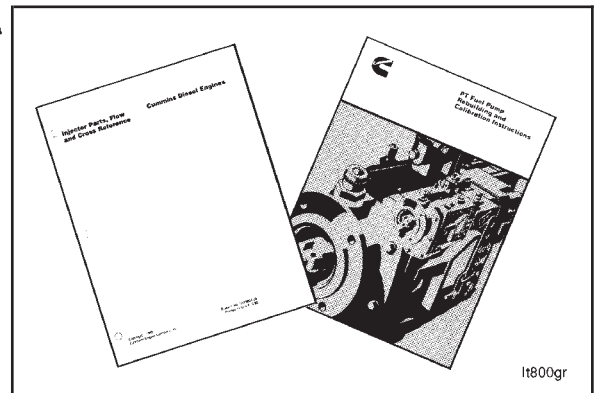
Cummins Engine Company, Inc. recommends monitoring block coolant pressure during run-in to aid in early indication of a cooling system problem.



Obtain the CPL number from the engine dataplate and the fuel pump code from the fuel pump dataplate.

Engine performance specifications and fuel system calibration values are listed for specific engine CPL and fuel pump codes in the following publications:

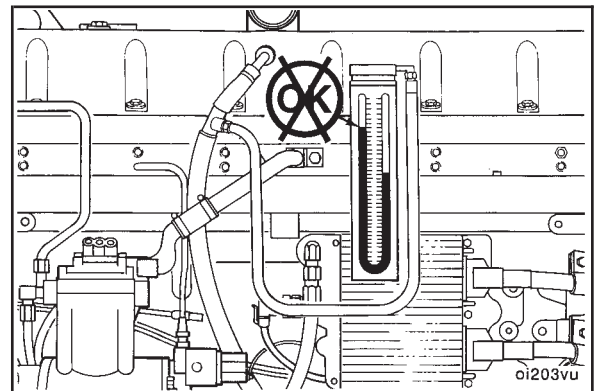
1. Fuel Pump Calibration Values, Bulletin No. 3379352.
2. Injector Parts Flow and Cross Reference, Bulletin No. 3379664.
3. Engine Data Sheets

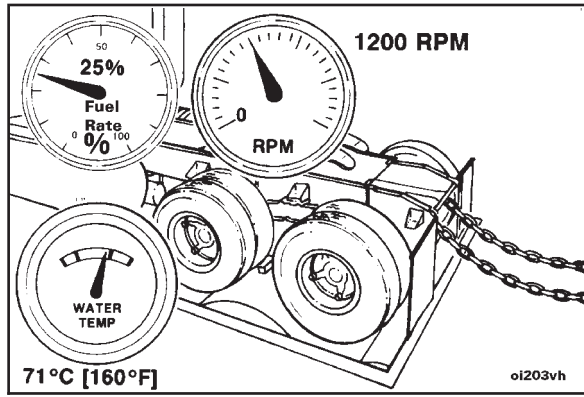


During the test, if a sudden increase in blowby occurs, or if blowby exceeds the maximum allowable limit during any run-in, return to the previous step of the test and continue the run-in. If blowby does **not** reach an acceptable level during the next step, discontinue the run-in and determine the cause.

Do **not** proceed to the next step until a steady, acceptable blowby reading is obtained.

NOTE: Blowby **must** be measured by using Service Tool, Part No. 3375150 or 3822566 with manometer, Part No. ST-1111-3, or equivalent. Service Tool, Part No. 3375150, as shown, utilizes a chamfered 7.67 mm [0.302 in] orifice.



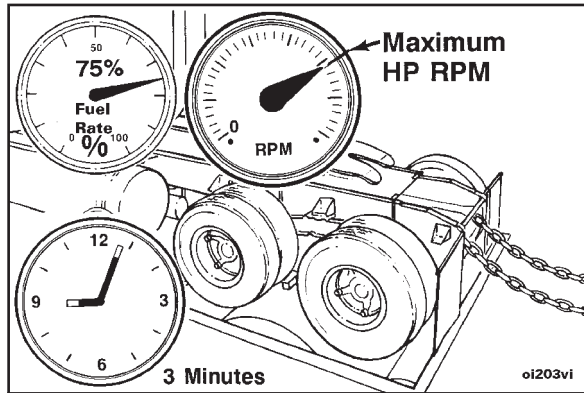


Move the throttle to obtain 1200 rpm engine speed, and apply a test load sufficient to develop 25 percent rated fuel pressure on STC engines or 25 percent fuel rate on CELECT™ and CELECT™ Plus engines.



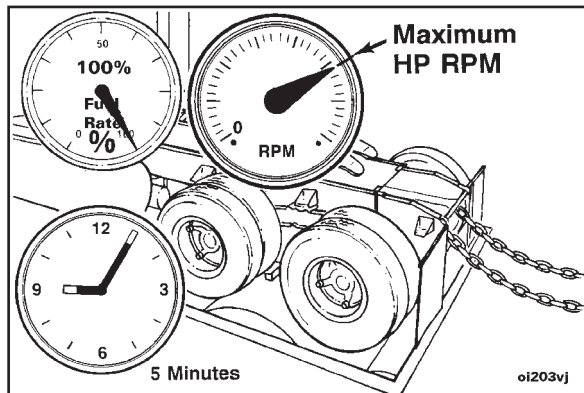
Operate the engine at this speed and load level until the coolant temperature reaches 71°C [160°F].

Check all gauges and record the data.

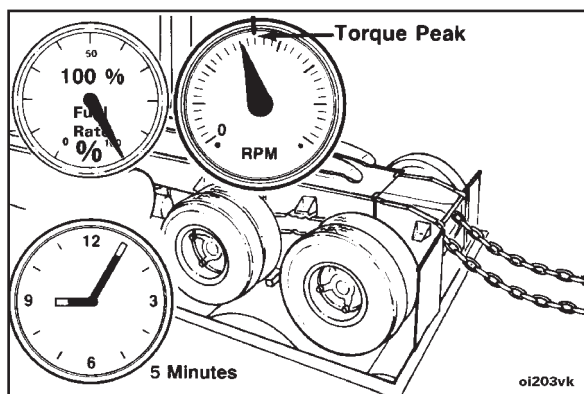


Operate the engine at maximum horsepower rpm and 75 percent of rated fuel pressure on STC engines, or 75 percent fuel rate on CELECT™ and CELECT™ Plus engines, for 3 minutes. Check the gauges, and record the readings.

Do **not** proceed to the next step until a steady, acceptable blowby reading is obtained.



Operate the engine at maximum horsepower rpm and advertised horsepower with a wide open throttle, for 5 minutes. Check the gauges, and record the readings.

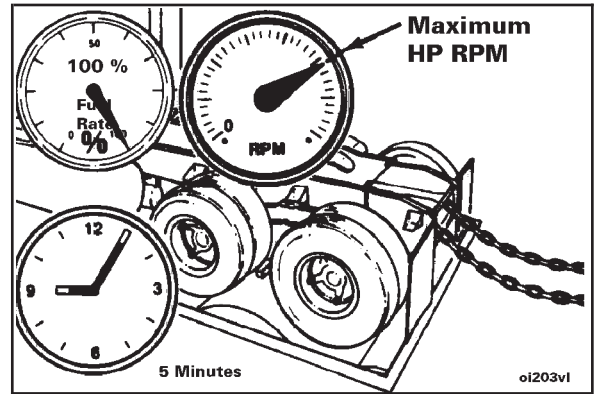


Operate the engine at nominal torque peak rpm, wide open throttle, for 5 minutes. Check the gauges, and record the readings.

Refer to the engine "Data Sheet" for the torque peak rpm of the engine model being tested.

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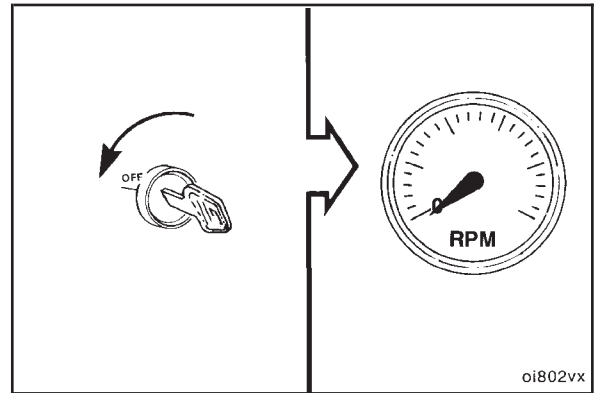
Operate the engine at maximum horsepower rpm with a wide open throttle for 5 minutes. Check the gauges, and record the readings. Compare the readings to those published on the appropriate engine "Data Sheet".



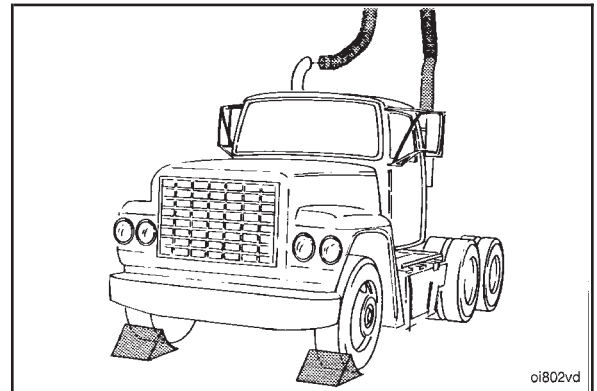
▲ CAUTION ▲

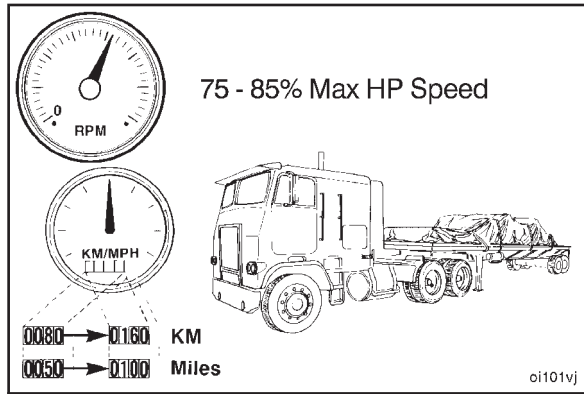
Do not shut off the engine immediately after the run-in is completed. Allow the engine to cool by operating it at 700 to 900 rpm for a minimum of 3 to 5 minutes to avoid internal component damages. This allows the turbocharger and other components to cool.

Shut off the engine.



Make sure all instrumentation is removed before removing the vehicle from the chassis dynamometer.





Engine Run-in (Without Dynamometer) (014-004)

Run-In Instructions (014-004-276)

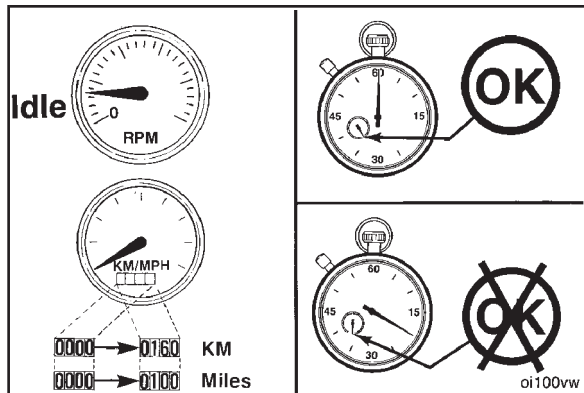
On-Highway Applications



Refer to “Engine Testing - General Information” and “Specifications — Engine Testing” at the front of this section before operating the engine to avoid internal component damage.

Operate the vehicle pulling the heaviest available trailer allowed for the first 80 to 160 km [50 to 100 miles] after a rebuild. Operate the vehicle in the highest gear possible within the normal operating rpm range of the engine. It is necessary to operate the engine at or near full throttle at 75 percent to 85 percent of maximum horsepower rpm indicated on the data plate.

Do **not** idle the engine for more than 5 minutes at any one time during the first 160 km [100 miles] of operation.

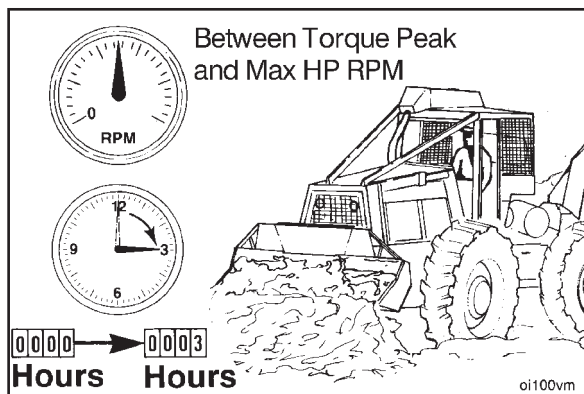


Off-Highway Applications

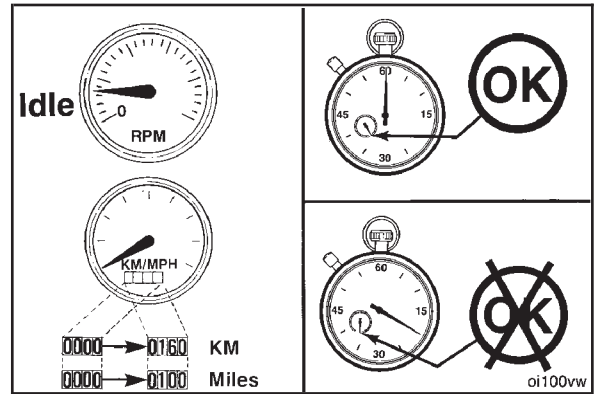


Refer to “Engine Testing — General Information” and “Specifications — Engine Testing” at the front of this section before operating the engine to avoid internal component damage.

Operate the engine under the highest load possible at full throttle within the normal operating rpm range of the engine for the first 3 hours of operation after rebuild.



Do **not** idle the engine for more than 5 minutes at any one time during the first 3 hours of operation after a rebuild.



Engine Testing (Engine Dynamometer) (014-005)

Setup (014-005-011)

NOTE: Be sure the dynamometer capacity is sufficient to permit testing at 100 percent of the engine rated horsepower. If the capacity is **not** enough, the testing procedure **must** be modified to the restrictions of the dynamometer.

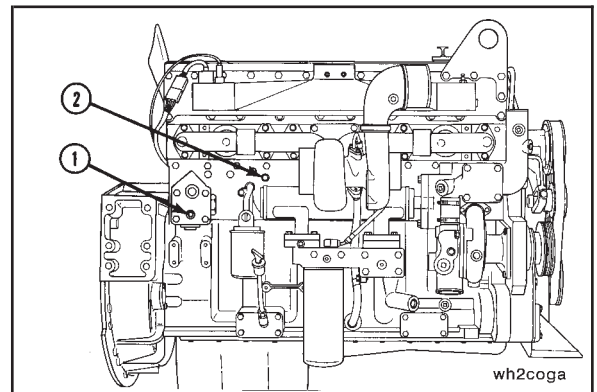
Use engine lifting fixture, Part No. 3822512, to install the engine to the test stand. Align and connect the dynamometer. Refer to the manufacturer's instructions for aligning and testing the engine.

Refer to Service Bulletin No. 3666005, Dynamometer and Road Engine Testing, for detailed instructions on auxiliary aftercooling system attachment.

NOTE: Some engines are equipped with fittings used for Compuchek® testing sensors. The sensor probes used for Compuchek® and dynamometer testing are **not** compatible. If the same location is used, remove the Compuchek® fitting and install adapters for the dynamometer sensor.

Install the coolant pressure sensor (1).

Install the coolant temperature sensor (2).

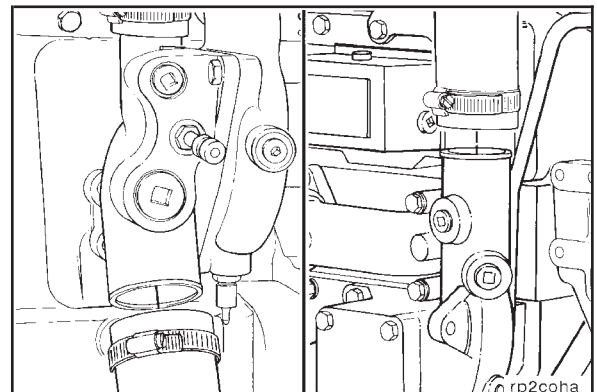


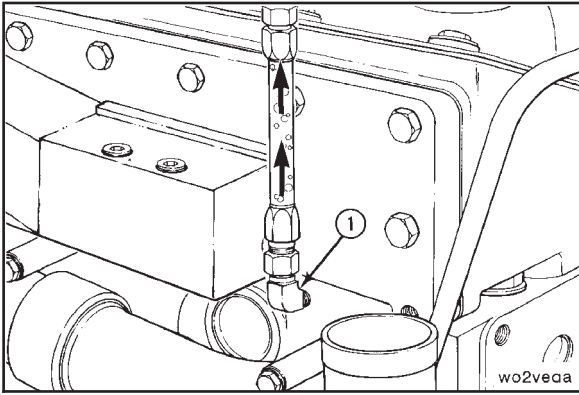
Coolant Plumbing

Connect the coolant supply to the water inlet connection.

Connect the coolant return to the water outlet connection.

Install the drain plugs and close all of the water drain cocks.

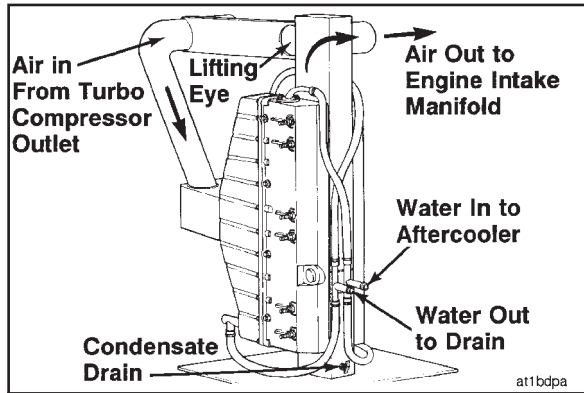




Loosen the cooling system vent line.

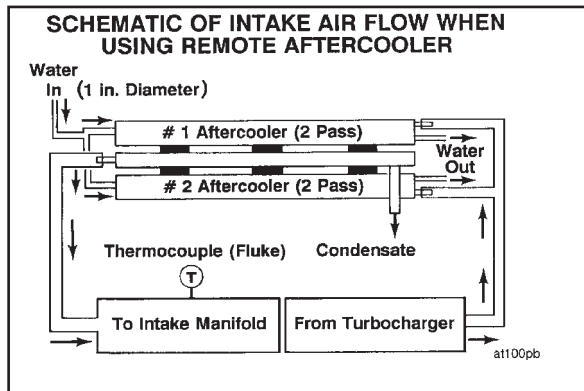
NOTE: Make sure the vent lines are connected to the cylinder head.

Fill the system with coolant until it flows from the vent. Tighten the vent line and finish filling the system.



Intake Air Temperature Control

The use of a remote aftercooler is mandatory whenever a Cummins CAC engine is attached to an engine dynamometer for the purpose of engine run-in, performance testing and engine diagnostics. Do **not** attempt to run a Cummins CAC engine without any means of controlling the intake manifold air temperature. Service tool, Part No. 3823978, utilizes twin aftercooler assemblies arranged for parallel air and water flow to cool the intake air to acceptable levels.



The parallel air flow circuit heat exchangers provide optimum performance by delivering air to the intake manifold at temperatures no higher than 66°C [150°F], and with less than the maximum allowable intake air pressure drop (102 mm Hg [4 in Hg]).

The remote aftercooler removes energy from the intake air which is compressed and heated by the turbocharger to temperatures as high as 210°C [410°F] then cooled to temperatures of 66°C [150°F] using city water at 16°C [60°F].

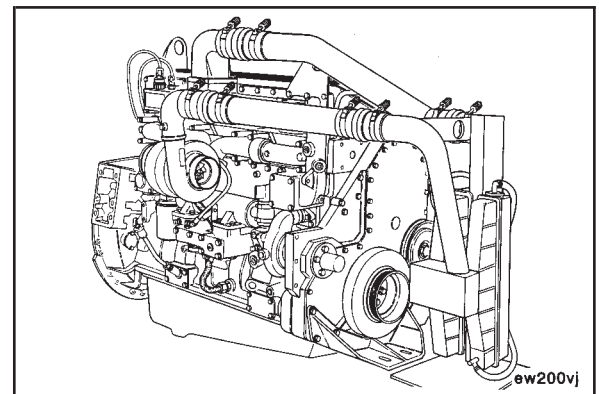
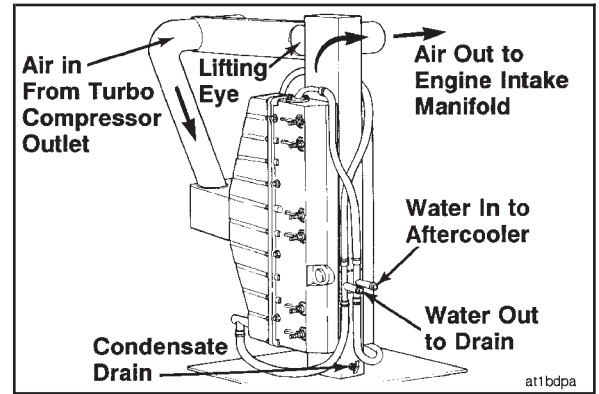
Water from a city tap line flows to the aftercoolers via a one inch I.D. neoprene hose. Testing has shown that 12 gallon per minute (GPM) city water flow is required (6 GPM per aftercooler core) to adequately cool the intake air. A typical garden hose is **not** suitable for this flow due to the excessive restriction. A low restriction ball type or gate valve is suitable for the operation provided the required flow rates are obtained.

Water returns to the drain or reservoir from the aftercoolers via a one inch I.D. hose. A low restriction gate valve or ball valve **must** be placed on the drain line(s) to allow regulation of the water flow through the aftercoolers. This enables one to maintain optimum intake air temperature during the test or run-in procedure.

The condensate that will develop, as the intake air is cooled in the remote aftercooler, is allowed to drain at all times through a hole at the bottom of the tubular steel manifold between the aftercoolers. This fitting **must** remain unobstructed throughout each use of the aftercoolers.

NOTE: Some air flow will escape through the condensate drain opening, but it is insignificant compared to the total air flow.

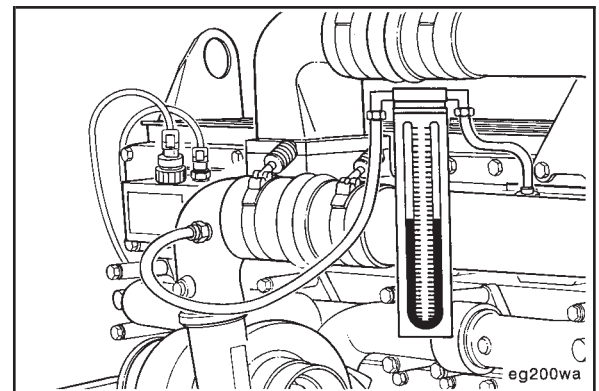
The air flow piping requires 4 inch I.D. aluminized steel piping. The flow circuit **must** have as few bends as possible maximizing the length of straight sections. However, when bends are required, use long elbows. Do **not** use square elbows, or anything that changes the air flow direction quickly. To reduce intake air restriction, air flow direction changes **must** occur gradually.

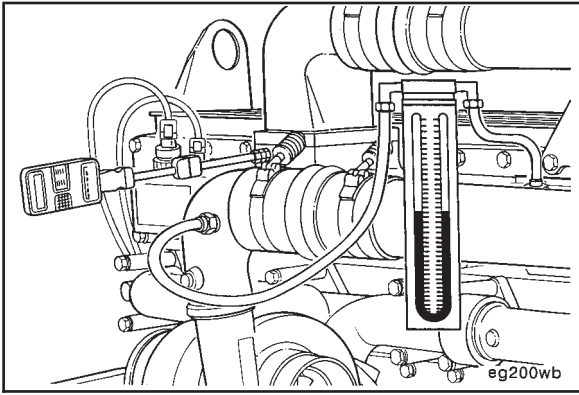


During engine test, monitor the pressure drop through the remote aftercooler. Install one end of a manometer to the Compuchek fitting in the turbocharger compressor outlet elbow. Install the other end of the manometer to the Compuchek™ fitting in the intake manifold. Although less accurate than a manometer, two individually calibrated press (in Hg) gauges can be used to monitor pressure drop.



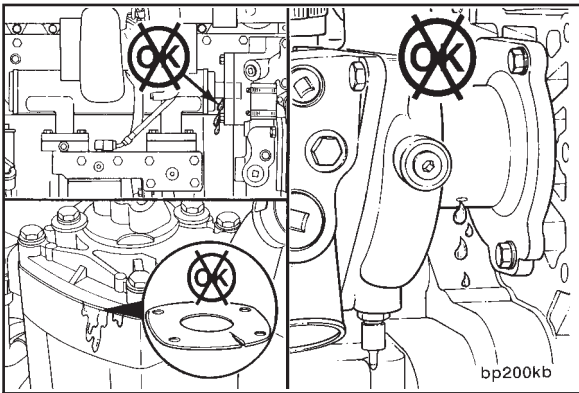
The pressure drop between these two locations **must not** be greater than 152 mm Hg [6 in Hg]. If the pressure drop is greater than 152 mm [6 in Hg], check the remote aftercoolers and air flow piping for plugging. Clean and replace if necessary.



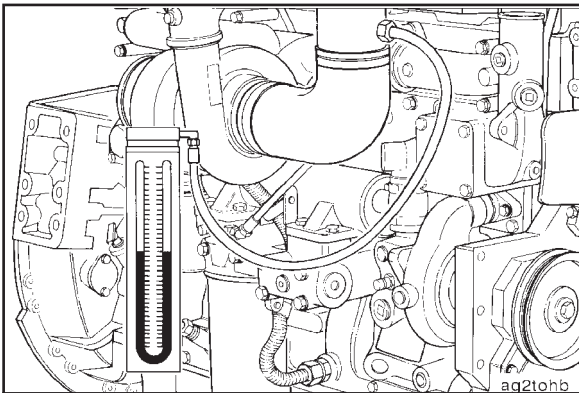


During engine test, also monitor intake manifold temperature. Install a thermocouple (Fluke) in the 1/2 inch pipe tap in the intake manifold. The intake air heats up as it passes through the intake manifold so the temperature **must** be measured as close to the intake manifold elbow as possible.

If the intake manifold temperature exceeds 66°C [150°F] during the test, make sure that there is an ample supply of clean cool water flowing through the aftercoolers. Under no circumstances **must** the intake air temperature be allowed to exceed 77°C [170°F].



Visually inspect the engine for coolant leaks.
Repair all leaks found.



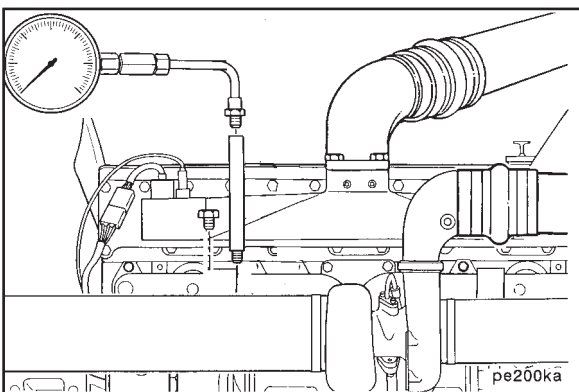
Air Inlet Restriction

Install a water manometer to the air inlet pipe of the turbocharger to measure inlet restriction.

The manometer adapter **must** be installed at a 90 degree angle to the air flow in a straight section of pipe, one pipe diameter before the turbocharger.

NOTE: A vacuum gauge **can** be used to record the intake air restriction.

Minimum Gauge Capacity: 760 mm H₂O [30 inches H₂O].



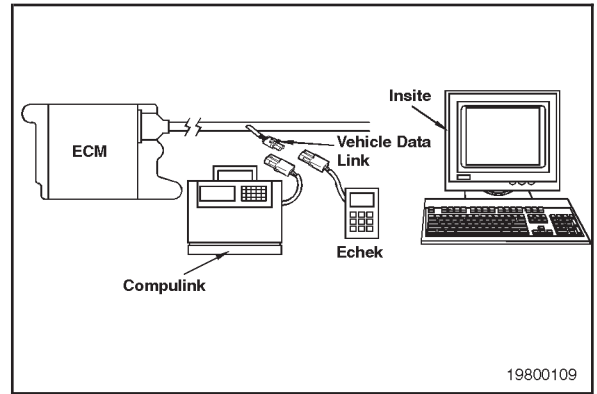
Exhaust Restriction

Connect a manometer to a straight section of the exhaust piping one pipe diameter from the turbocharger outlet to measure exhaust restriction.

Protect the hose from heat by using a 305 mm [12 in] minimum length of metal tubing leading from the exhaust pipe connection.

Lubricating Oil Temperature

Use a Cummins Electronic Service Tool to monitor the lubricating oil temperature.

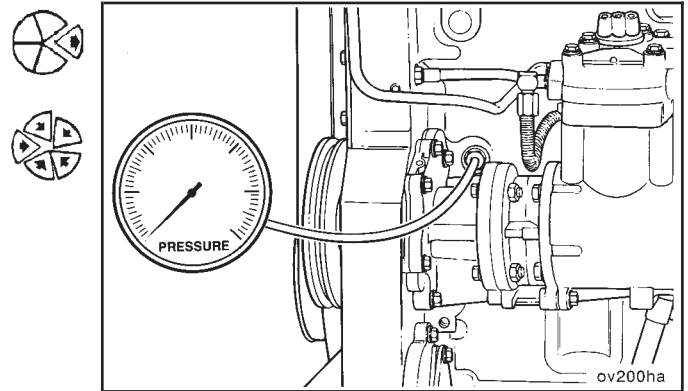


Lubricating Oil Pressure

On STC engines, remove the pipe plug from the main oil rifle drilling in the cylinder block.

Install the lubricating oil pressure gauge, Part No. 3375275.

On CELECT™ and CELECT™ Plus engines, use a Cummins Electronic Service Tool to monitor the lubricating oil temperature.

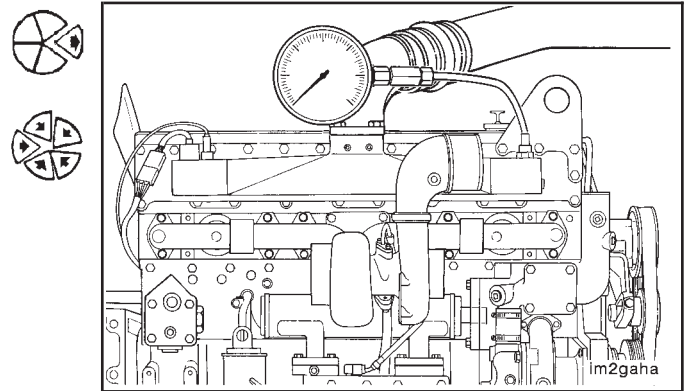


Intake Manifold Pressure

On STC engines, remove the pipe plug in the intake manifold just below the inlet air connection and install the intake manifold pressure gauge, Part No. ST-1273.

Install the lubricating oil pressure gauge, Part No. 3375275.

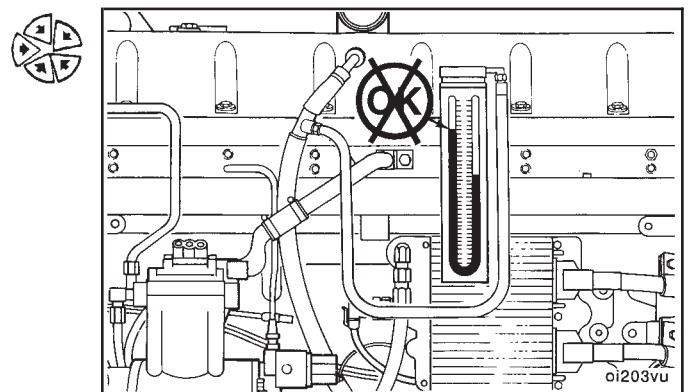
On CELECT™ and CELECT™ Plus engines, use a Cummins Electronic Service Tool to monitor the lubricating oil temperature.

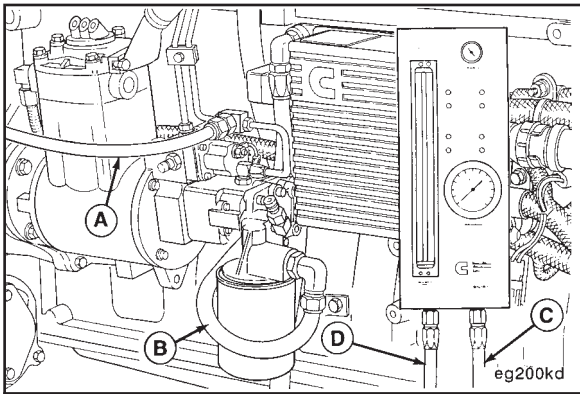


Engine Blowby

Install the Part No. 3822566, Engine Blowby Tool, to the breather on the rocker lever cover to measure engine crankcase pressure.

NOTE: A pressure gauge can be used to record the engine blowby.





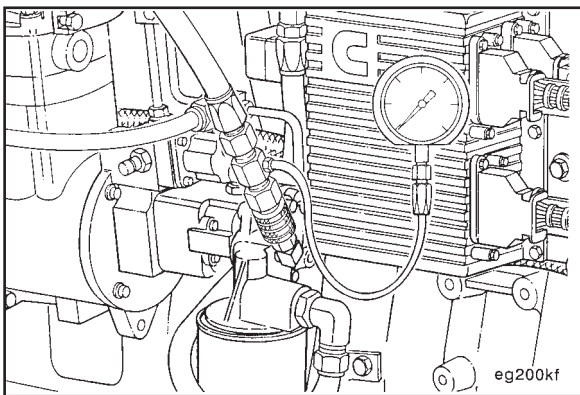
Fuel Rate

The Part No. 3376375, Fuel Measuring instrument, is used during the performance check to measure fuel consumption. For more details, refer to "Engine Testing - General Information".

Install the fuel measuring device as follows:

- The fuel return hose from the engine to the fuel measuring device (A).
- The fuel inlet hose to the fuel filter inlet (B).
- The return hose from the device (C) to the fuel tank.
- The fuel inlet hose to the device from the fuel tank suction line (D).

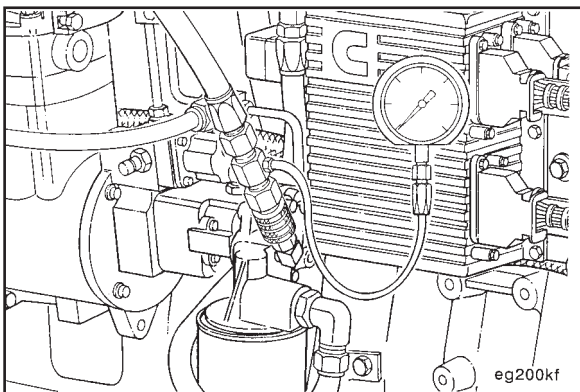
NOTE: Adjust fuel rate to compensate for temperature variation if required. The fuel temperature **must** be between 15.5°C and 48.9°C [60°F and 120°F] for accurate measurement.



Fuel Inlet Restriction

Measure the fuel inlet restriction. Install a vacuum gauge, Part No. ST-434, between the fuel filter and the gear pump inlet.

NOTE: Do **not** measure fuel inlet restriction with the fuel measuring device installed. This will **not** measure the inlet restriction of the vehicle's supply plumbing.

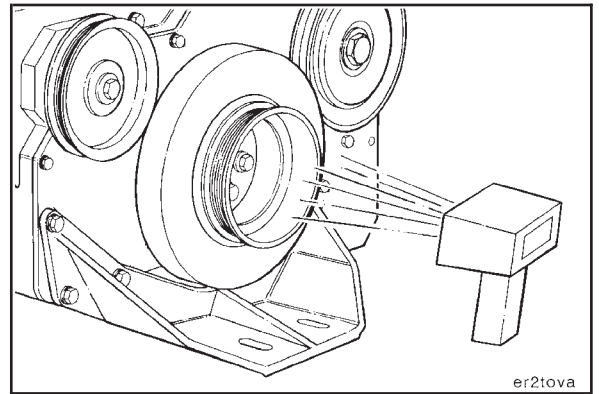


Hold the gauge at the same level as the gear pump.

NOTE: The gauge will **not** measure the correct vacuum if the gauge is **not** held at the same level as the gear pump.

Engine Speed (rpm) With a Verified Tachometer

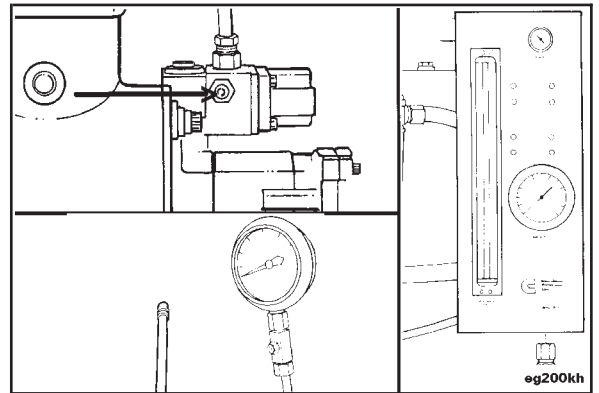
Use digital optical tachometer, Part No. 3377462, to check and verify engine speed.



Fuel Pressure

Measure the fuel pressure. Install the pressure gauge, Part No. ST-435-6, or the pressure gauge in the fuel measuring device, Part No. 3376375, to the Compucheck® fitting on the fuel shutoff valve.

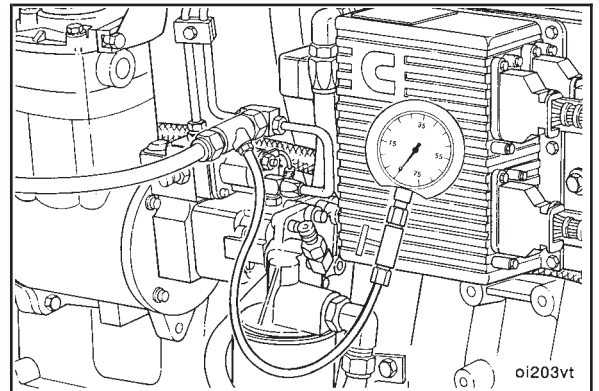
NOTE: Pressure gauge, Part No. ST-435-6, is included with snap rail pressure gauge, Part No. 3375932.



Fuel Drain Line Restriction

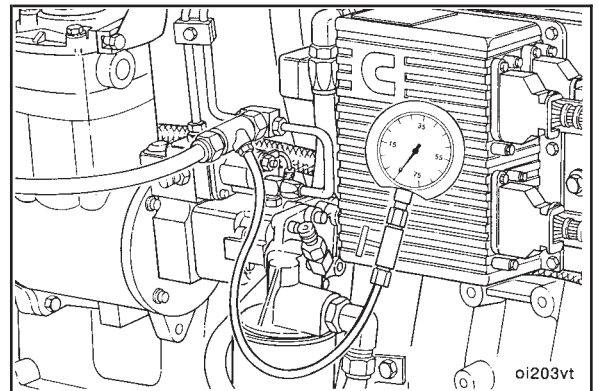
Use pressure gauge, Part No. ST-1273, to measure fuel drain line restriction.

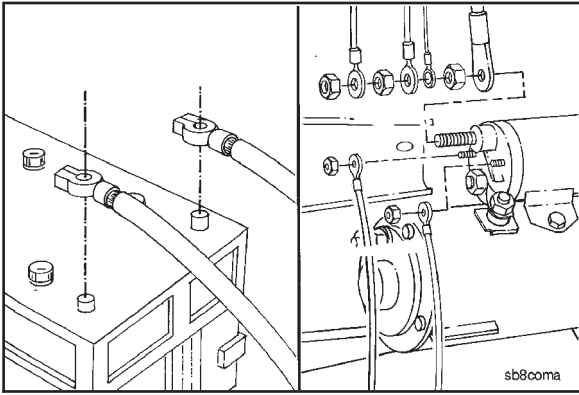
NOTE: Do **not** measure fuel drain line restriction with the fuel measuring device installed. This will **not** measure the drain line restriction of the vehicle's return plumbing.



Hold the gauge at the same level as the connection.

NOTE: The gauge will **not** measure the correct pressure if the gauge is **not** held at the same level as the connection.





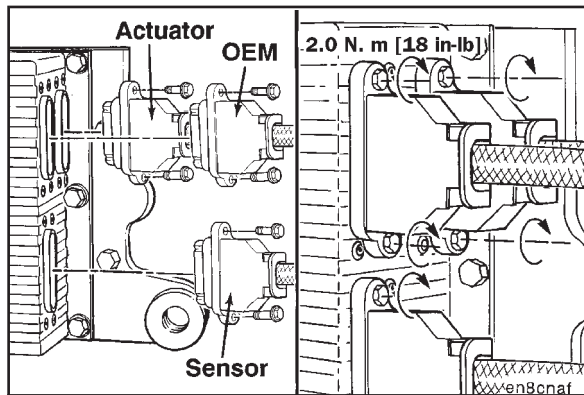
Starting Motor

Inspect the voltage rating on the starting motor before installing the electrical wiring.



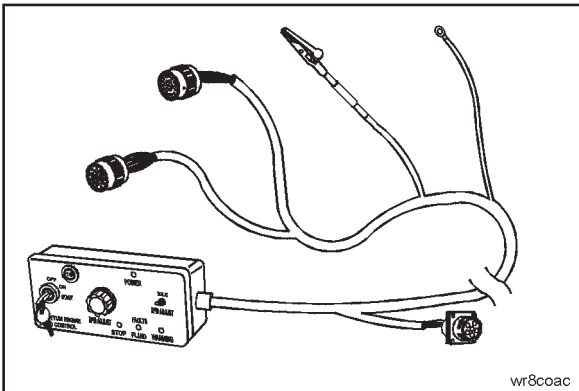
Install the electrical wiring to the starting motor and batteries, if used.

NOTE: If another method of starting the engine is used, follow the manufacturer's instructions to make the necessary connections.

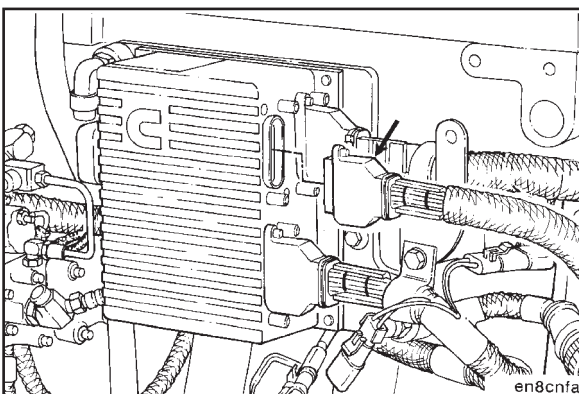


Engine Throttle Control

CELECT™ and CELECT™ Plus engines which are run on an engine dynamometer require that the engine harness be installed, and connected to the engine. Additionally, a special engine dynamometer version of the OEM wiring harness and throttle control **must** be installed.



A special wiring harness and throttle control, Part No. 3823948, has been developed to enable engine operation out of chassis.



Connect the dynamometer test OEM wiring harness amp connector to the ECM. Tighten the connector capscrews to the ECM.



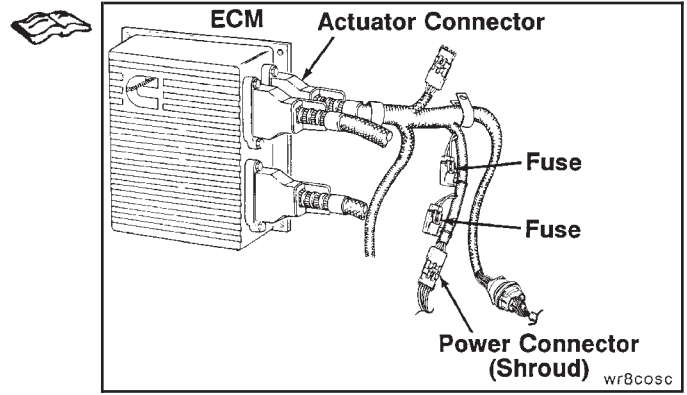
Torque Value: 2.0 N•m [18 in-lb]

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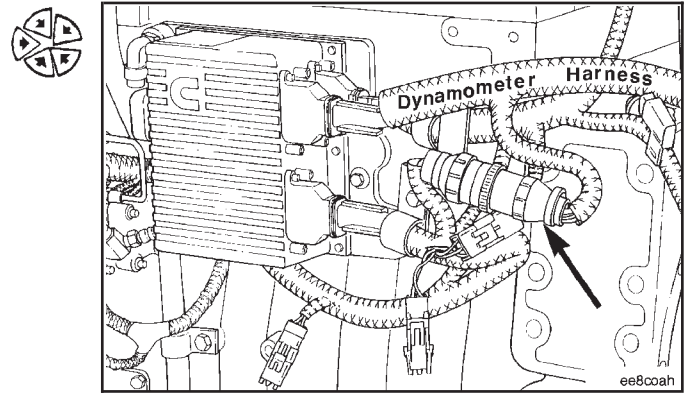
Connect the dynamometer test OEM wiring harness 3-pin connector to the engine harness power connector (shroud).

To save, adjust, and write parameters to and from the ECM, refer to the applicable Cummins Electronic Service Tool.

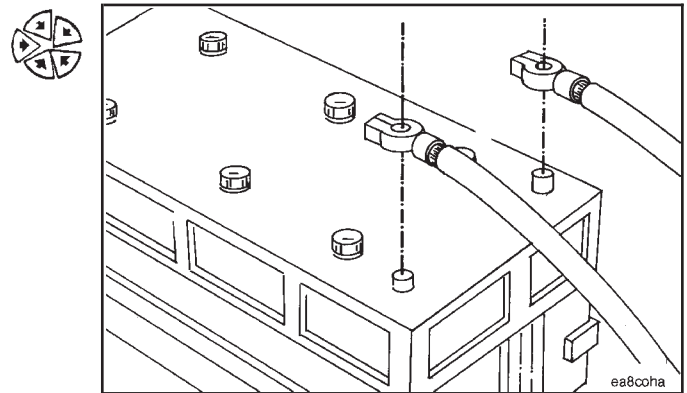
NOTE: Parameters **must** be returned to their original value when the test or run-in is completed.



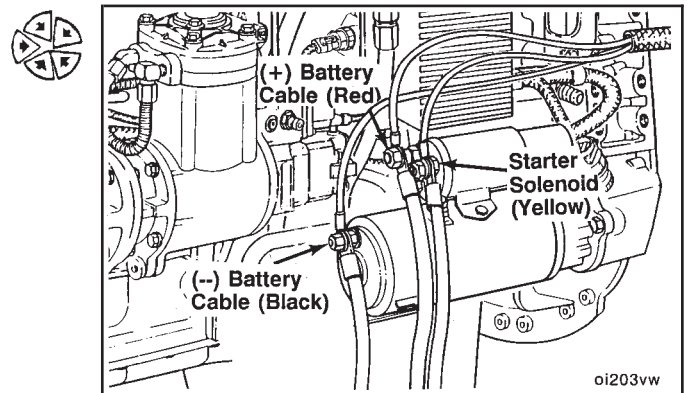
Connect the dynamometer test OEM wiring harness 9-pin connector to the engine harness 9-pin connector.

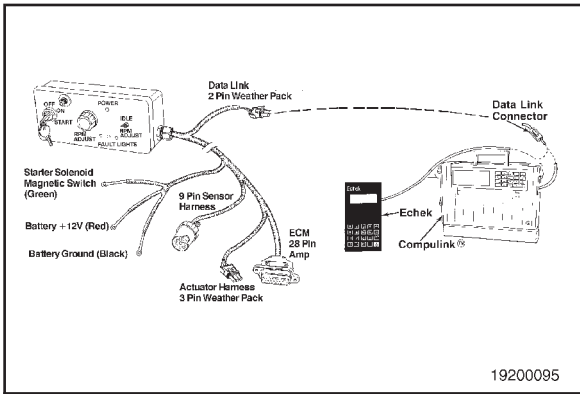


Connect battery power to the starter.



Connect the dynamometer test OEM wiring harness starter solenoid lead (yellow) to the starter solenoid. Connect the ground lead (black) to the starter or battery negative or ground side. Connect the positive 12 VDC power lead (red) to either the starter or battery positive (+ 12 VDC) side.

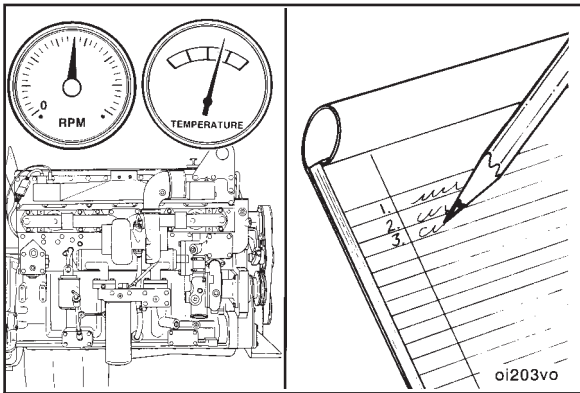




Connect the keyswitch panel data link cable to the Cummins Electronic Service Tool.

Set up for dyno mode.

The setup is now completed, and the auto/manual throttle control can be used to control engine speed.

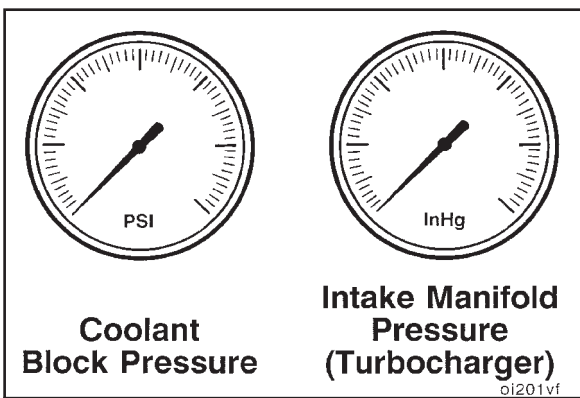


Engine Run-in (Engine Dynamometer) (014-006)

Run-In Instructions (014-006-276)

Measurements from these indicators and gauges **must** be observed closely during all phases of the engine run-in period.

- Engine speed
- Engine horsepower
- Lube oil pressure
- Lube oil temperature
- Coolant out temperature
- Fuel pressure
- Crankcase blowby
- Fuel rate (using Service Tool, Part No. 3376375)
- Intake manifold air temperature
- Intake manifold pressure
- Turbocharger inlet air temperature

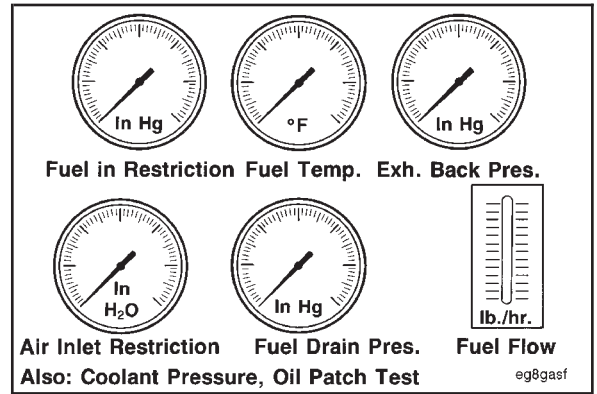


Refer to the Engine Dynamometer Worksheet, Procedure 014-001.

Cummins Engine Company, Inc. recommends monitoring block coolant pressure during run-in to aid in early indication of a cooling system problem.

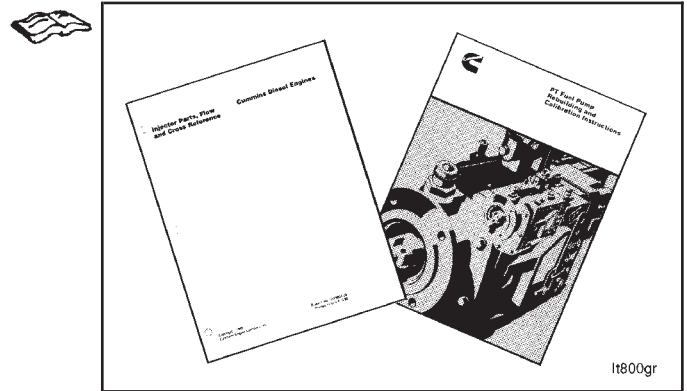
It is a good practice to observe these measurements even if engine performance meets specifications. If engine performance does **not** meet specifications, these measurements can indicate possible reasons for under performance. The measurements taken are:

- Fuel inlet restriction at fuel pump inlet
- Fuel temperature
- Exhaust system back pressure
- Air inlet restriction pressure
- Fuel drain pressure
- Coolant pressure
- Oil patch test



Obtain the CPL number from the engine data plate and the fuel pump code from the fuel pump data plate. Engine performance specifications and fuel system calibration values for specific engine CPL and fuel pump codes are listed in the following publications:

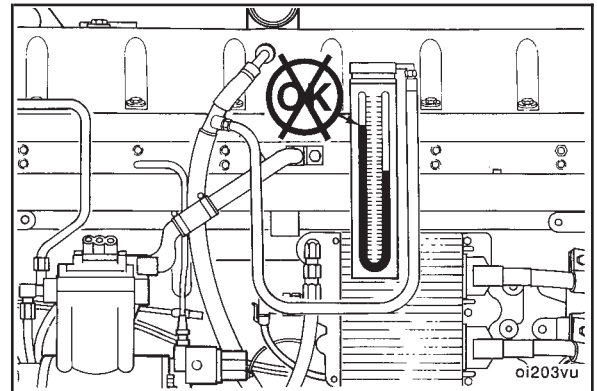
1. Fuel Pump Calibration Values, Bulletin No. 3379352.
2. Injector Parts Flow and Cross Reference, Bulletin No. 3379664.
3. Engine Data Sheets.



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 during the next step, discontinue the run-in and determine the cause.

Do **not** proceed to the next step until a steady blowby reading is obtained.

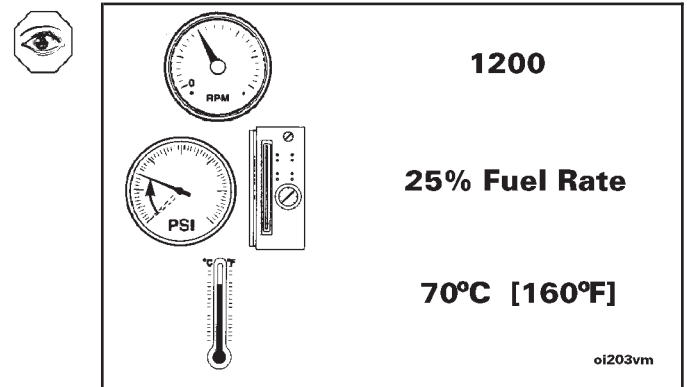
NOTE: Blowby **must** be measured by using Service Tool, Part No. 3375150 or 3822566, with manometer, Part No. ST-1111-3, or equivalent. Service Tool, Part No. 3375150, as shown, utilizes a chamfered 7.67 mm [0.302 inch] orifice.

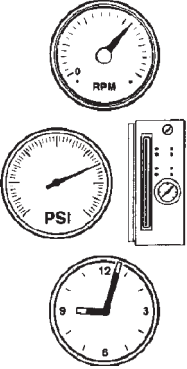


Start the engine.

Move the throttle to obtain 1200 rpm engine speed, and apply a test load sufficient to develop 25 percent of rated fuel pressure or 25 percent fuel rate on CELECT™ and CELECT™ Plus engines.

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.





**Maximum
Horsepower RPM**

75% Fuel Rate

3 Minutes

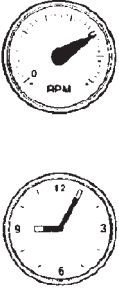
oi203vn



Open the throttle to obtain a speed at which maximum horsepower is developed and adjust the dynamometer load to achieve 75 percent of rated fuel pressure or 75 percent fuel rate on CELECT™ and CELECT™ Plus engines. Operate the engine at this speed and load level for 3 minutes.

Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until blowby is stable within specifications.



**Maximum
Horsepower RPM**

Full Throttle

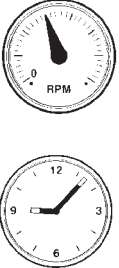
5 Minutes

oi201vd



Move the throttle lever to its fully opened position, and increase the dynamometer load until 100 percent rated fuel pressure or 100 percent fuel flow on CELECT™ and CELECT™ Plus engines is developed. Operate the engine at this condition and load level for 5 minutes, or until the blowby becomes stable within specifications.

Check all gauges and record the data.



**Full Throttle
Torque Peak RPM**

7 Minutes

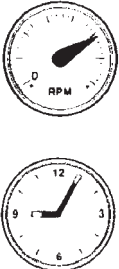
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Increase the dynamometer load until the engine speed reduces to the engine's torque peak RPM.

Operate the engine at torque peak rpm for 7 minutes.

Check all gauges and record the data.



**Maximum
Horsepower RPM**

Full Throttle

5 Minutes

oi201ve



Reduce the dynamometer load until the engine speed increases to the engine's maximum horsepower rpm.

Operate the engine at maximum horsepower rpm for 5 minutes.

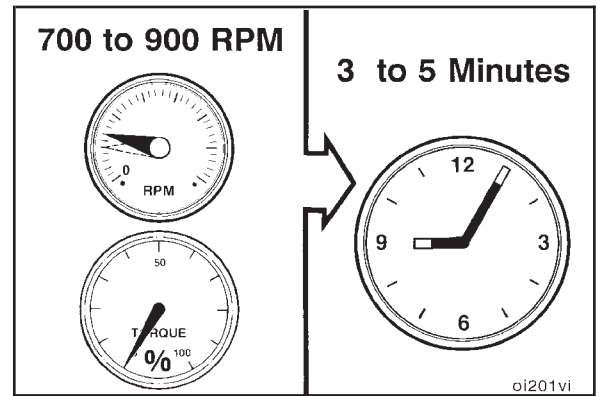
Check all gauges and record the data.

Compare the readings to the specifications listed in the previously mentioned publications.

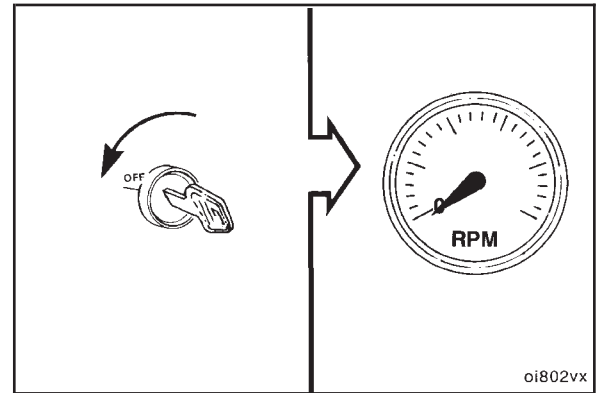
▲ CAUTION ▲

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.

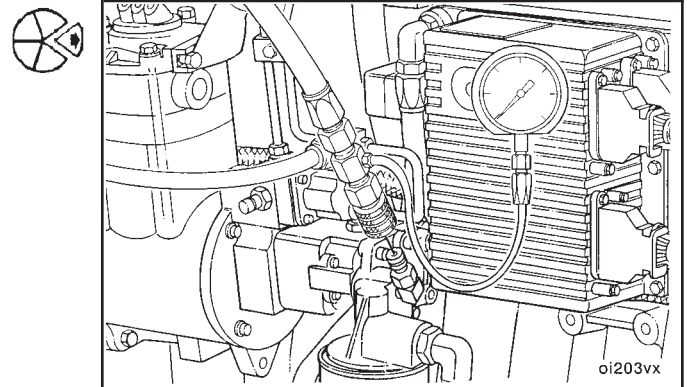
Remove the dynamometer load completely, and operate the engine at 700 to 900 rpm for 3 to 5 minutes. This period will allow the turbocharger and other components to cool.



Shut off the engine.



Make sure all instrumentation is removed before removing the engine from the dynamometer.



Engine Testing (Portable Dynamometer or Load Bank) (014-009)

General Information

When it is **not** possible to load an engine immediately after rebuild or repair, (example: on-highway tractor that **must** be "bobtailed" for delivery, a standby generator or fire pump that **cannot** be operated because of customer restrictions, a fire truck that **cannot** be loaded with the water pump, etc.), the engine **must** be run-in on a chassis dynamometer, portable dynamometer or load bank following the recommendations outlined in the preceding procedures.

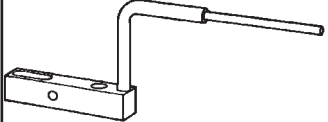
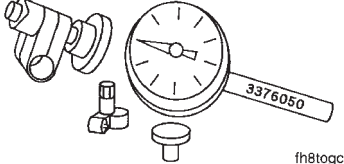
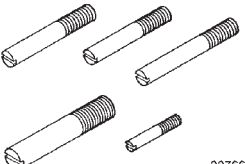
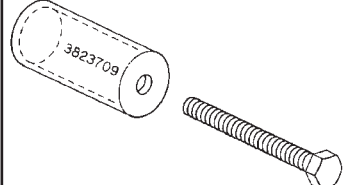
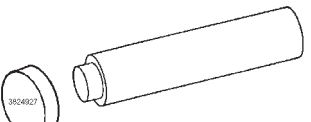

Section 16 - Mounting Adaptations - Group 16

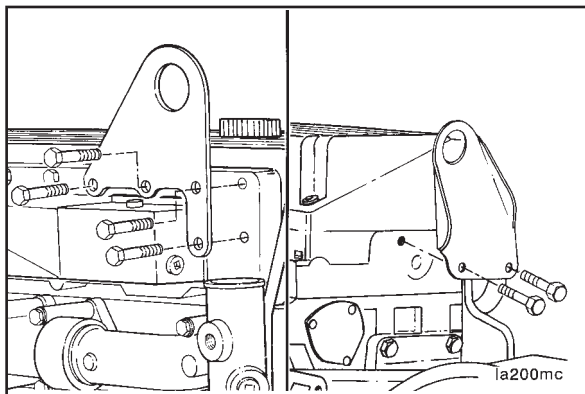
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Service Tools Mounting Adaptations

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

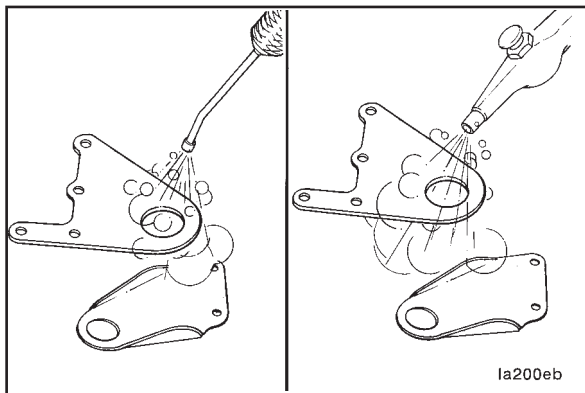
Tool No.	Tool Description	Tool Illustration
ST-1325	<p>Dial Gauge Attachment</p> <p>Attaches to crankshaft flange to provide measuring of flywheel and flywheel housing runout with dial bore gauge.</p>	 <p style="text-align: right;">fh8togb</p>
3376050	<p>Dial Indicator and Sleeve Assembly</p> <p>Use with Part No. ST-1325 Dial Gauge Attachment to measure flywheel and flywheel housing runout.</p>	 <p style="text-align: right;">fh8togc</p>
3824926	<p>Guide Pin Kit</p> <p>Aid during removal and installation of flywheel and flywheel housing.</p>	 <p style="text-align: right;">3376695</p>
3823709	<p>Idler Shaft Puller and Capscrew</p> <p>Used to remove the idler shaft from the idler gear and flywheel housing on engines equipped with a REPTO flywheel housing.</p>	 <p style="text-align: right;">3823709</p>
3824927	<p>Cup Plug Driver</p> <p>Used to install the cup plug in a REPTO flywheel housing. Requires a cup plug driver handle.</p>	 <p style="text-align: right;">3824927</p>
3824928	<p>Offset Wrench</p> <p>Used to loosen or tighten four hidden mounting capscrews on engines equipped with a REPTO flywheel housing.</p>	 <p style="text-align: right;">3823711</p>



Engine Lifting Brackets (016-001)

Remove (016-001-002)

Remove the capscrews and the front lifting bracket.
Remove the capscrews and the rear lifting bracket.



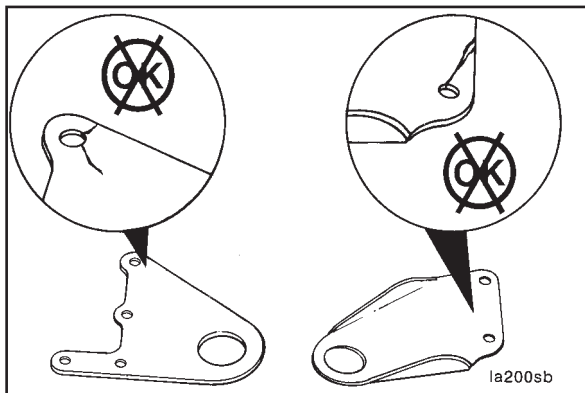
Clean (016-001-006)



WARNING

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

Use steam or solvent to clean the lifting brackets. Dry with compressed air.



Inspect for Reuse (016-001-007)

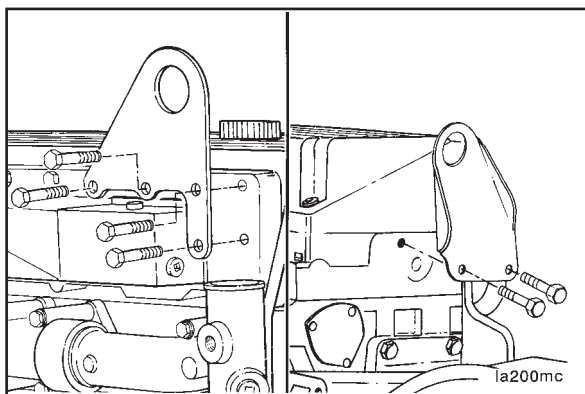


CAUTION

Do not use a cracked or damaged bracket. Do not weld a cracked bracket. Personal injury can result.

Visually inspect the brackets for cracks or damage.

Replace the bracket if it is cracked.



Install (016-001-026)

Install the front bracket and capscrews.

Torque Value: 47 N•m [35 ft-lb]



Install the rear bracket and capscrews.

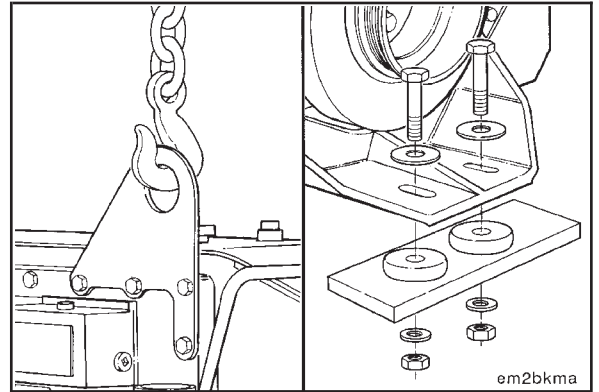
Torque Value: 81 N•m [60 ft-lb]

Engine Support Bracket, Front (016-002)

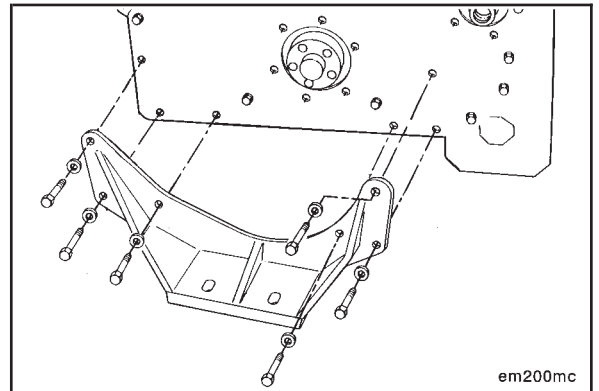
Remove (016-002-002)

Use a hoist or lifting fixture to support the front of the engine.

Remove the capscrews from the front engine mount.



Remove the six mounting capscrews and the front engine support.



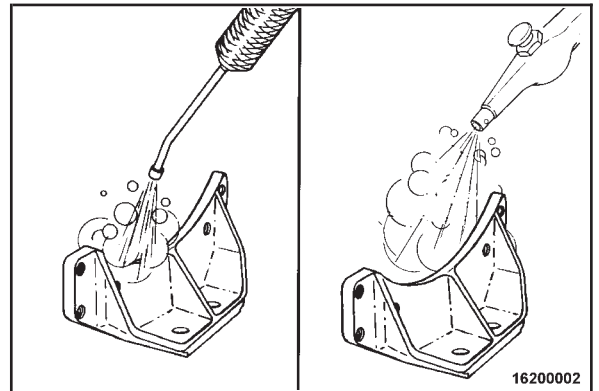
Clean (016-002-006)



WARNING

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

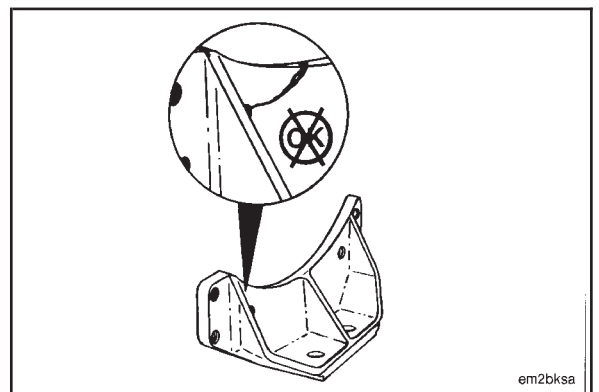
Use steam or solvent to clean the front engine support. Dry with compressed air.

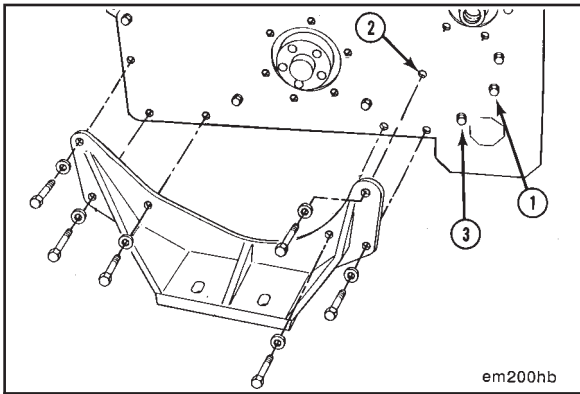


Inspect for Reuse (016-002-007)

Visually inspect the support for cracks or damage.

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





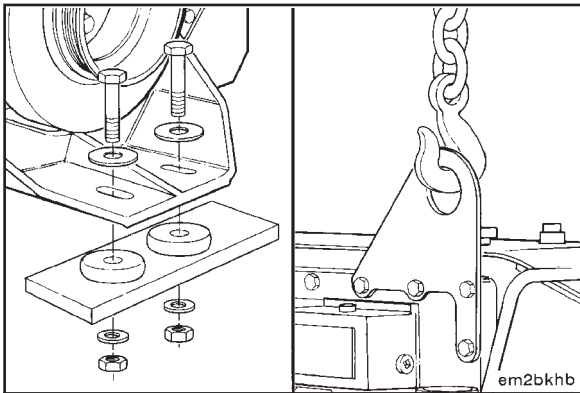
Install (016-002-026)

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



Install the front support and mounting capscrews.

Torque Value: 68 N•m [50 ft-lb]



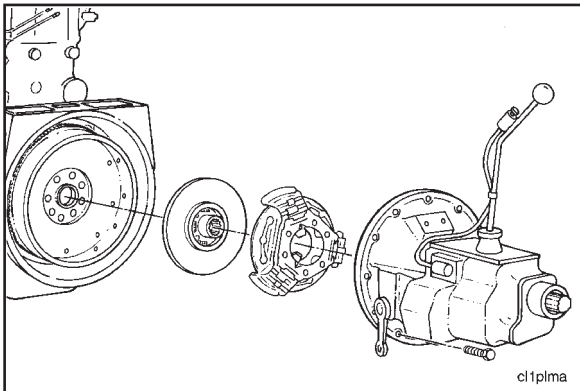
Lower the front of the engine.

Install the front engine mount capscrews.



Tighten the capscrews to the manufacturer's specifications.

Remove the lifting fixture or hoist from the front of the engine.



Flywheel (016-005)

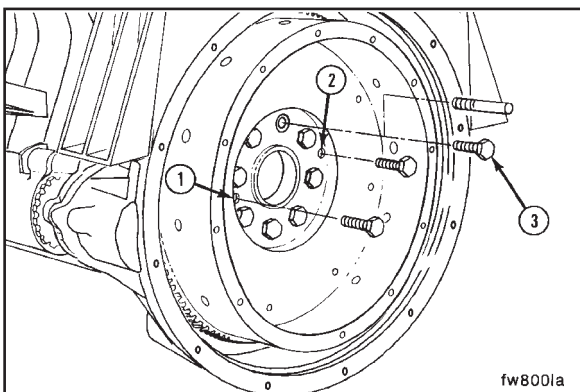
Remove (016-005-002)



Remove the vehicle drive line and transmission. Refer to the manufacturer's instructions.

Remove the clutch discs and pressure plate.

Hold the flywheel to prevent rotation.



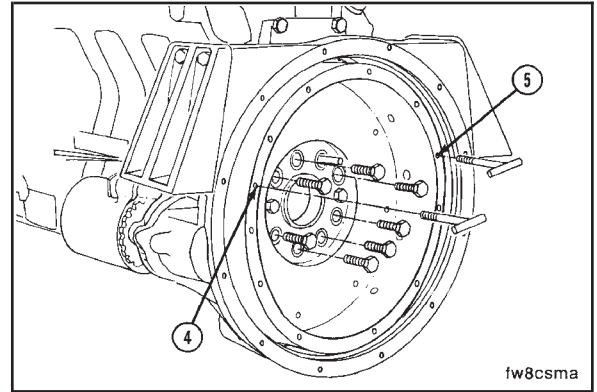
Install M10 - 1.50 x 40 puller capscrews at points (1) and (2).

Remove capscrew (3) and install guide pin, Part No. 3376696.

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be sure to use the correct capscrews.

Determine the capscrew thread design and size, and install two "T-handles" in the flywheel at points (4) and (5).

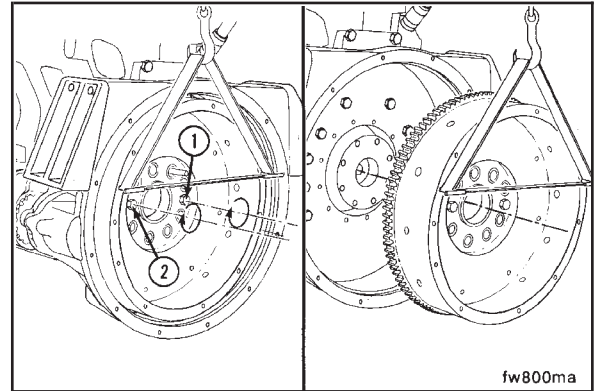
Remove the remaining seven flywheel mounting capscrews.



Tighten capscrews (1) and (2) in alternating sequence to loosen the flywheel.

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

Remove the flywheel from the guide pin.



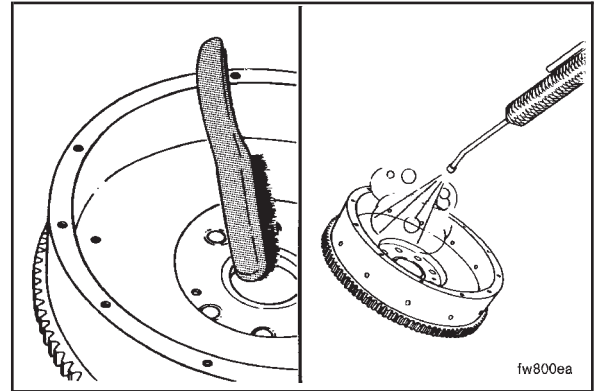
Clean (016-005-006)

Use a wire brush to clean the crankshaft pilot bore.



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

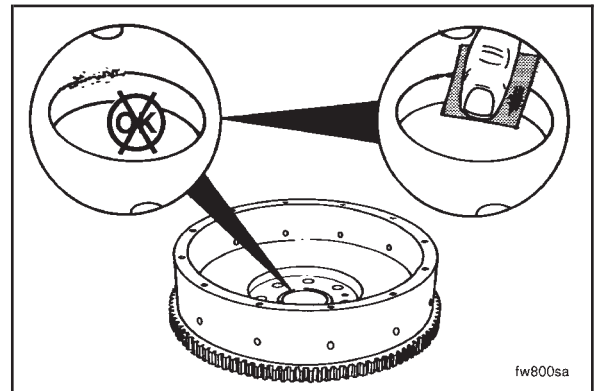
Use steam or solvent to clean the flywheel. Dry with compressed air.

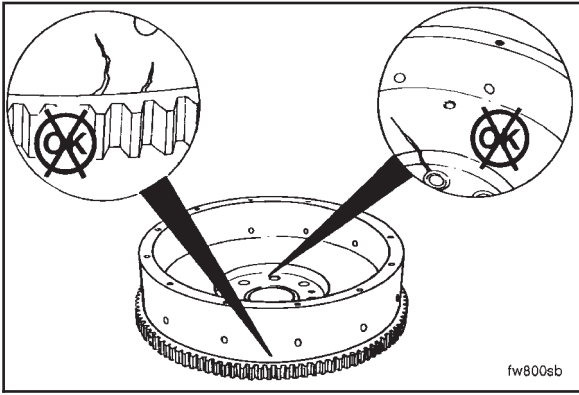


Inspect for Reuse (016-005-007)

Visually inspect for nicks or burrs.

Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, to remove small nicks and burrs.

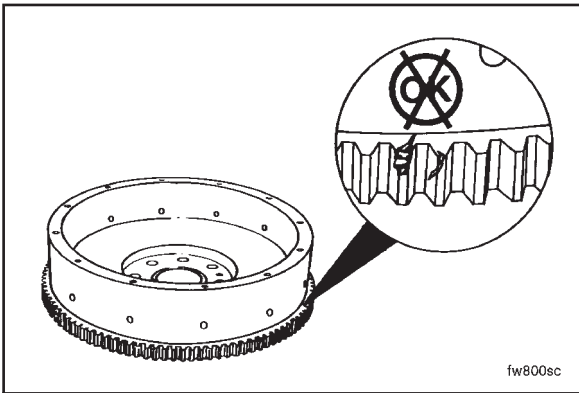




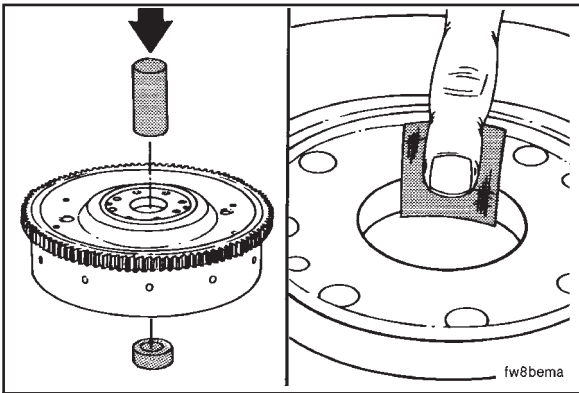
⚠ WARNING ⚠

Do not use a cracked flywheel. A cracked flywheel can break and cause serious personal injury or property damage.

Inspect the flywheel for cracks.



Inspect the flywheel ring gear teeth for cracks and chips. If the ring gear teeth are cracked or broken, the ring gear **must** be replaced.



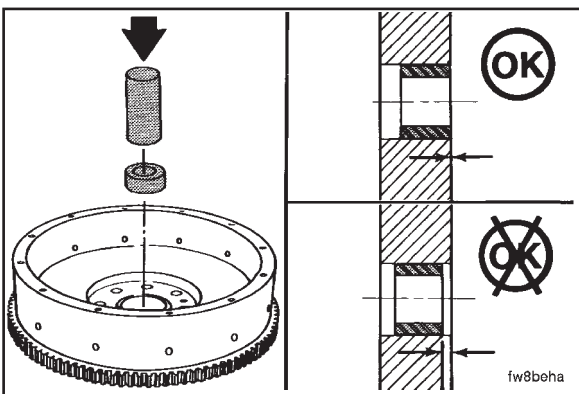
Install (016-005-026)

Use a new pilot bearing when installing a new or rebuilt clutch.



Remove the pilot bearing with a mandrel and hammer.

Clean the pilot bore with Scotch-Brite® 7448, Part No. 3823258 or equivalent.



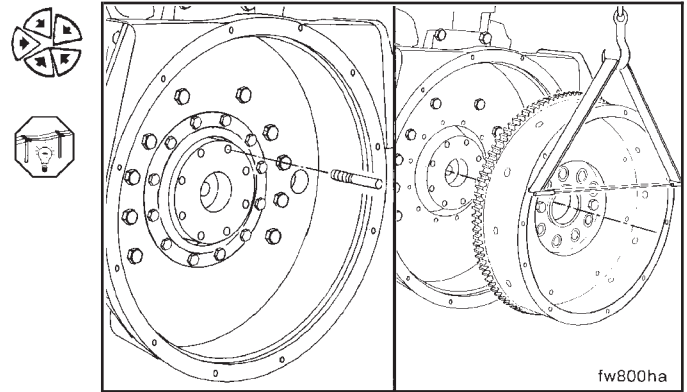
Install the pilot bearing with a mandrel and hammer.

The pilot bearing **must** be installed flush with the pilot bore surface.

Install guide pin, Part No. 3376696, in the crankshaft flange.

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

Install the flywheel on the guide pin.



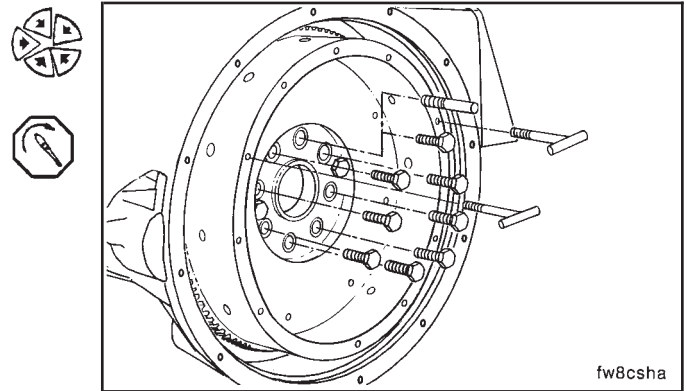
Install the seven capscrews.

Remove the “T-handles” and the guide pin.

Install the remaining capscrew in the hole.

Tighten the capscrews in a star pattern.

Torque Value: 183 N•m [135 ft-lb]



Measure (016-005-010)

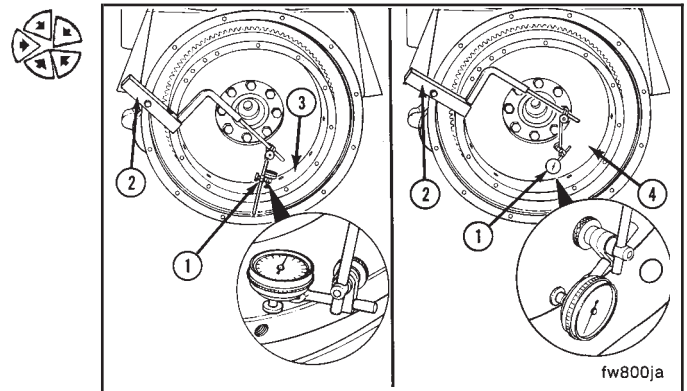
Bore Run Out

Use dial indicator gauge (1), Part No. 3376050 or equivalent, and dial gauge attachment (2), Part No. ST-1325, to inspect the flywheel bore (3) and face (4) run out.

Install the attachment to the flywheel housing.

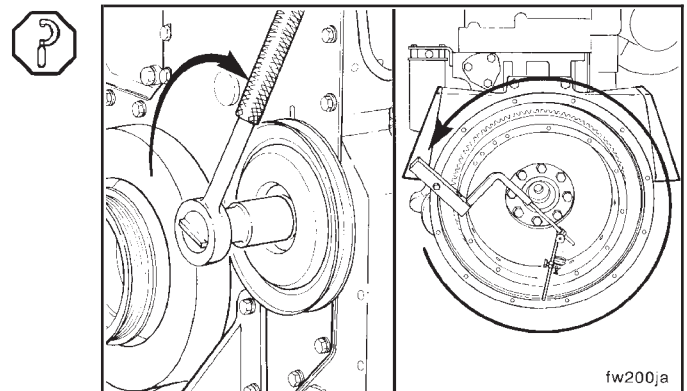
Install the gauge on the attachment.

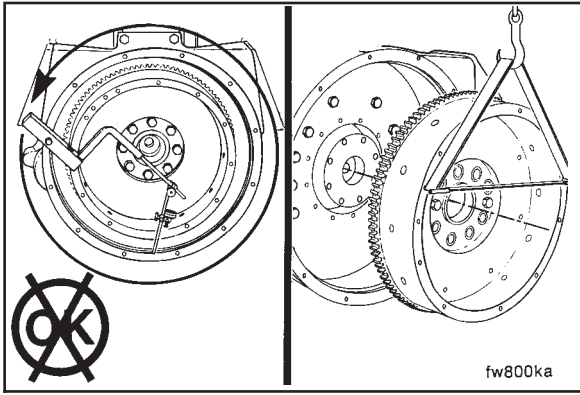
Install the contact tip of the indicator against the inside diameter of the flywheel bore.



Use the accessory drive shaft to rotate the crankshaft one complete revolution (360 degrees).

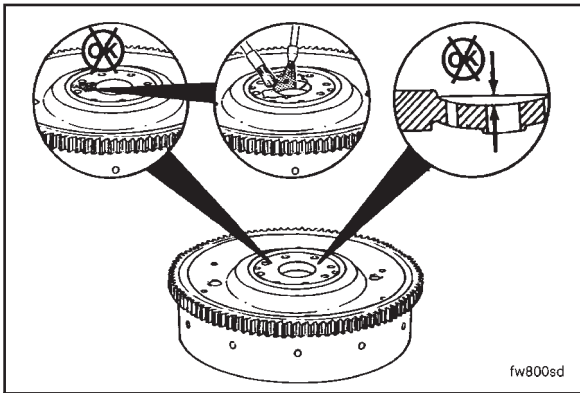
The total indicator reading (TIR) **must not** exceed 0.127 mm [0.0050 inch].



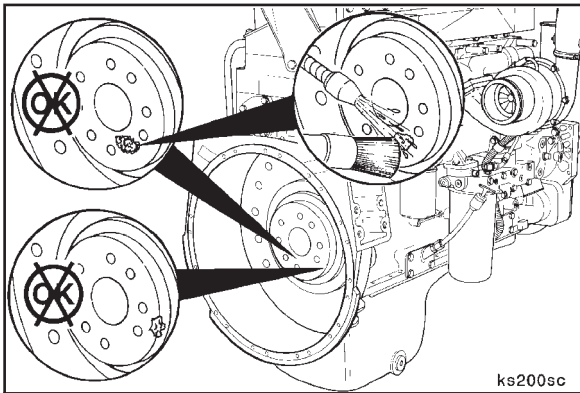


If the TIR is greater than the specification:

- Remove the flywheel

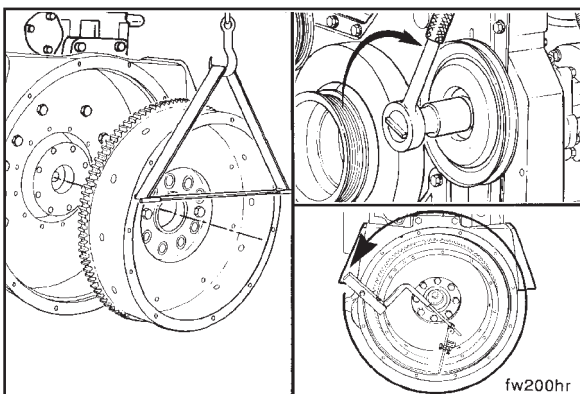


- Inspect the flywheel mounting surface for dirt or damage.



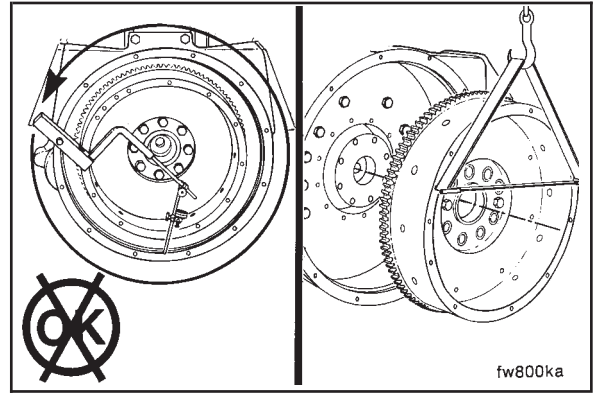
- Inspect the crankshaft for dirt or damage.

Refer to Engine Shop Manual, Bulletin No. 3666075, to replace the crankshaft.



- Install the flywheel and inspect the bore run out again.

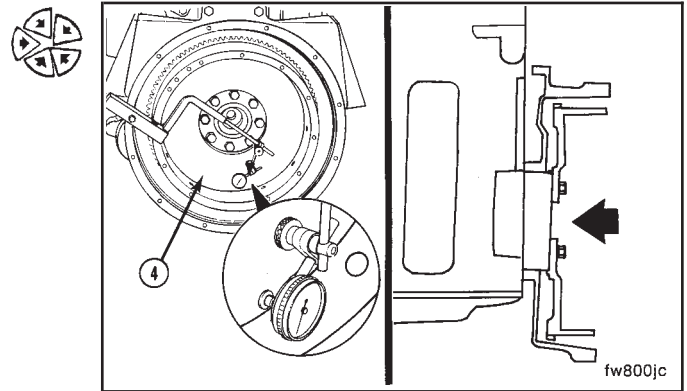
- Replace the flywheel if the run out does **not** meet specifications.



Face Run Out

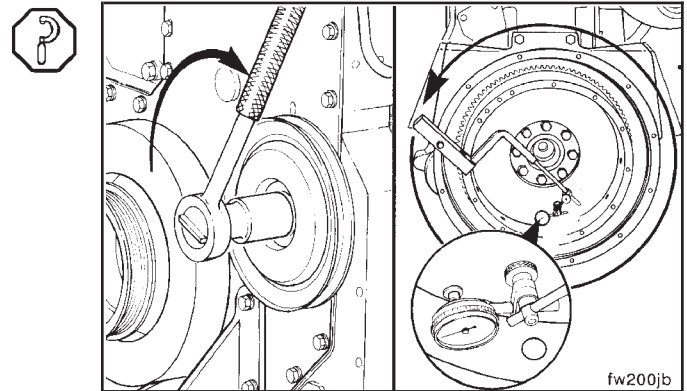
Install the contact tip of the indicator against the flywheel face as close to the outside diameter as possible to inspect the face (4) run out.

Push the flywheel forward to remove the crankshaft end thrust.



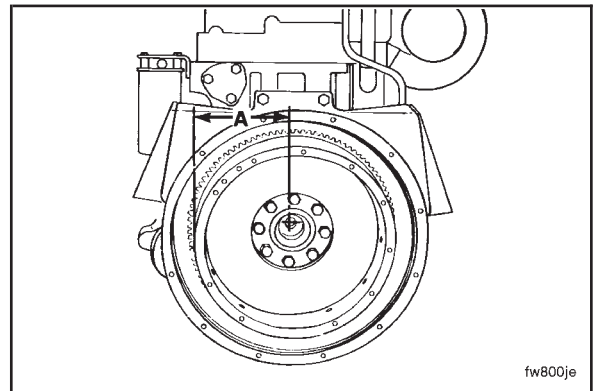
Use the accessory drive shaft to rotate the crankshaft one complete revolution (360 degrees) while keeping the crankshaft end thrust pushed forward.

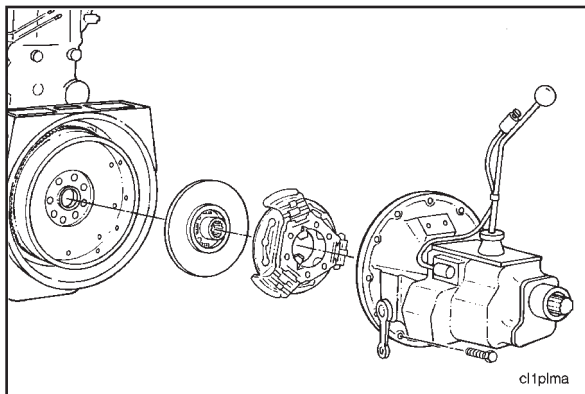
The total indicator reading (TIR) **must not** exceed the following specifications.



Flywheel Face Run Out TIR

Flywheel Radius (A)		Maximum (TIR) of Flywheel Face	
mm	in	mm	in
203	8	0.203	0.008
254	10	0.254	0.010
305	12	0.305	0.012
356	14	0.356	0.014
406	16	0.406	0.016

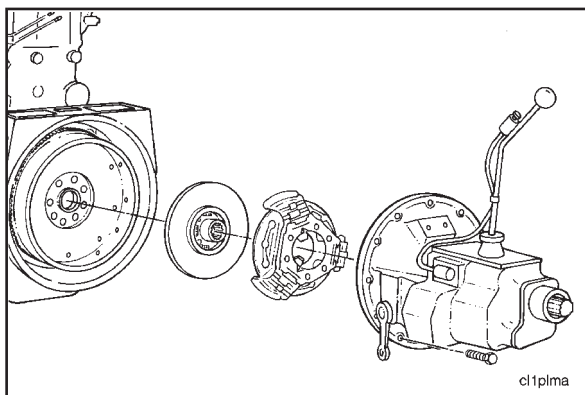




Install the clutch discs, pressure plate, transmission and drive line, if equipped, in reverse order of removal. Refer to the manufacturer's instructions.



Align the universal joints on each end of the drive shaft to prevent vibration.

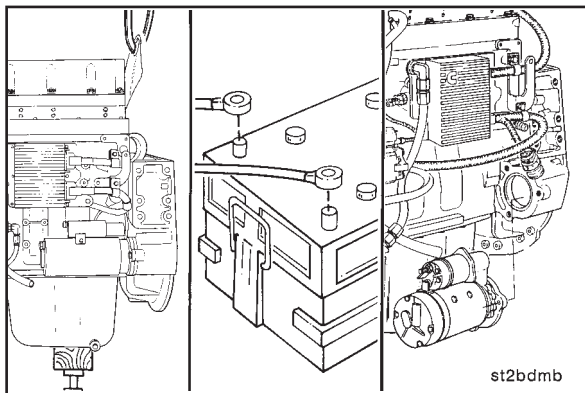


Flywheel Housing (016-006) Remove (016-006-002)



Remove the transmission, clutch and all related components, if equipped. Refer to the manufacturer's instructions.

Remove the flywheel. Refer to Procedure 016-005-002.



CAUTION

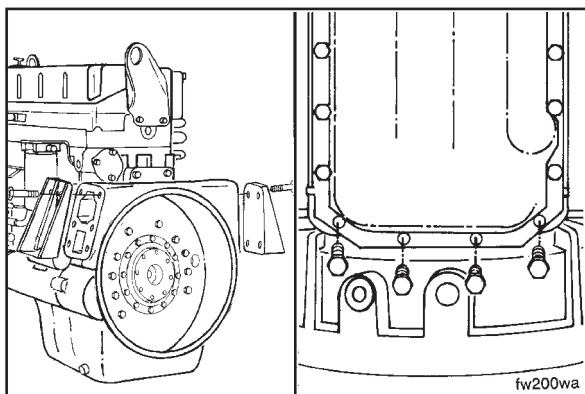
Place a wooden block, the width of the oil pan, between the floor jack and oil pan to prevent damage to the engine.



Use a floor jack or a suitable lifting fixture to support the rear of the engine.

Disconnect the battery cables.

Remove the starting motor. Refer to Procedure 013-020-002.

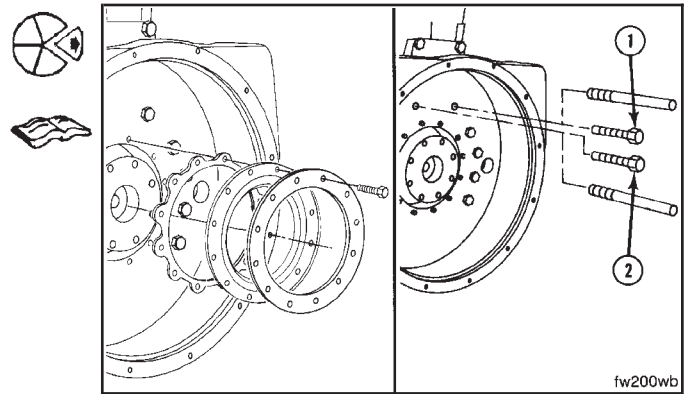


Remove the capscrews and both rear engine mounts.

Remove the four oil pan rear mounting capscrews.

Remove the rear crankshaft oil seal. Refer to Procedure 001-024-002.

Remove capscrews (1) and (2) and install two guide pins, Part No. 3376697.



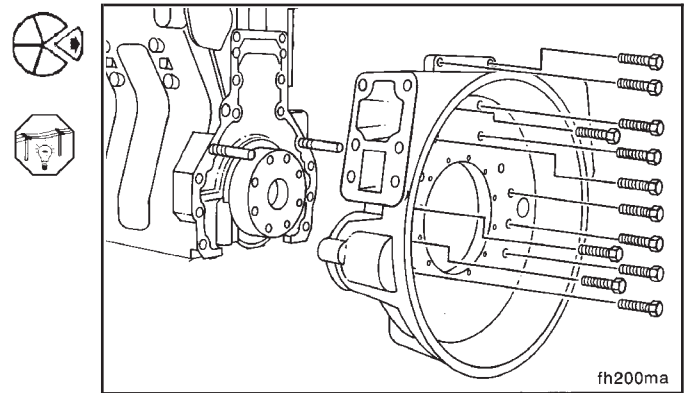
Remove the remaining capscrews.

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

Use a rubber hammer to loosen the flywheel housing.

NOTE: Do **not** damage the rear of the oil pan gasket when removing the flywheel housing.

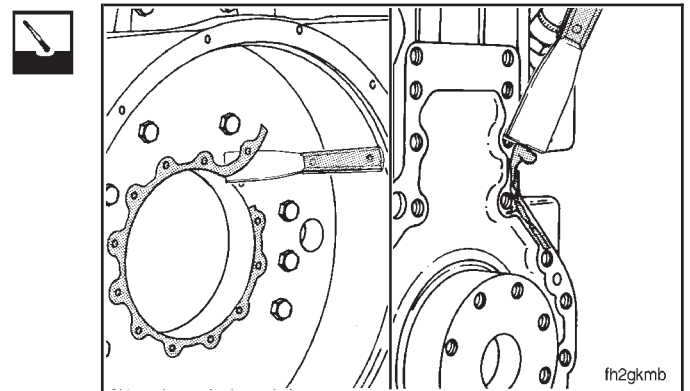
Remove the flywheel housing.



Clean (016-006-006)

Remove the gasket material from the flywheel housing oil seal gasket surface.

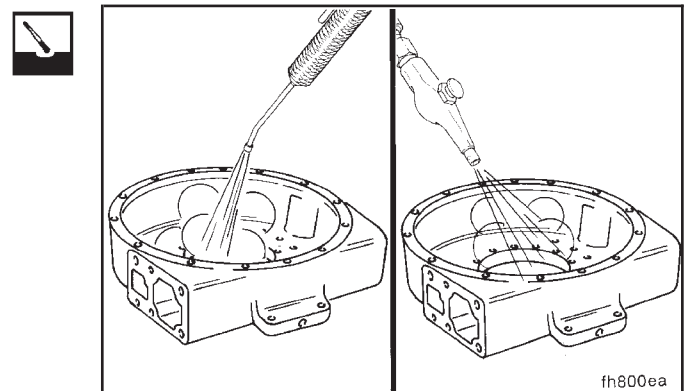
Clean the sealant from the cylinder block surface.

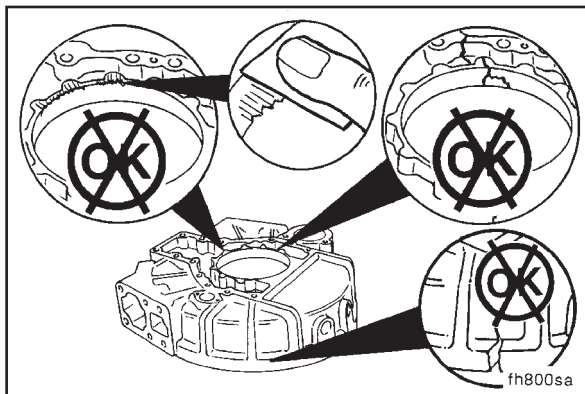


⚠ WARNING ⚠

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

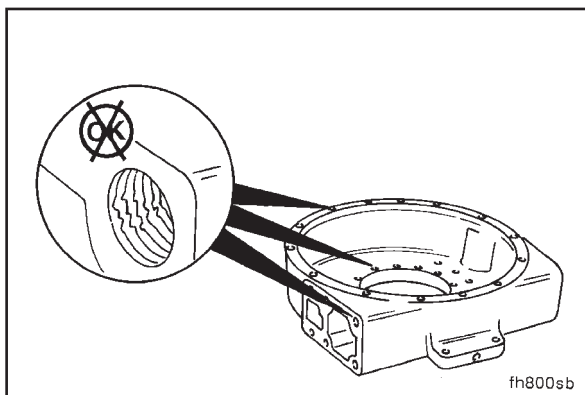
Use steam or solvent to clean the flywheel housing. Dry with compressed air.





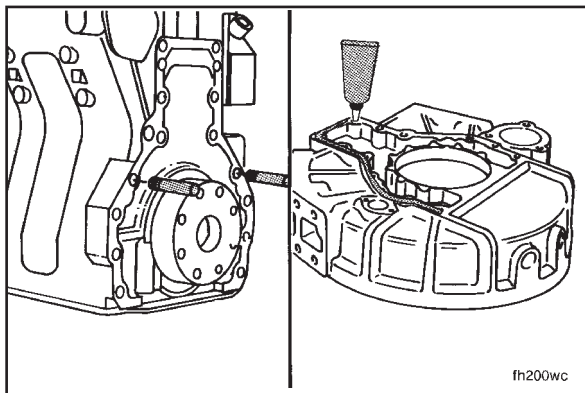
Inspect for Reuse (016-006-007)

Visually inspect all surfaces for nicks, burrs or cracks.
Use fine crocus cloth to remove small nicks and burrs.



Inspect all threaded capscrew holes for damage.

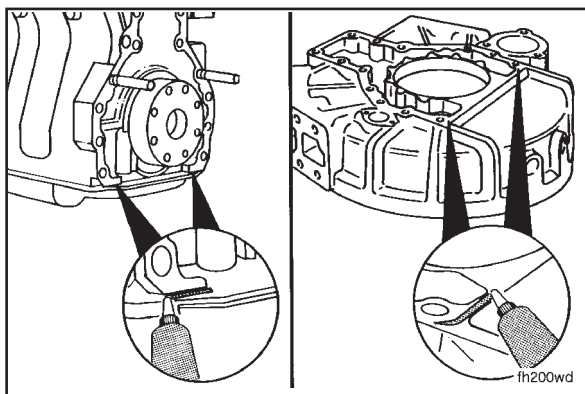
Repair or replace the housing if the capscrew holes are damaged.



Install (016-006-026)

Install two guide pins, Part No. 3376697, in the cylinder block to help support and align the housing during installation.

Apply a 2 mm [1/16 inch] bead of silicone sealant, Part No. 3823494, on the mounting surface of the housing and around each capscrew hole.



Apply silicone sealant to each rear corner of the oil pan gasket and flywheel housing mating surface.

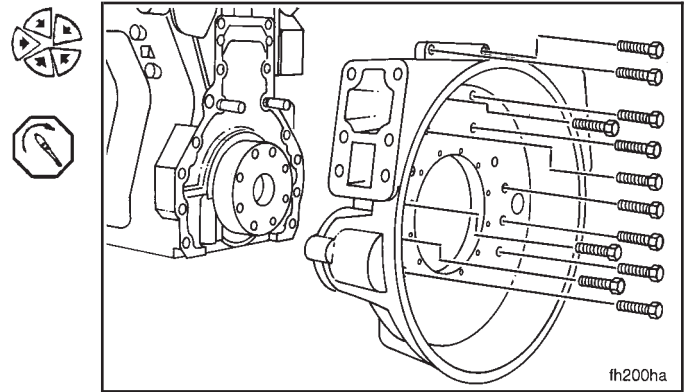
Install the flywheel housing over the guide pins.

NOTE: Do **not** damage the oil pan gasket when installing the flywheel housing.

The flywheel housing bore **must** be aligned with the crankshaft. Do **not** tighten the capscrews to the final torque value until the flywheel housing is aligned.

Install the capscrews. Remove the guide pins and install the remaining two capscrews.

Torque Value: 7 N•m [60 in-lb]



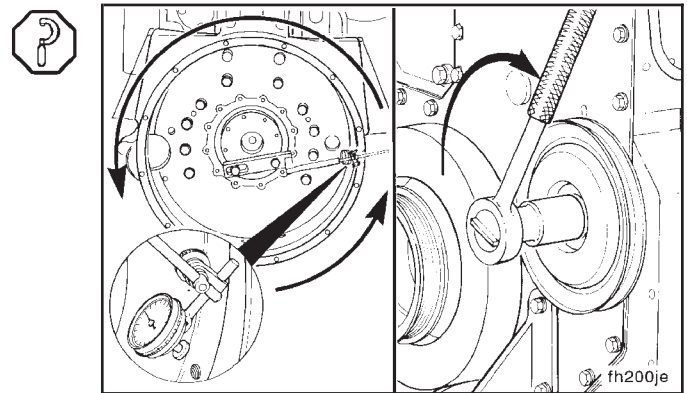
Measure (016-006-010)

Bore Alignment

Use dial indicator gauge (1), Part No. 3376050, and dial gauge attachment (2), Part No. ST-1325, to measure the bore alignment.

Adjust the dial indicator gauge to zero "0".

Use the accessory drive shaft to rotate the crankshaft one complete revolution (360 degrees).



Flywheel Housing Bore Alignment Maximum TIR		
mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008

If the maximum bore alignment does **not** meet the specifications, use a rubber hammer to move the housing in the necessary direction and repeat the measurement procedure.

If the bore alignment will **not** meet the specifications or the bore is **not** round, the housing **must** be replaced.

Face Alignment

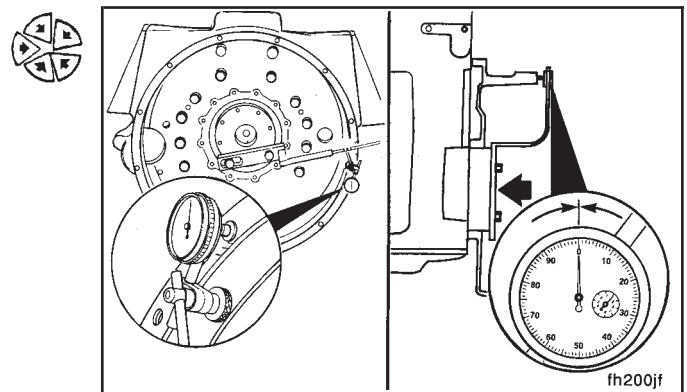
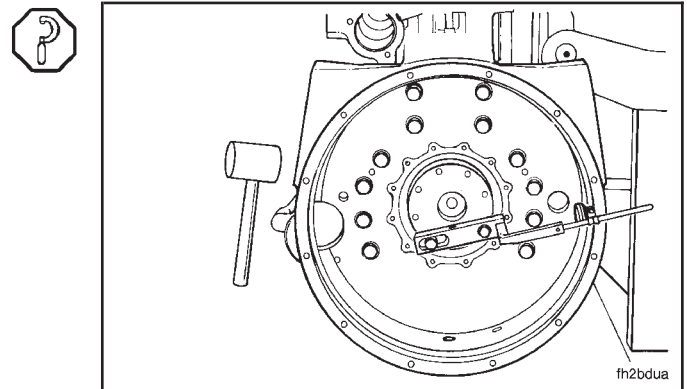


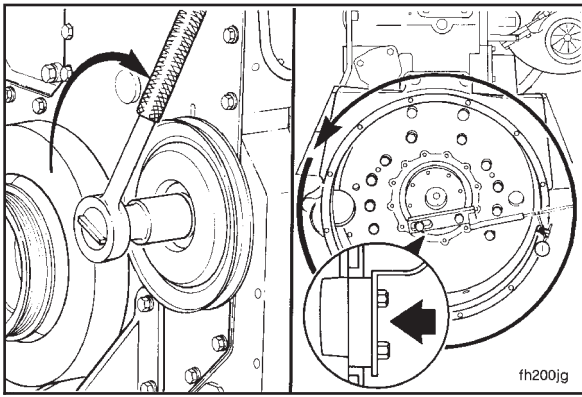
The tip of the gauge must not enter the capscrew holes or the gauge will be damaged.

Install the contact tip of the dial indicator gauge against the flywheel housing face.

Push the crankshaft toward the front of the engine.

Adjust the dial indicator gauge to zero "0".

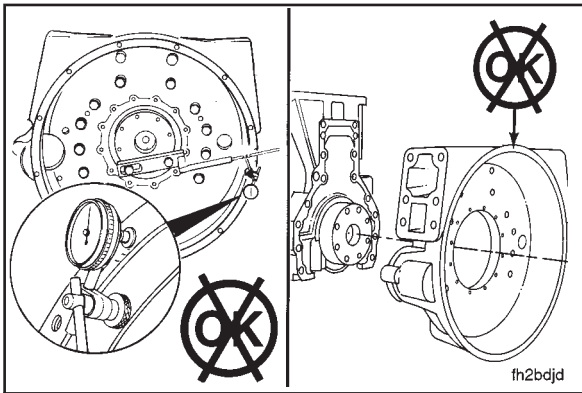




Monitor the dial indicator gauge while turning the crankshaft.

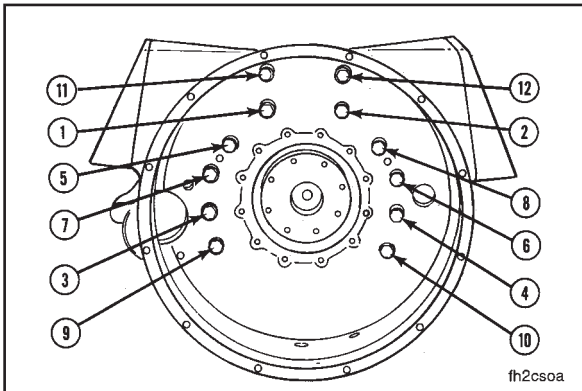


Use the accessory drive shaft to rotate the crankshaft one complete revolution (360 degrees) while keeping the crankshaft end thrust pushed forward.



Flywheel Housing Face Alignment Maximum TIR		
mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008

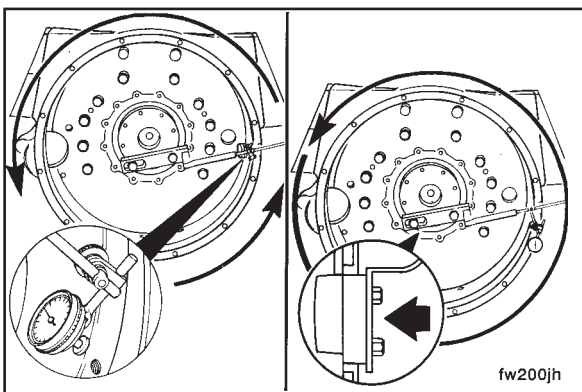
If the maximum face alignment does **not** meet the specifications, the flywheel housing **must** be replaced.



Tighten all capscrews in the sequence shown.

Torque Value:

Step 1	68 N•m	[50 ft-lb]
2	129 N•m	[95 ft-lb]
3	197 N•m	[145 ft-lb]



Measure the bore and face alignment again.

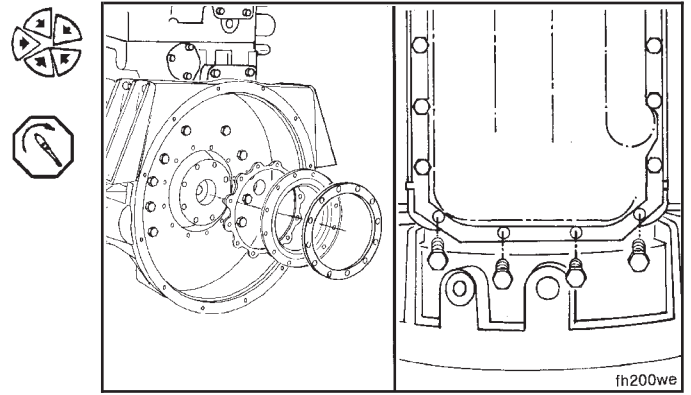
If bore and face alignment does **not** meet the specifications, loosen the housing capscrews. Tighten the capscrews and measure the bore and face alignment again.

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Install the rear crankshaft oil seal. Refer to Procedure 001-024-026.

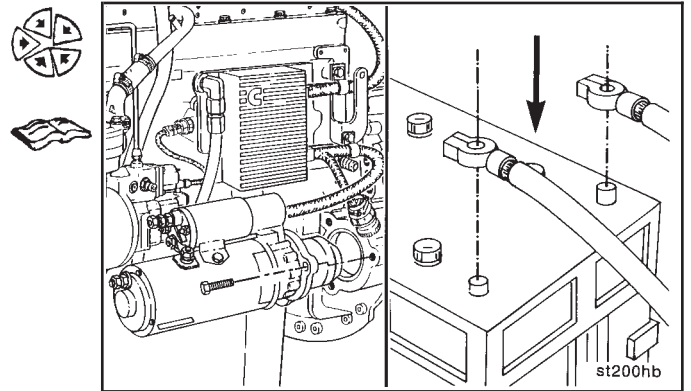
Install the four oil pan rear mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]



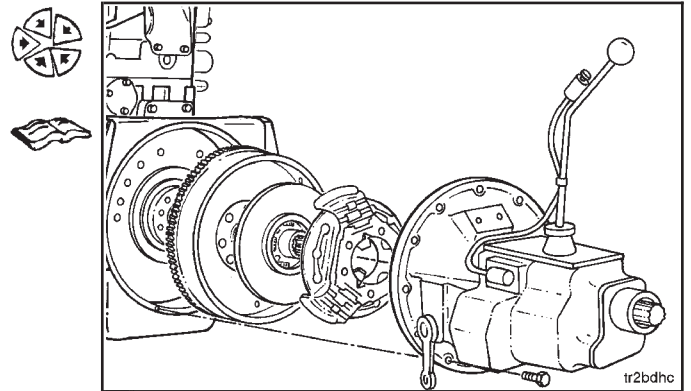
Install the starting motor. Refer to Procedure 013-020-026.

Connect the battery cables.



Install the flywheel and clutch, if equipped. Refer to Procedure 016-005-026.

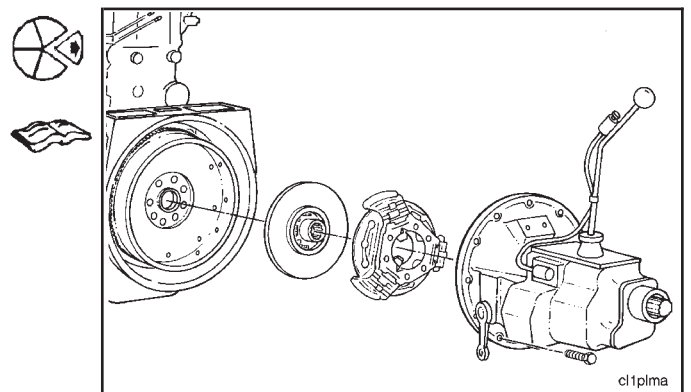
Install the transmission and related components. Refer to the manufacturer's instructions.

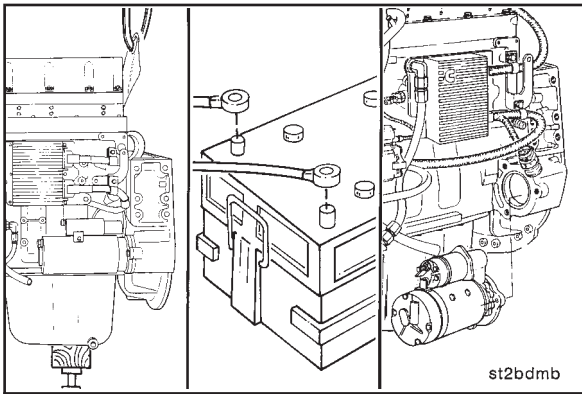


Flywheel Housing, REPTO (016-007)
Remove (016-007-002)

Remove the transmission, clutch and all related components, if equipped. Refer to the manufacturer's instructions.

Remove the flywheel. Refer to Procedure 016-005-002.





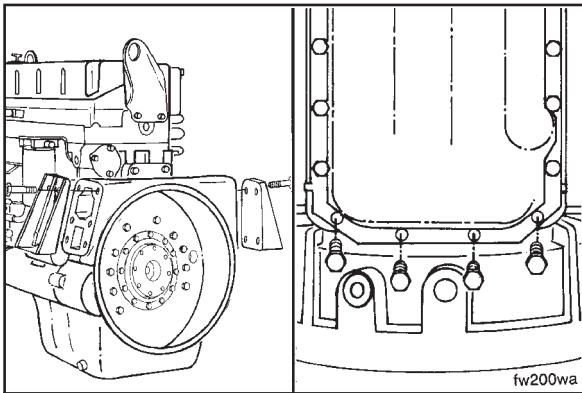
CAUTION

Place a wooden block, the width of the oil pan, between the floor jack and oil pan to prevent damage to the engine.

Use a floor jack or a suitable lifting fixture to support the rear of the engine.

Disconnect the battery cables.

Remove the starting motor. Refer to Procedure 013-020-002.

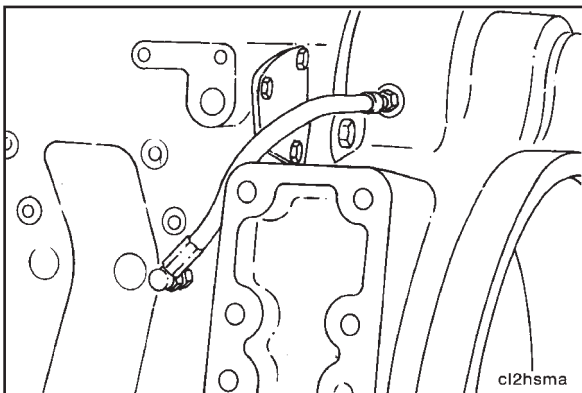


Remove the capscrews and both rear engine mounts.

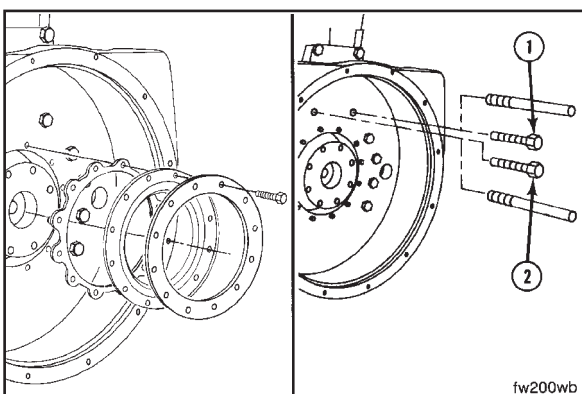
Remove the four oil pan rear mounting capscrews.

Loosen six capscrews on each side of the oil pan at the end closest to the flywheel housing. This will allow enough clearance to for removal of the flywheel housing.

NOTE: Be careful **not** to tear the oil pan gasket. If the oil pan gasket is damaged, the oil pan **must** be removed and the gasket replaced.



Remove the oil supply line from the flywheel housing.



Remove the rear crankshaft oil seal. Refer to Procedure 001-024-002.

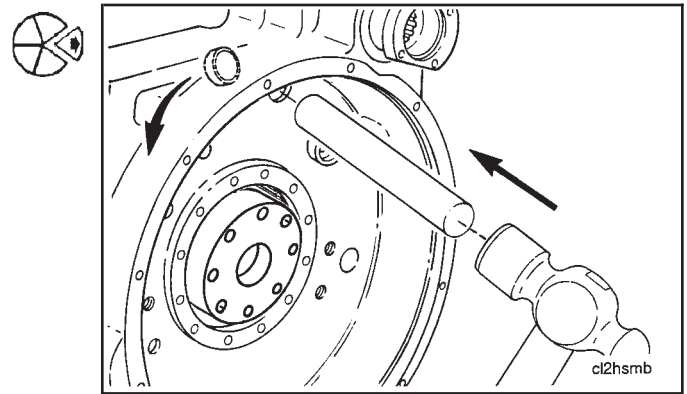


Remove capscrews (1) and (2) and install two guide pins, Part No. 3824929.

To gain access to the housing capscrews, use a cup plug driver, Part No. 3824927, to drive the cup plugs straight through into the housing.

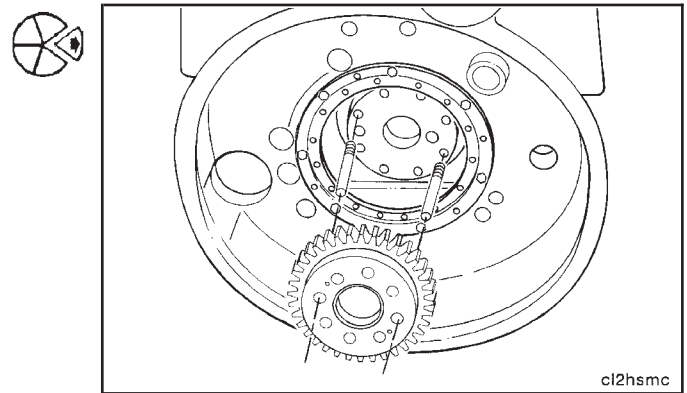
Retrieve the plugs from inside of the housing.

NOTE: Do **not** attempt to back out or rotate the plugs out of the housing. The cup plug bore will be damaged and oil leakage will occur.



Remove the crankshaft drive gear.

Remove the two guide pins from the crankshaft.

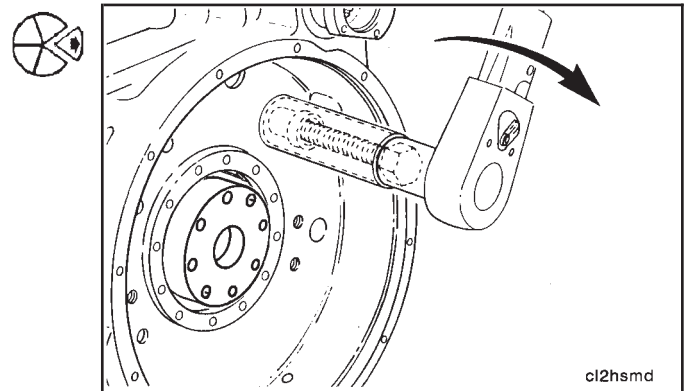


Remove the idler shaft retaining capscrew.

CAUTION

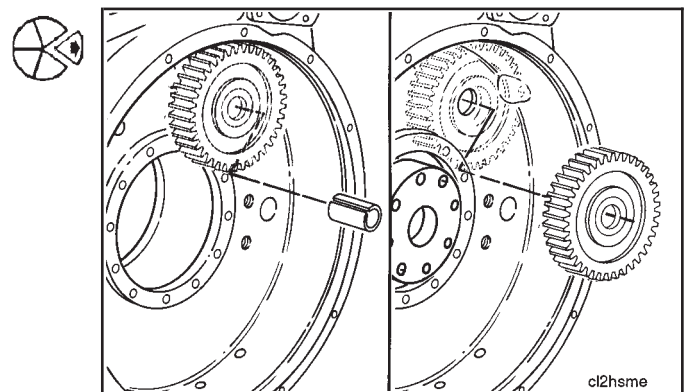
When the idler shaft is removed, the idler gear can fall and become damaged. Hold the idler gear before pulling the idler shaft out.

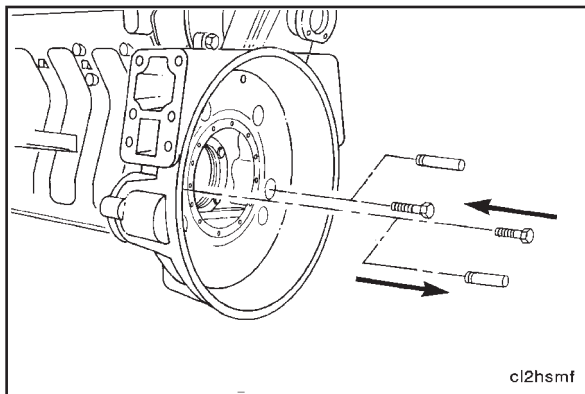
Use idler shaft puller, Part No. 3823709, to remove the idler shaft.



Remove the idler gear to gain access to the rest of the housing capscrews.

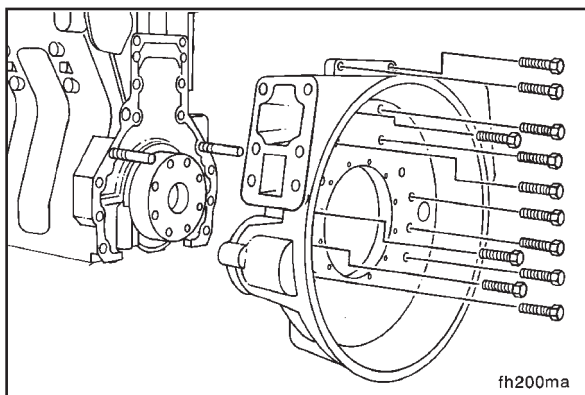
NOTE: Do **not** drop the idler gear bearings as the idler gear is removed. Damage to the bearings can result.





Remove two of the mounting capscrews and install two guide pins, Part No. 3824930, to support the housing during removal.

Use offset wrench, Part No. 3824928, to remove the capscrews which are **not** in view. These capscrews are inside the housing.



Remove the remaining capscrews.

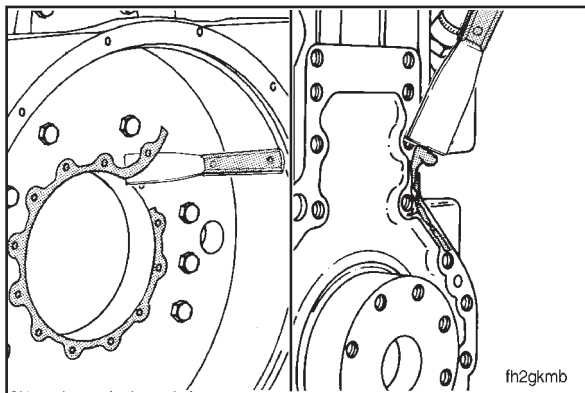
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.



Use a rubber hammer to loosen the flywheel housing.

NOTE: Do **not** damage the rear of the oil pan gasket when removing the flywheel housing.

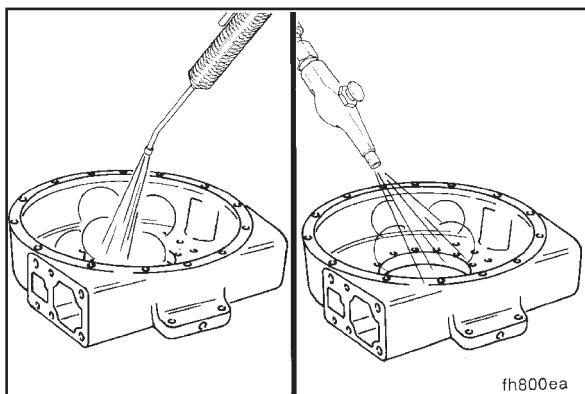
Remove the flywheel housing.



Clean (016-007-006)

Remove the gasket material from the flywheel housing oil seal gasket surface.

Clean the sealant from the cylinder block surface.



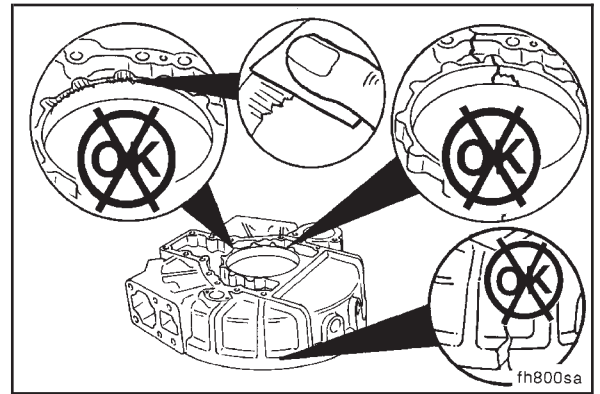
▲ WARNING ▲

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

Use steam or solvent to clean the flywheel housing. Dry with compressed air.

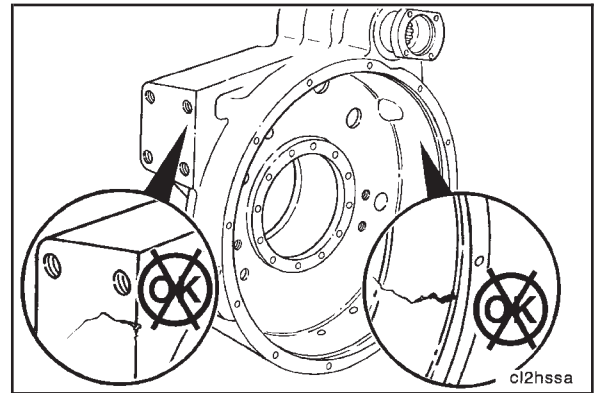
Inspect for Reuse (016-007-007)

Visually inspect all surfaces for nicks, burrs or cracks.
Use fine crocus cloth to remove small nicks and burrs.



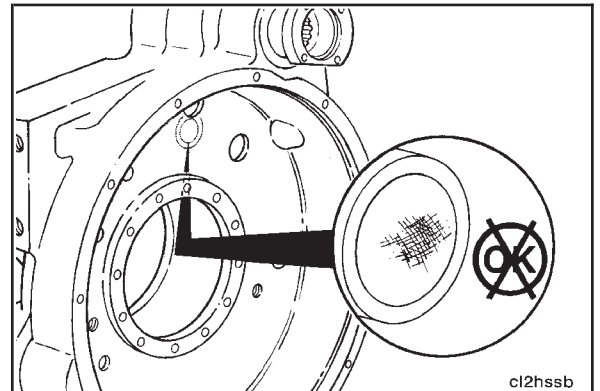
Inspect the REPTO housing for cracks at the rear engine mounting surfaces and the flywheel bore.

Replace the housing if it is cracked.



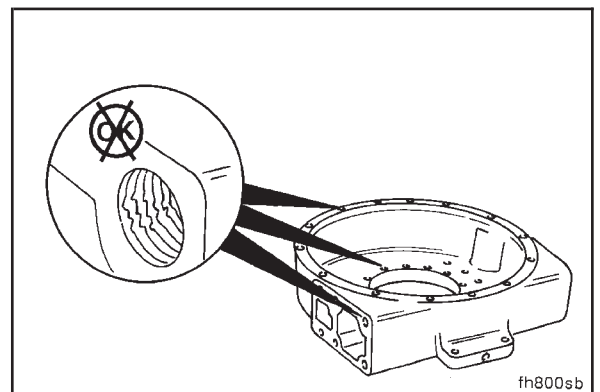
Inspect the idler shaft bushing for wear.

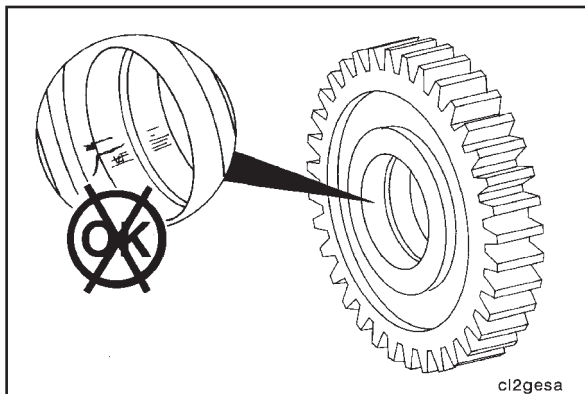
Replace the bushing if it is worn.



Inspect all threaded capscrew holes for damage.

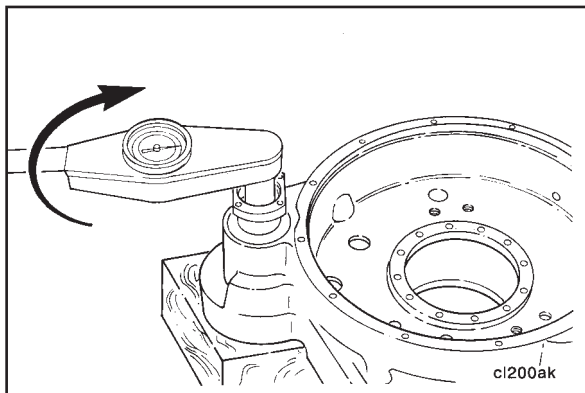
Repair or replace the housing if the capscrew holes are damaged.





Closely inspect the bore, side faces and the teeth of the REPTO idler gear.

Replace the gear if there are cracks, discoloration from excessive heat or other damage.

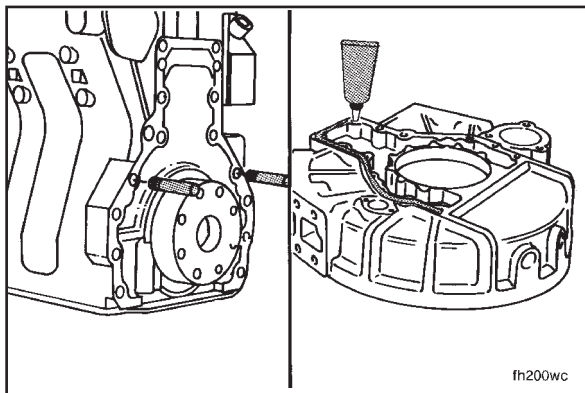


Check the output shaft rolling resistance with a torque wrench.

The rolling resistance **must** be between 0.6 to 1.1 N•m [5 to 10 in-lb].

If the resistance does **not** meet these specifications, refer to Engine Shop Manual, Bulletin No. 3810476, to add or subtract shims to obtain the correct rolling resistance.

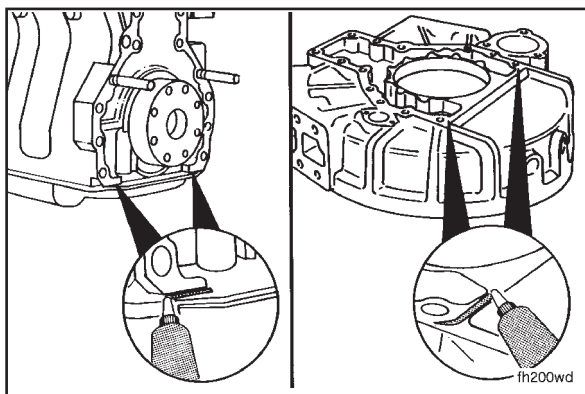
NOTE: Adding more shims will increase the resistance, and removing shims will decrease resistance. Any combination of shims can be used.



Install (016-007-026)

Install two guide pins, Part No. 3376697, in the cylinder block to help support and align the housing during installation.

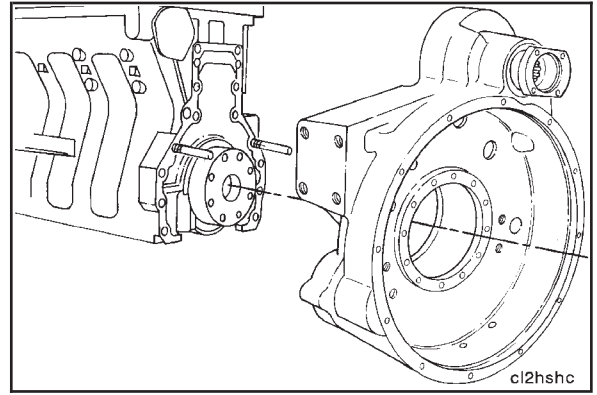
Apply a 2 mm [1/16 inch] bead of silicone sealant, Part No. 3823494, on the mounting surface of the housing and around each capscrew hole.



Apply silicone sealant to each rear corner of the oil pan gasket and flywheel housing mating surface.

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

Use a hoist when installing the REPTO flywheel housing over the guide pins.



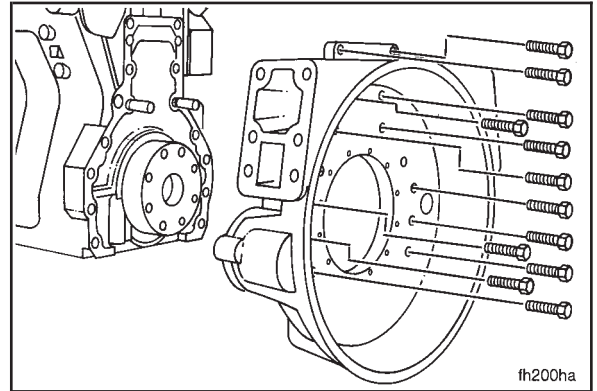
Install the flywheel housing over the guide pins.

NOTE: Do **not** damage the oil pan gasket when installing the flywheel housing.

The flywheel housing bore **must** be aligned with the crankshaft. Do **not** tighten the capscrews to the final torque value until the flywheel housing is aligned.

Install the capscrews. Remove the guide pins and install the remaining two capscrews.

Torque Value: 7 N•m [60 in-lb]



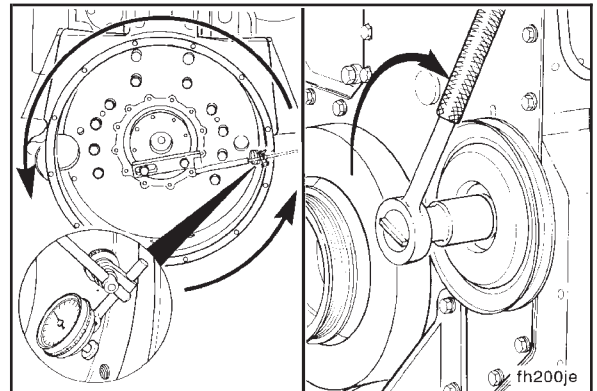
Measure (016-007-010)

Bore Alignment

Use dial indicator gauge (1), Part No. 3376050, and dial gauge attachment (2), Part No. ST-1325, to measure the bore alignment.

Adjust the dial indicator gauge to zero “0”.

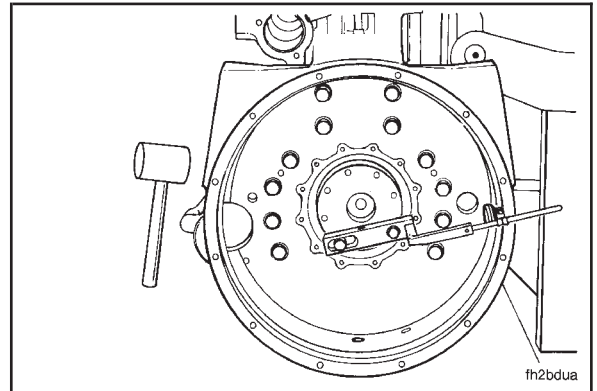
Use the accessory drive shaft to rotate the crankshaft one complete revolution (360 degrees).

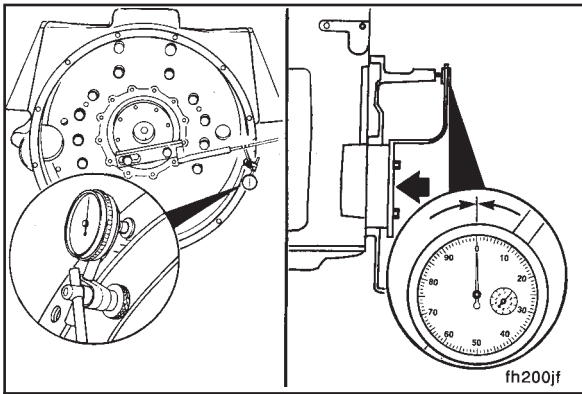


Flywheel Housing Bore Alignment Maximum TIR		
mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008

If the maximum bore alignment does **not** meet the specifications, use a rubber hammer to move the housing in the necessary direction and repeat the measurement procedure.

If the bore alignment will **not** meet the specifications or the bore is **not** round, the housing **must** be replaced.





Face Alignment

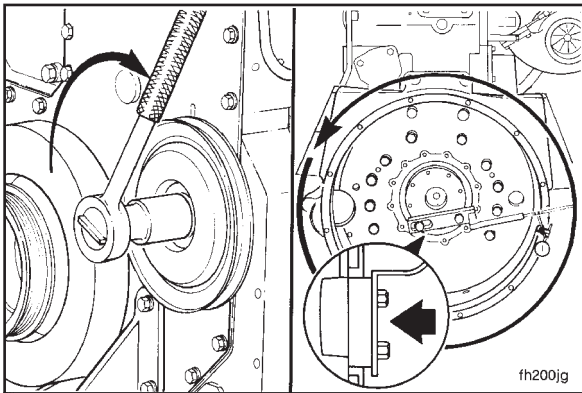


The tip of the gauge must not enter the capscrew holes or the gauge will be damaged.

Install the contact tip of the dial indicator gauge against the flywheel housing face.

Push the crankshaft toward the front of the engine.

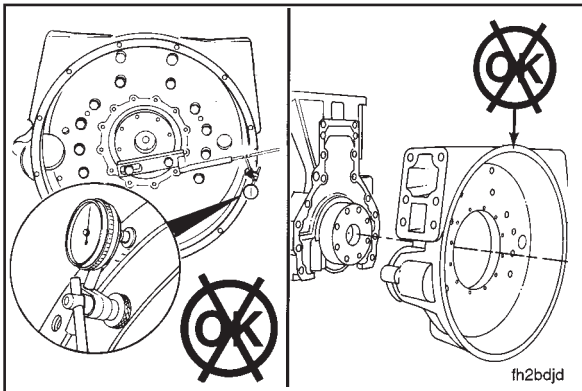
Adjust the dial indicator gauge to zero "0".



Monitor the dial indicator gauge while turning the crankshaft.



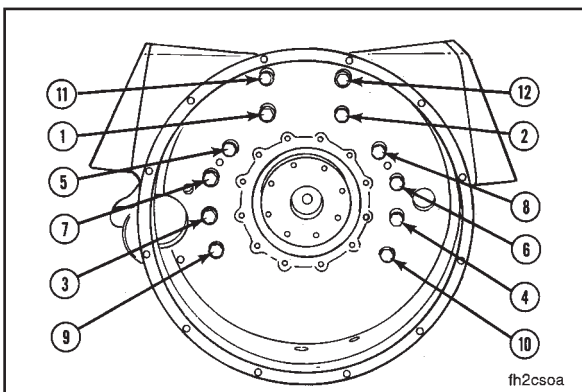
Use the accessory drive shaft to rotate the crankshaft one complete revolution (360 degrees) while keeping the crankshaft end thrust pushed forward.



Flywheel Housing Face Alignment Maximum TIR

mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008

If the maximum face alignment does **not** meet the specifications, the flywheel housing **must** be replaced.



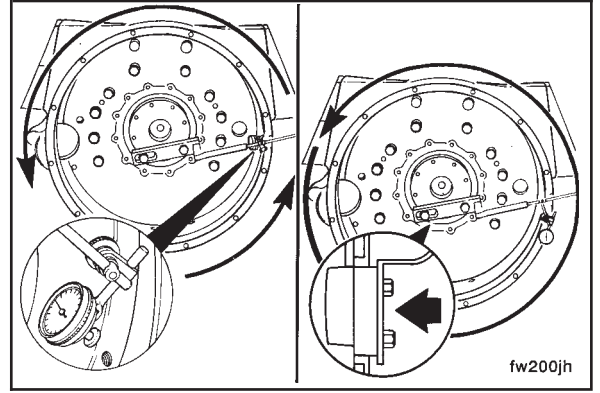
Tighten all capscrews in the sequence shown.

Torque Value:

Step 1	68 N•m	[50 ft-lb]
2	129 N•m	[95 ft-lb]
3	197 N•m	[145 ft-lb]

Measure the bore and face alignment again.

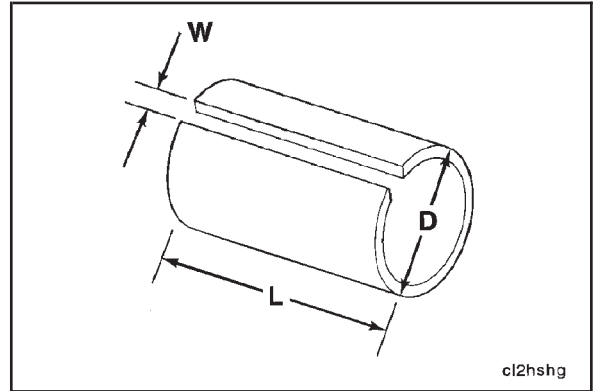
If bore and face alignment does **not** meet the specifications, loosen the housing capscrews. Tighten the capscrews and measure the bore and face alignment again.



Manufacture a sleeve from 38.1 mm O.D. [1.50 in O.D.] (D) PVC, aluminum, thin wall hose, or equivalent, to the following dimensions:

Length (L): 25.4 mm [1.00 in]

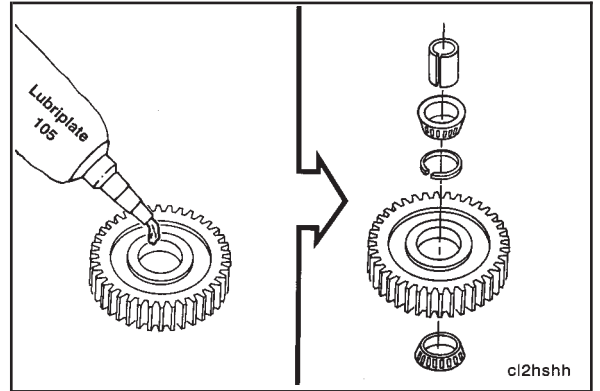
Slot (W) 6.3 mm [0.25 in]



Apply Lubriplate® 105, or equivalent, on the outer races and the bearings.

NOTE: The outer bearing races of new replacement gears are already pressed into the gear.

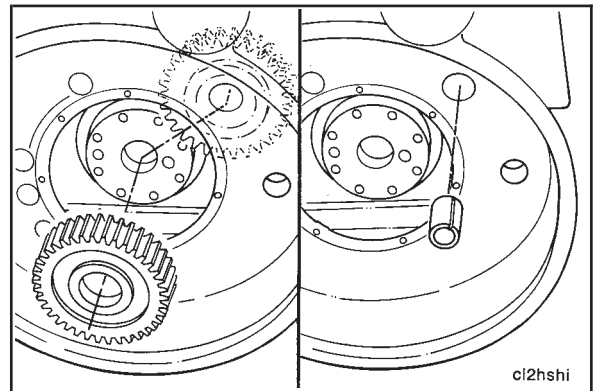
Install the bearing and spacer into the idler gear. Use the manufactured sleeve to hold the bearing assembly together when installing the idler gear assembly.

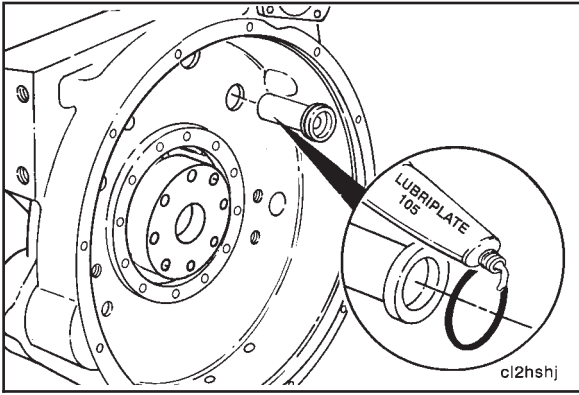


Apply a thin film of Lubriplate® 105, or equivalent, into the idler shaft bore of the housing and on the idler shaft.

Install the idler gear assembly into the flywheel housing.

Hold the idler gear and bearings in place and remove the plastic sleeve.



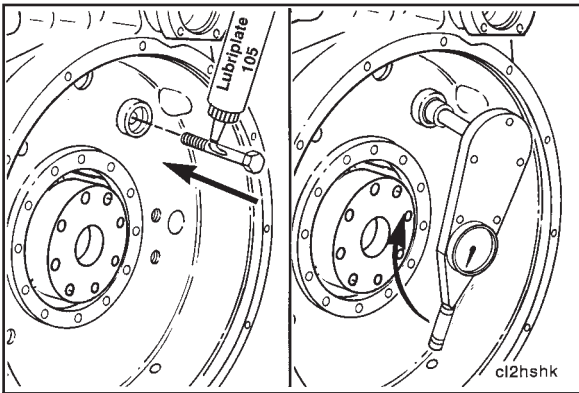


Use clean Lubriplate to lubricate the idler shaft o-ring and install the o-ring onto the shaft.



Hold the gear assembly in place and insert the idler shaft through the housing and idler gear bearings.

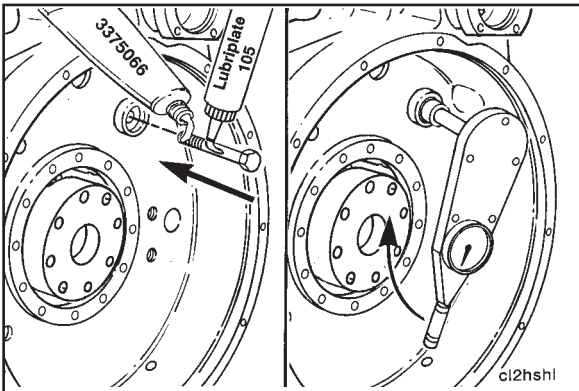
NOTE: Do **not** use a hammer when installing the idler shaft and capscrew, or the part can be damaged.



Apply Lubriplate® 105 under the head of the idler shaft capscrew. Insert the capscrew through the idler shaft. Tighten the installation capscrew with a torque wrench.



NOTE: The torque needed to draw the idler shaft in place **must not** exceed 88 N•m [65 ft-lb]. If installation torque exceeds this amount, it indicates misalignment between the bore and the shaft. Remove the idler shaft and install it again.

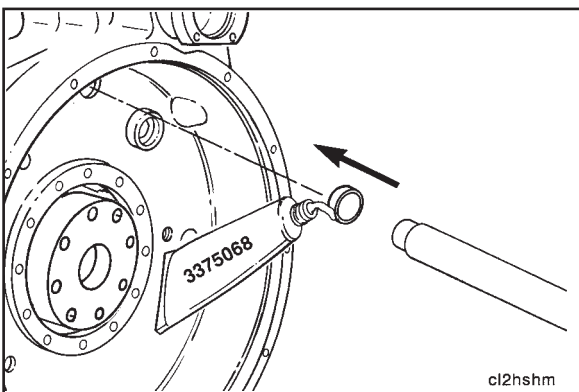


After the idler shaft has been seated, remove the capscrew.



Apply pipe sealant, Part No. 3375066, to the threads of the idler shaft capscrew. Apply Lubriplate® 105 under the head of the capscrew. Install the capscrew and tighten to its final torque value.

Torque Value: 102 N•m [75 ft-lb]

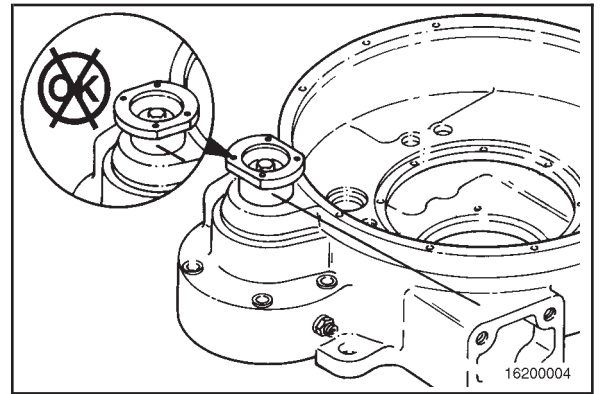


Apply a film of cup plug sealant, Part No. 3375068, to the outside diameter of the cup plug.

Use driver, Part No. 3823710, to install the cup plug into the housing as shown.

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Section 16 - Mounting Adaptations - Group 16

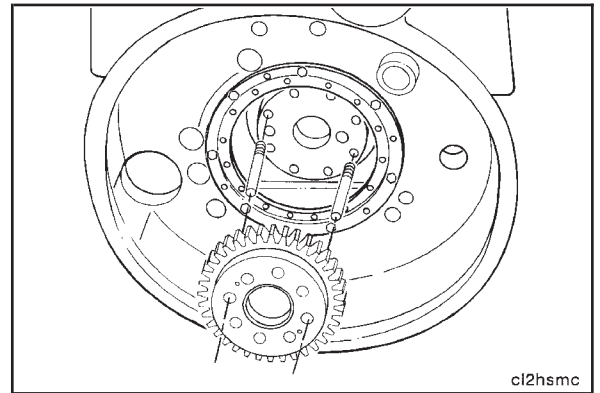
Turn the output flange so that the flat sides are on the top and bottom. This prevents any interference when the transmission is installed onto the housing.



Install two guide pins, Part No. 3824929, into the crankshaft flywheel mounting flange 180 degrees apart.

Make sure the crankshaft and crankshaft gear are clean.

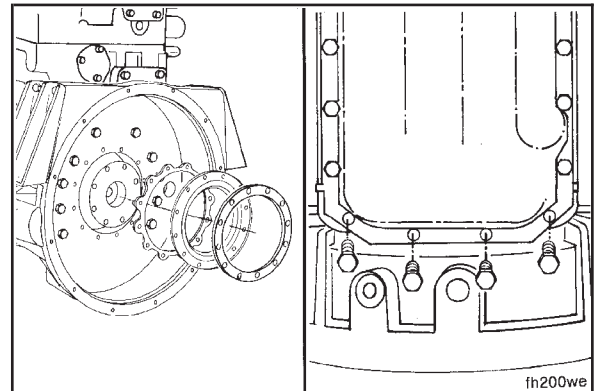
Install the crankshaft gear on the guide pins.



Install the rear crankshaft oil seal. Refer to Procedure 001-024-026.

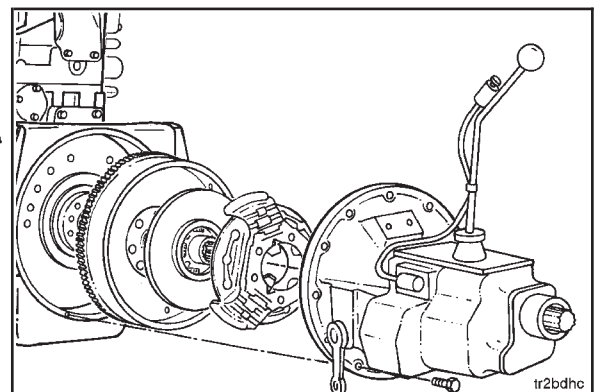
Install the four oil pan rear mounting capscrews.

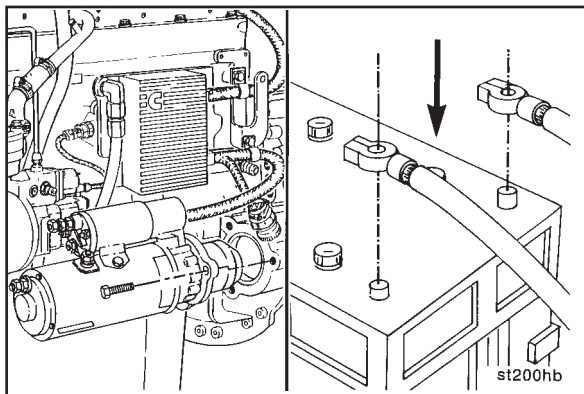
Torque Value: 47 N•m [35 ft-lb]



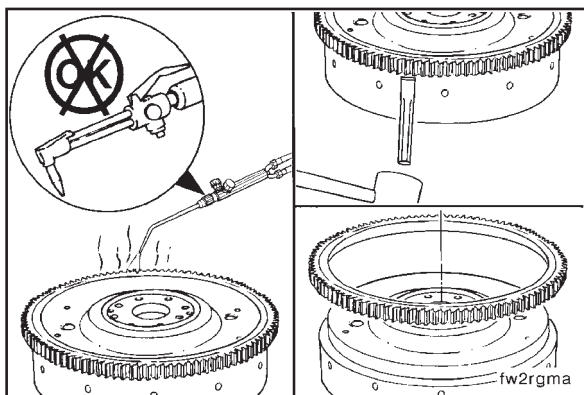
Install the flywheel and clutch, if equipped. Refer to Procedure 016-005-026.

Install the transmission and related components. Refer to the manufacturer's instructions.





Install the starting motor. Refer to Procedure 013-020-026.
Connect the battery cables.



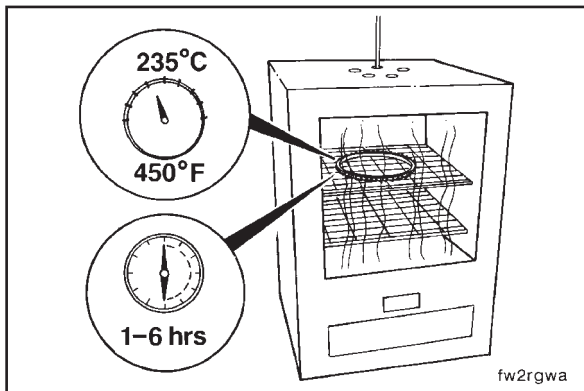
Flywheel Ring Gear (016-008) Remove (016-008-002)



Do not use a cutting torch to heat the ring gear. The flywheel can be damaged.

Heat the outside diameter of the ring gear with a heating torch.

Use a hammer and blunt chisel to remove the gear from the flywheel.



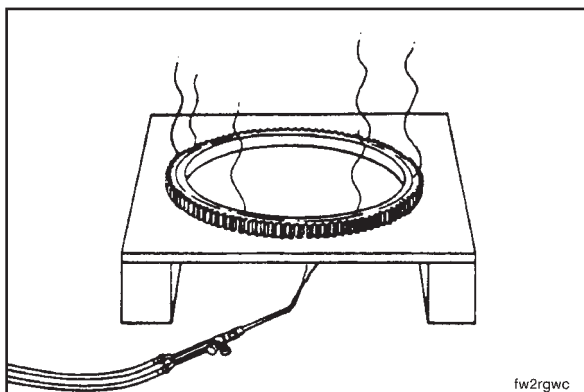
Install (016-008-026)

Do **not** attempt to install the ring gear without using heat.

Use an oven to heat the new ring gear for a minimum of one hour. Do **not** heat the ring gear for more than six hours.

Temperature 235° °C [450° °F]

NOTE: Do **not** exceed the specified time or temperature.



If an oven is **not** available, use a heating torch to heat the gear. Use a Tempilstik™ crayon, or equivalent, to check the temperature of the gear.

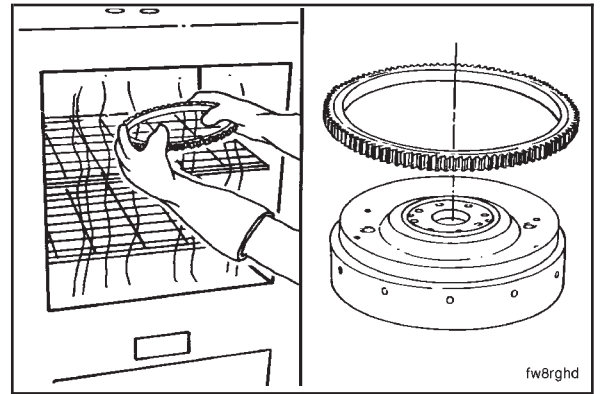
A more even temperature is obtained by placing the ring gear on a metal plate and then heating the bottom side of the plate with the torch. Do **not** exceed the specified temperature.

Temperature 235° °C [450° °F]

 **WARNING** 

Use insulated gloves, Part No. 3823730, when handling heated parts. Hot parts can cause serious personal injury.

Install the ring gear on the flywheel before it cools. Allow the air to cool the gear. Do not use water or oil to reduce the cooling time.



Section 17 - Miscellaneous - Group 17

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Remove.....	17-4

Cup Plug (017-002)

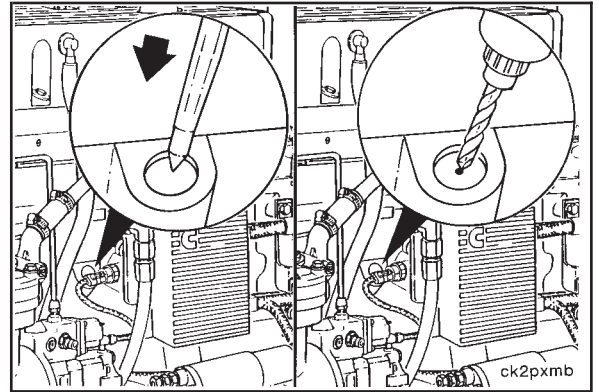
Remove (017-002-002)

Use a center punch to mark the cup plugs for drilling.



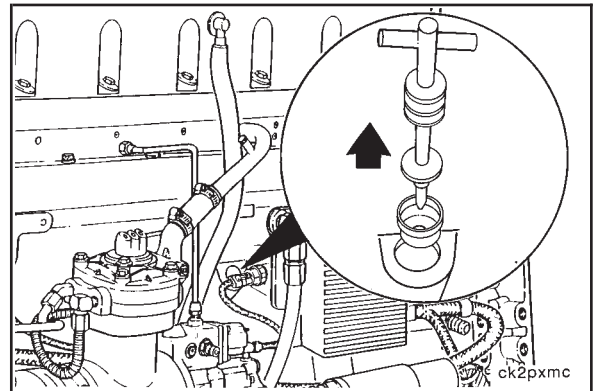
Do not allow metal shavings to fall inside the engine when drilling a hole in the cup plug. Damage to engine components can occur.

Drill a 1/8 inch hole in the cup plug.



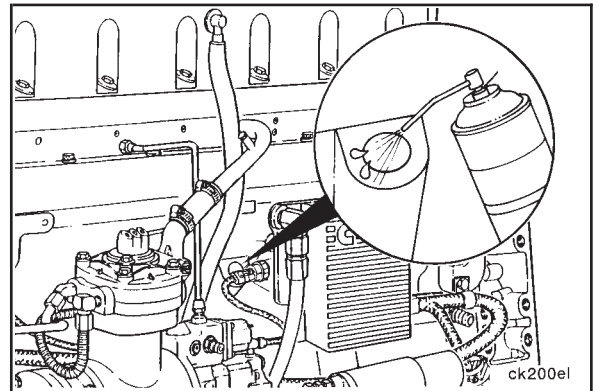
Use a dent puller to remove the plug.

Discard all used cup plugs. Do **not** use them again.



Clean (017-002-006)

Use spray cleaner, Part No. 3823717 or equivalent, to clean the cup plug bores.

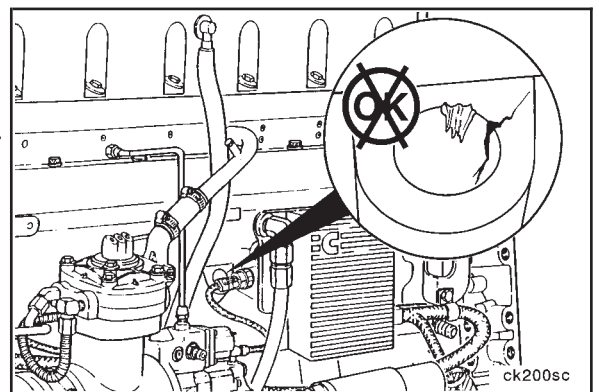


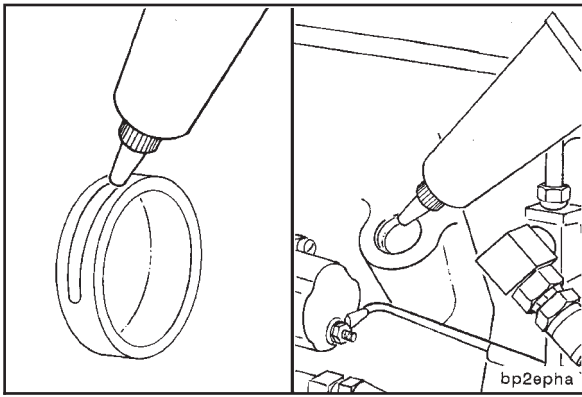
Inspect for Reuse (017-002-007)

Visually inspect the cup plug bores for damage.

Repair the cup plug bores if necessary.

Refer to the Alternative Repair Manual, Bulletin No. 3810310, for repair procedures and cup plug bore dimensions.



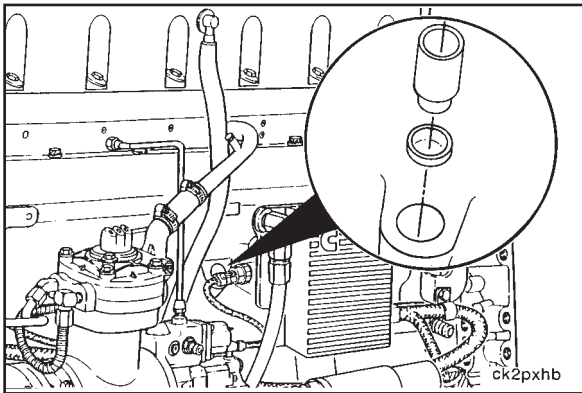


Install (017-002-026)



Excessive sealant can run back into the engine and cause damage to other components. Allow the sealant to dry for a minimum of two hours before operating the engine.

Apply a 2 mm [1/16 inch] bead of cup plug lock 'N seal, Part No. 3375068 or equivalent, to the outside diameter of the cup plug and the inside diameter of the cup plug installation bore.

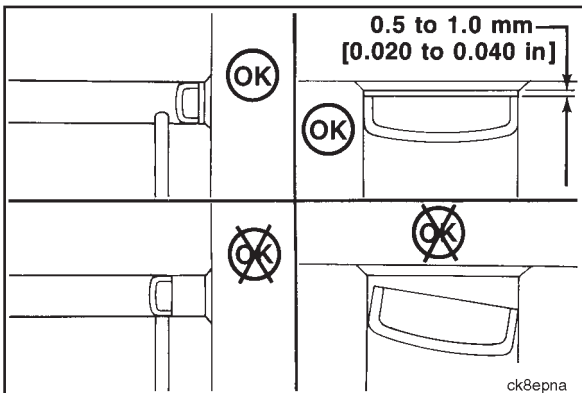


A cup plug driver must be used to install the cup plug to the correct depth in the cup plug bore.

Use the following cup plug drivers:

- Part No. 3822372 - 9.7 mm [0.38 inch] cup plug.
- Part No. 3376816 - 25.4 mm [1.00 inch] cup plug.
- Part No. 3376058 - 60.5 mm [2.38 inch] cup plug.

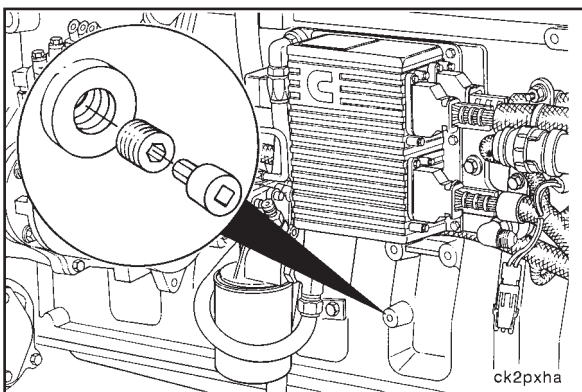
Use cup plug driver handle, Part No. 3376795, with cup plug driver, Part No. 3376816.



The cup plug **must** be installed with the edge of the plug 0.5 to 1.0 mm [0.020 to 0.040 inch] deeper than the entrance chamber of the bore.



Do **not** install the plug too deep. The cross drillings in the cylinder block can be blocked shut. If the plug is **not** installed straight and flat, it **must** be replaced with a new cup plug.

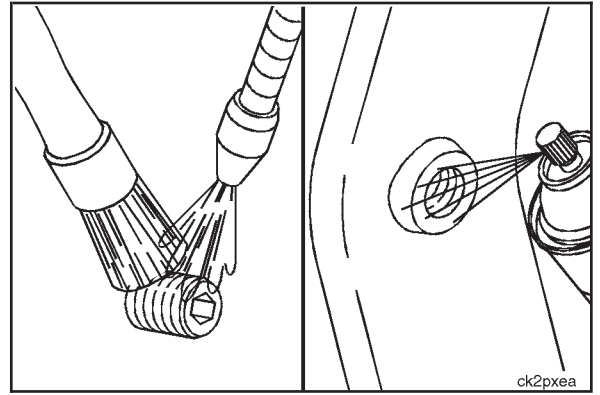


Pipe Plug (017-007) Remove (017-007-002)

Select the appropriate size Allen wrench and remove the pipe plug.

Clean (017-007-006)

Use spray cleaner, Part No. 3823717 or equivalent, to clean the threads of the pipe plugs and threaded bores.

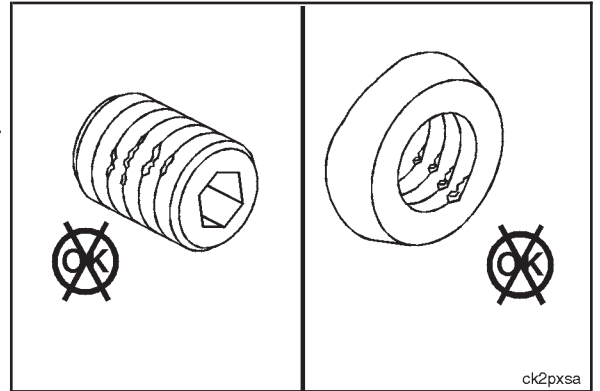


Inspect for Reuse (017-007-007)

Visually inspect the threads of the pipe plugs for mutilation or damage.

Visually inspect the threaded bores for damage.

Repair the bores if necessary. Refer to the Alternative Repair Manual, Bulletin No. 3810310.

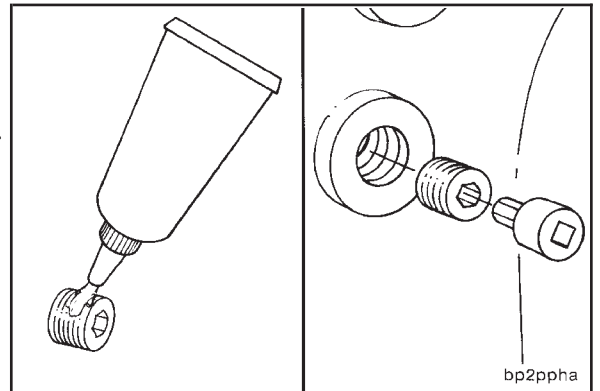


Install (017-007-026)

Apply a film of pipe plug sealant, Part No. 3375066 or equivalent, to the threads.

Install and tighten the pipe plugs.

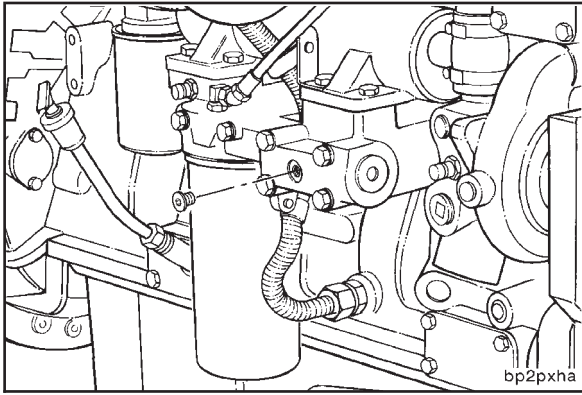
Refer to the following chart for torque values:



Tighten pipe plugs to the appropriate torque values.



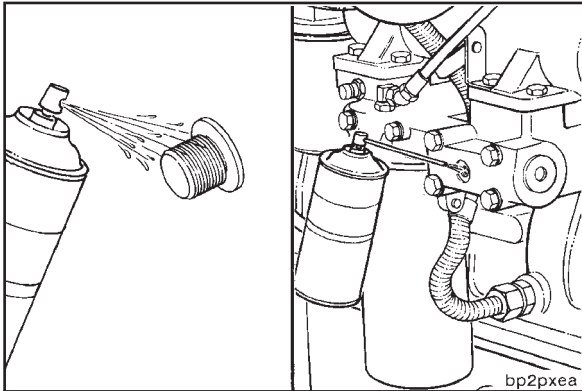
		Pipe Plug Torque Values			
Size		Torque		Torque	
Thread	Actual Thread O.D.	In Aluminum Components		In Cast Iron or Steel Components	
in.	mm [in]	N•m	[ft-lbs]	N•m	[ft-lbs]
1/16	8.1 [0.32]	5	[45 in-lb]	15	[10]
1/8	10.4 [0.41]	15	[10]	20	[15]
1/4	13.7 [0.54]	20	[15]	25	[20]
3/8	17.3 [0.68]	25	[20]	35	[25]
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]



Straight Thread Plug (017-011)

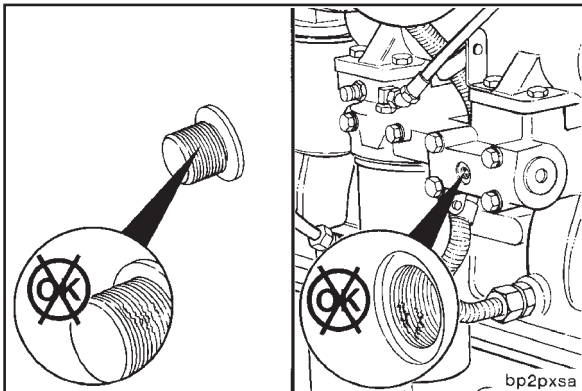
Remove (017-011-002)

Select the appropriate size Allen wrench or socket and remove the plug.



Clean (017-011-006)

Use spray cleaner, Part No. 3823717 or equivalent, to clean the threads of the straight thread plugs and threaded bores.



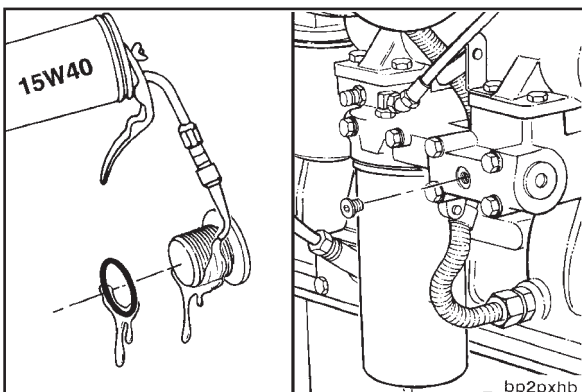
Inspect for Reuse (017-011-007)

Visually inspect the threads of the pipe plugs for mutilation or damage.



Visually inspect the threaded bores for damage.

Repair the bores if necessary. Refer to the Alternative Repair Manual, Bulletin No. 3810310.



Install (017-011-026)

Install a new o-ring on the plug. Lubricate with clean 15W-40 oil.



Install and tighten the plugs.

Refer to the following chart for torque values:



Tighten straight thread plugs to the appropriate torque value.



Straight Thread O-Ring Plugs				
Thread Size Inches	Torque - lbf			
	N·m	In-lb	N·m	ft-lb
1/4	4	35		
3/8	6	50		
1/2	8	70		
9/16	12	105		
5/8	16	145		
3/4			20	15
7/8			35	20
1			40	30
1-1/16			45	35
1-3/16			55	40
				oi203vg

Section 20 - Vehicle Braking - Group 20

Section Contents

	Page
Engine Brake	20-1
Adjust.....	20-7
Clean	20-4
Initial Check	20-1
Inspect for Reuse	20-5
Install	20-5
Remove.....	20-3

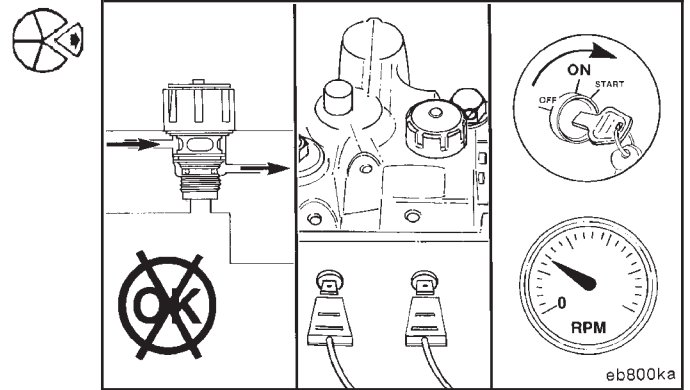
Engine Brake (020-001)

Initial Check (020-001-001)

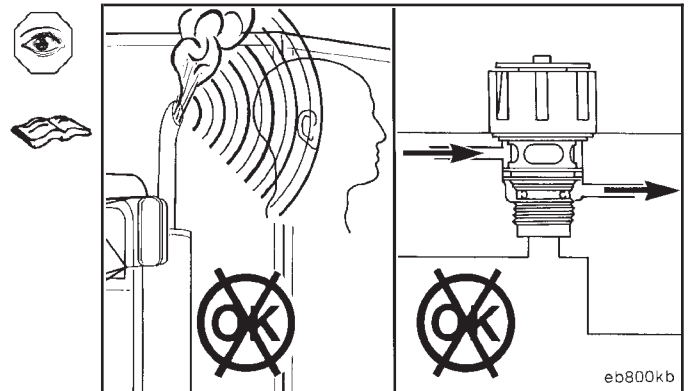
An engine equipped with an engine brake can fail to start or perform properly due to one or more of the following:

- Engine will **not** start due to a stuck oil flow solenoid valve

NOTE: To check for a stuck solenoid valve, disconnect the electrical wires to the engine brakes and operate the engine.

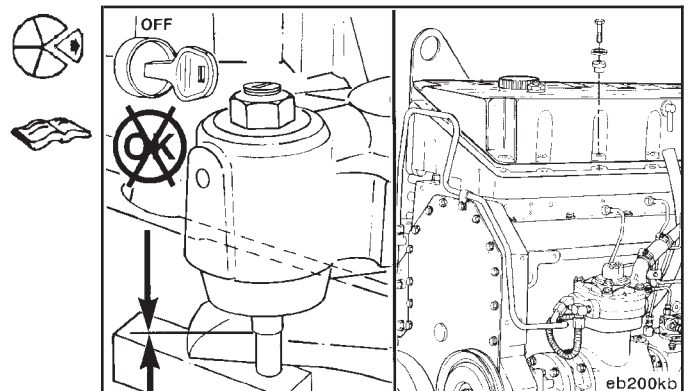


If exhaust gases can be heard escaping past the valves, the solenoid valve or valves **must** be replaced. Contact an authorized engine brake dealer.



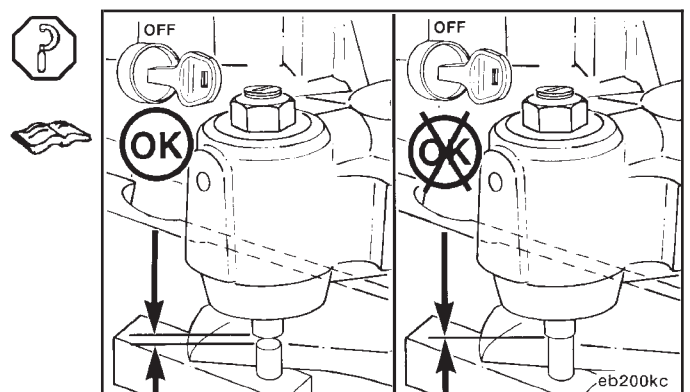
- Engine will **not** start or runs rough due to a slave piston adjusted incorrectly or damaged

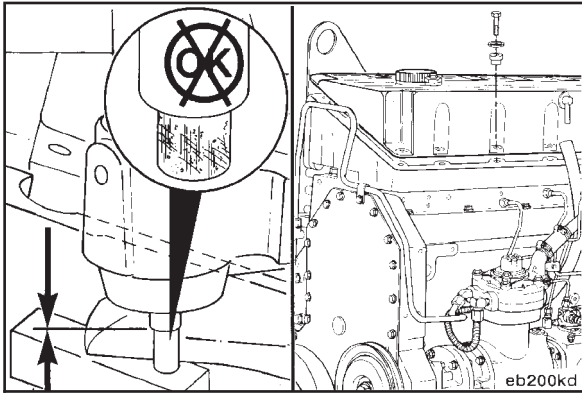
To check the slave piston, remove the rocker lever cover. Refer to Procedure 003-011-002.



Check the slave piston clearance. The clearance **must** be 0.38 mm [0.015 in].

Refer to "Engine Brake — Adjustment" in Procedure 003-004 to adjust the clearance.



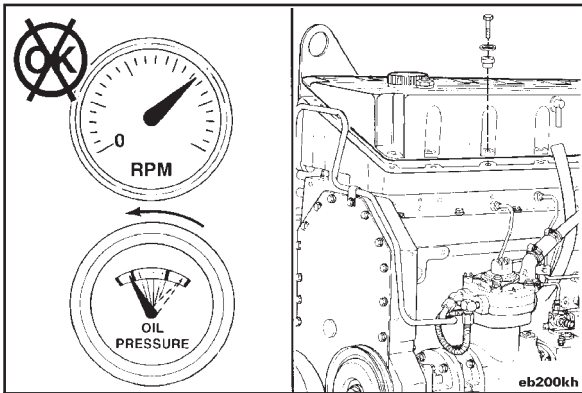


Visually inspect the slave piston for damage.

NOTE: If the slave piston is damaged, contact an authorized engine brake dealer for repair.



Install the rocker lever cover. Refer to Procedure 003-011-026.



- Sudden drop in lubricating oil pressure

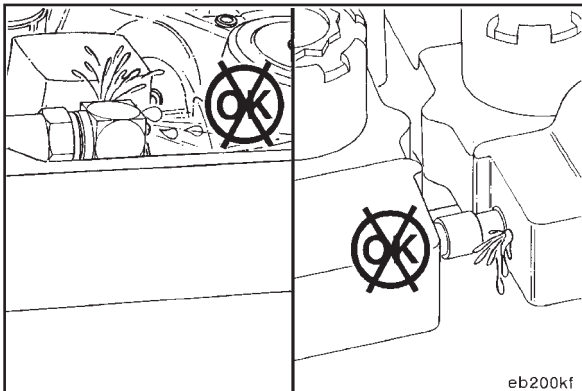
Remove the rocker lever cover. Refer to Procedure 003-011-002.



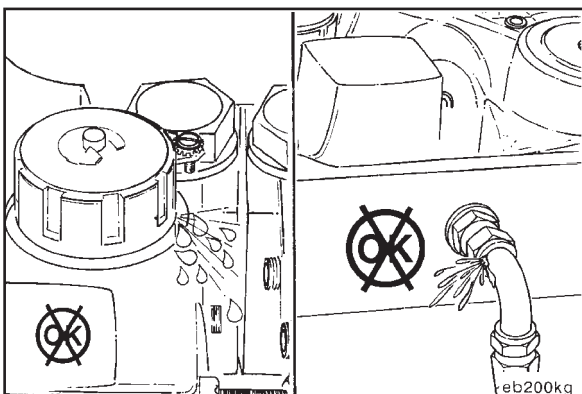
NOTE: If repairs are necessary, contact an authorized engine brake dealer.



Operate the engine and check for the following problems:

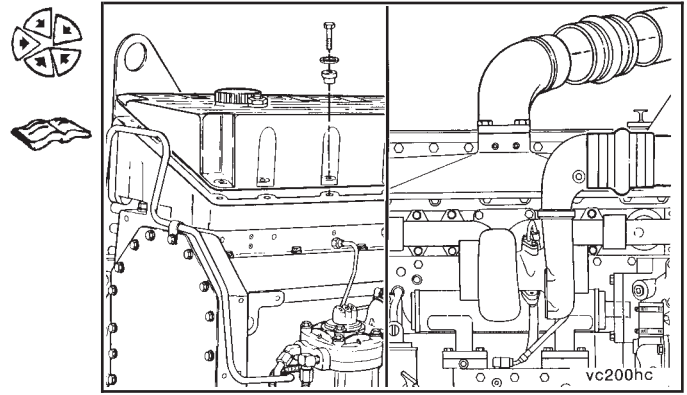


- Oil supply hose loose or missing
- Oil connector seal loose or missing



- Upper solenoid valve seal ring missing or damaged
- External oil supply hose or fitting cracked or leaking

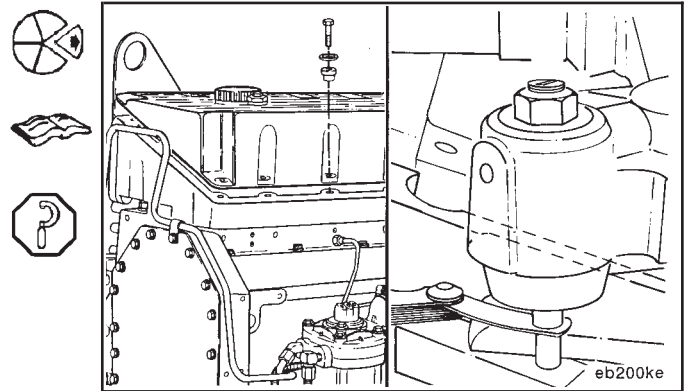
Install the rocker lever cover. Refer to Procedure 003-011-026.



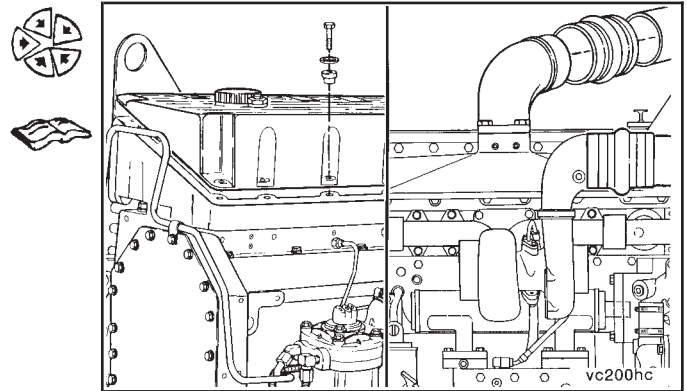
- Engine misfiring or loss of power

Remove the rocker lever cover. Refer to Procedure 003-011-002.

Adjust the slave piston clearance. Refer to "Engine Brake — Adjustment" in Procedure 003-004.

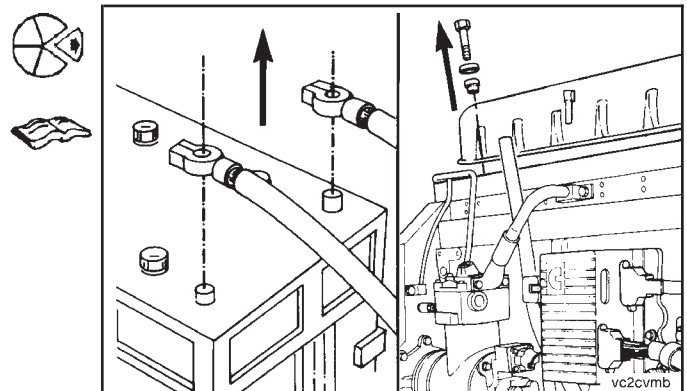


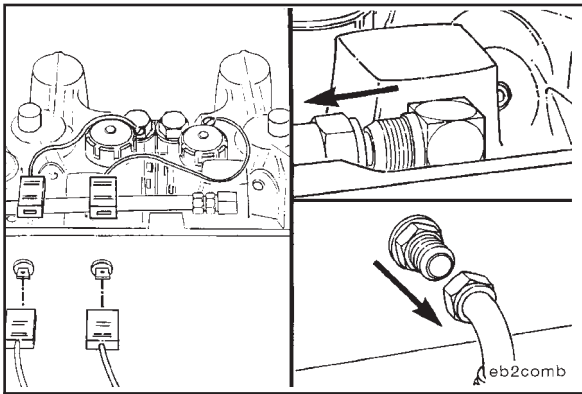
Install the rocker lever cover. Refer to Procedure 003-011-026.



Remove (020-001-002)

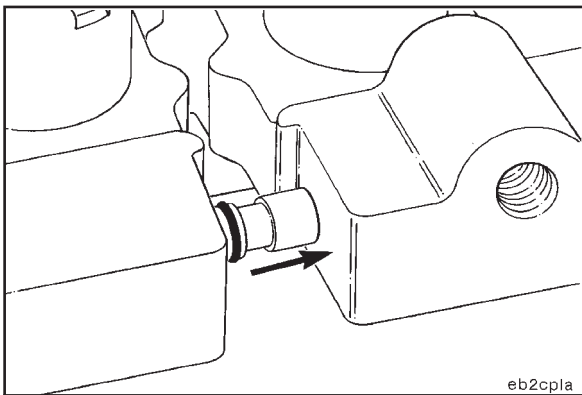
Remove the rocker lever cover. Refer to Procedure 003-011-002.



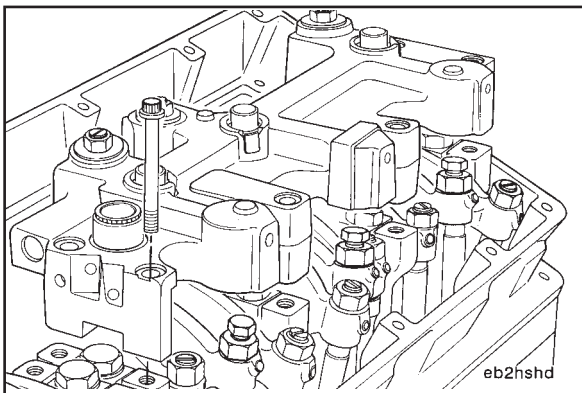


Disconnect the two electrical wires from the terminals on the inside of the rocker lever housing spacer.

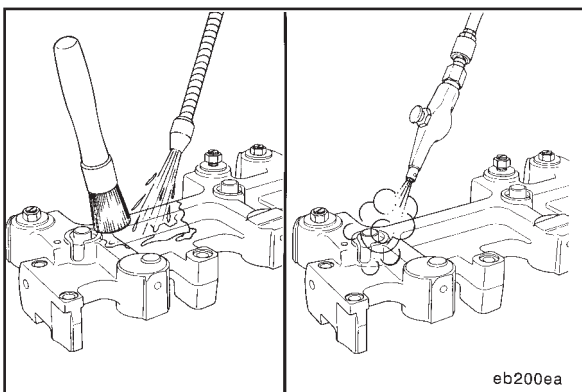
Disconnect the oil supply hose connections.



Press the connector into the front housing to allow clearance for housing removal.



Remove the capscrews and both engine brake housings.

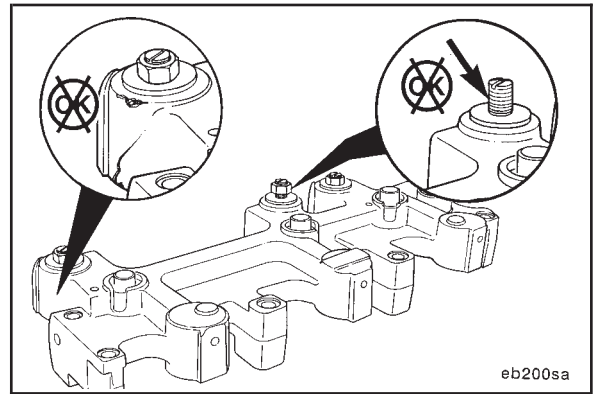


Clean (020-001-006)

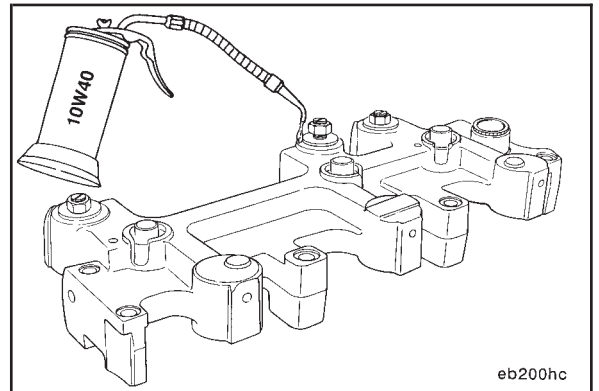
Use an approved solvent to clean the brake housings. Dry with compressed air.

Inspect for Reuse (020-001-007)

Visually inspect the housings for any missing or damaged parts.



Apply a thin film of clean 15W-40 oil to the machined surfaces.

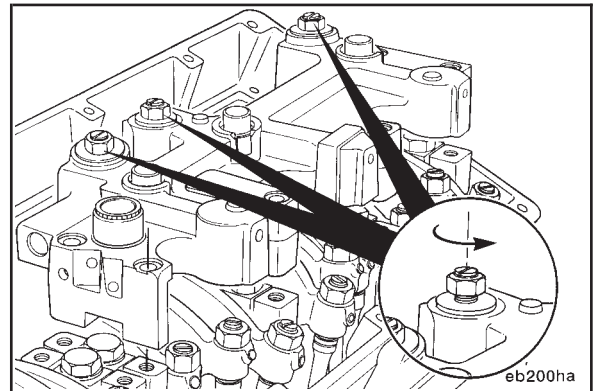


Install (020-001-026)

Loosen the locknuts on the slave pistons.

Make sure the slave pistons are fully retracted.

Install the rear engine brake housing on the rear rocker lever supports.

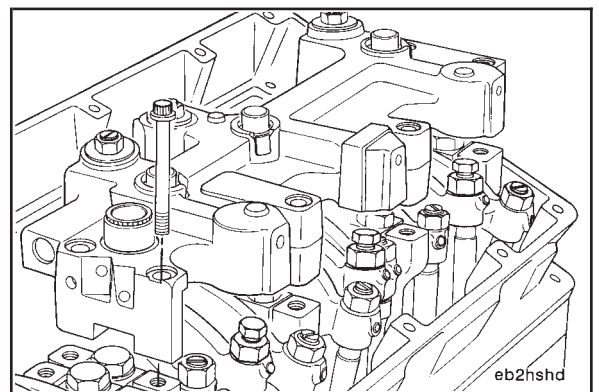


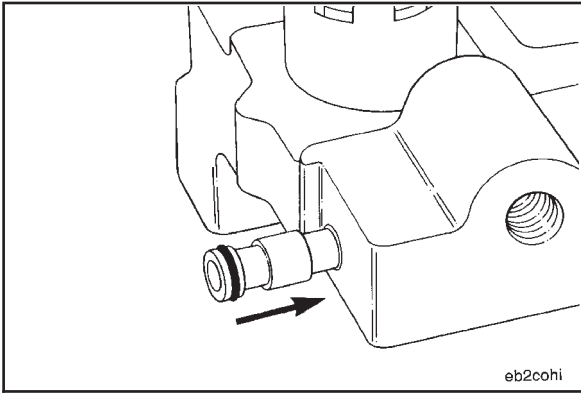
Use clean 15W-40 oil to coat the bottom side of the capscrew heads and the threads.

NOTE: Washers are **not** used with the capscrews.

Install the capscrews in the rocker lever supports.

Do **not** tighten the capscrews.



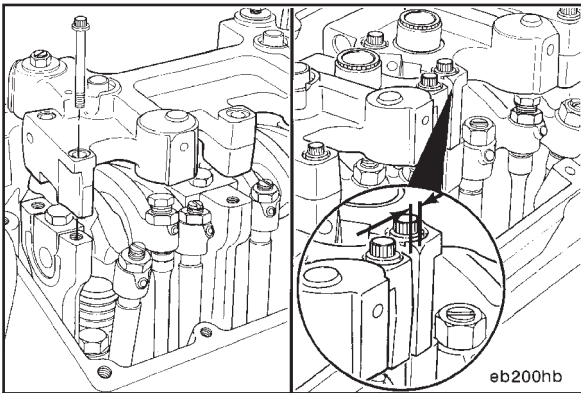


Use clean 15W-40 oil to lubricate the o-rings.

Press the connector all the way into the front housing by hand.

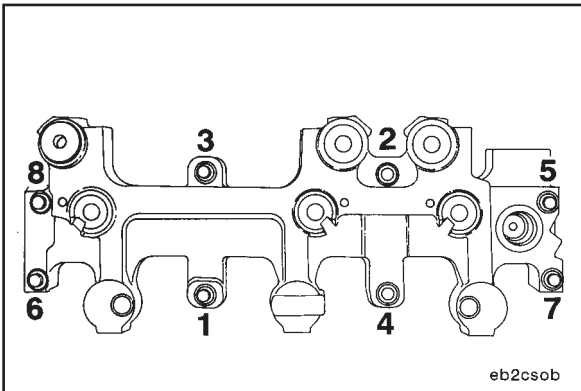


When installing the front housing, be sure the oil connector and o-ring are in position to be pushed into the rear housing.



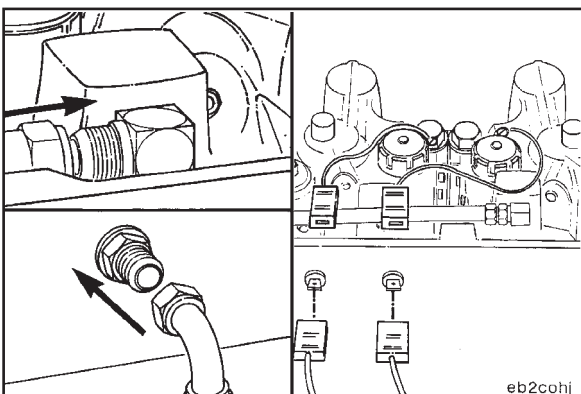
Install the front engine brake housing on the front rocker lever supports.

Center the oil connector between the front and rear housings before tightening the capscrews.



Tighten the capscrews in the sequence shown.

Torque Value: 81 N•m [60 ft-lb]



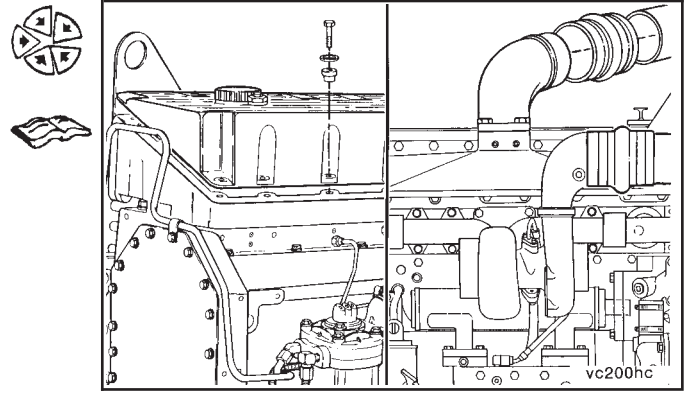
Install the oil connector supply hose and tighten the capscrews.

Torque Value: 19 N•m [14 ft-lb]



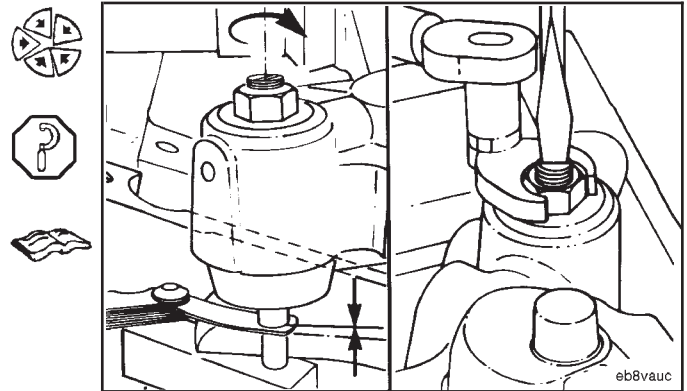
Connect the two electrical wires to the terminals on the inside of the rocker lever housing spacer.

Install the rocker lever cover. Refer to Procedure 003-011-026.



Adjust (020-001-029)

To obtain maximum brake operating efficiency, the engine brakes **must** be adjusted. Refer to Procedure 003-004 (Overhead Adjustment) for the correct engine brake adjusting procedure.



Section L - Service Literature

Section Contents

	Page
Additional Service Literature	L-1
Literature Order Form	L-3
Service Literature Ordering Location	L-2

Additional Service Literature

The following publications can be purchased by filling in and mailing the Literature Order Form:

Bulletin No.	Title of Publication
3379133	Control Parts List
3387137	Troubleshooting Driveability Complaints
3387245	Troubleshooting Excessive Fuel Consumption
3666130	Troubleshooting and Repair Manual, CELECT™ Plus System M11 and N14 Engines
3666084	Troubleshooting and Repair Manual, CELECT Sytem L10, M11 and N14 Engines
3666075	Shop Manual, M11 Series Engines
3666076	Specifications Manual, M11 Series Engines
3666144	CELECT™ Plus Compulink™ 1.0 Cartridge Manual
3666145	CELECT™ and CELECT™ Plus Echek™ 4.0 Cartridge Manual
3666083	Standard Repair Times, M11 Series Engines
3810388	L10 Overhead Reuse Guidelines
3810389	CELECT™ Fault Code Manual
3810340	Cummins Engine Oil Recommendations
3379001	Fuel for Cummins Engines (QP-20)
3810344	PT (Type D) Top Stop Injector Shop Manual
3379084	Fuel Pump (PT Type G) Rebuild and Calibrate
3810490	Shop and Installation Manual - Rear Engine Power Takeoff

Service Literature Ordering Location

Region

Ordering Location

United States and Canada

Cummins Distributors

or

Contact 1-800-DIESELS
(1-800-343-7357)

U.K., Europe, Mid-East, Africa,
and Eastern European Countries

Cummins Engine Co., Ltd.
Royal Oak Way South
Daventry
Northants, NN11 5NU, England

South and Central America
(excluding Brazil and Mexico)

Cummins Americas, Inc.
16085 N.W. 52nd Avenue
Hialeah, FL 33104

Brazil and Mexico

Cummins Engine Co., Inc.
International Parts Order Dept., MC 40931
Box 3005
Columbus, IN 47202-3005

Far East (excluding
Australia and New Zealand)

Cummins Diesel Sales Corp.
Literature Center
8 Tanjong Penjuru
Jurong Industrial Estate
Singapore

Australia and New Zealand

Cummins Diesel Australia
Maroondah Highway, P.O.B. 139
Ringwood 3134
Victoria, Australia

Obtain current price information from your local Cummins Distributor.

Literature Order Form

Use this form for prompt handling of your literature order.

Item	Bulletin Number	Title of Publication	Quantity	U.S. Price Each	Amount
1				\$	\$
2					
3					
4					
5					
6					
Order Total					\$

Contact your Cummins distributor for prices and availability.

For problems with literature orders (for U.S.A. and Canada), contact 1-800-DIESELS (1-800-343-7357). All other locations contact your local Distributor.

Prices subject to change without notice.

Please cut on dotted line



Literature Order Form

Use this form for prompt handling of your literature order.

Item	Bulletin Number	Title of Publication	Quantity	U.S. Price Each	Amount
1				\$	\$
2					
3					
4					
5					
6					
Order Total					\$

Contact your Cummins distributor for prices and availability.

For problems with literature orders (for U.S.A. and Canada), contact 1-800-DIESELS (1-800-343-7357). All other locations contact your local Distributor.

Prices subject to change without notice.

Mail the Literature Order Form along with your ship-to address to your nearest Cummins distributor.

FROM:		
Name:		
Street Address:		
City:	State/Province:	Zip/Postal Code:
Country:		

SHIP TO: (Name and address where literature is to be shipped)		
Name:		
Street Address:		
City:	State/Province:	Zip/Postal Code:
Country:		

Please cut on dotted line

Mail the Literature Order Form along with your ship-to address to your nearest Cummins distributor.

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City:	State/Province:	Zip/Postal Code:
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SHIP TO: (Name and address where literature is to be shipped)		
Name:		
Street Address:		
City:	State/Province:	Zip/Postal Code:
Country:		

Section M - Component Manufacturers

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Air Heaters.....	M-1
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Torque Converters	M-3

Component Manufacturers' Addresses

NOTE: The following list contains addresses and telephone numbers of suppliers of accessories used on Cummins engines. Suppliers can be contacted directly for any specifications **not** covered in this manual.

Air Compressors

Bendix Heavy Vehicles Systems
Div. of Allied Automotive
901 Cleveland Street
Elyria, OH 44036
Telephone: (216) 329-9000

Holset Engineering Co., Inc.
1320 Kemper Meadow Drive
Suite 500
Cincinnati, OH 45240
Telephone: (513) 825-9600

Midland-Grau
Heavy Duty Systems
Heavy Duty Group Headquarters
10930 N. Pamona Avenue
Kansas City, MO 64153
Telephone: (816) 891-2470

Air Cylinders

Bendix Ltd.
Douglas Road
Kingswood
Bristol
England
Telephone: 0117-671881

Catching Engineering
1733 North 25th Avenue
Melrose Park, IL 60160
Telephone: (708) 344-2334

TEC - Hackett Inc.
8909 Rawles Avenue
Indianapolis, IN 46219
Telephone: (317) 895-3670

Air Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Kim Hotstart Co.
P.O. Box 11245
Spokane, WA 99211-0245
Telephone: (509) 534-6171

Air Starting Motors

Ingersoll Rand
Chorley New Road
Horwich
Bolton
Lancashire
England
BL6 6JN
Telephone: 01204-65544

Ingersoll-Rand Engine
Starting Systems
888 Industrial Drive
Elmhurst, IL 60126
Telephone: (708) 530-3875

StartMaster
Air Starting Systems
A Division of Sycon Corporation
9595 Cheney Avenue
P. O. Box 491
Marion, OH 43302
Telephone: (614) 382-5771

Alternators

Robert Bosch Ltd.
P.O. Box 98
Broadwater Park
North Orbital Road
Denham
Uxbridge
Middlesex UD9 5HG
England
Telephone: 01895-833633

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 01744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.C. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 01908-66001

C. E. Niehoff & Co.
2021 Lee Street
Evanston, IL 60202
Telephone: (708) 866-6030

Delco-Remy America
2401 Columbus Avenue
P.O. Box 2439
Anderson, IN 46018
Telephone: (317) 646-3528

Leece-Neville Corp.
400 Main Street
Arcade, NY 14009
Telephone: (716) 492-1700

Auxiliary Brakes

The Jacobs Manufacturing Company
Vehicle Equipment Division
22 East Dudley Town Road
Bloomfield, CT 06002
Telephone: (203) 243-1441

Belts

Dayco Rubber U.K.
Sheffield Street
Stockport
Cheshire
SK4 1RV
England
Telephone: 061-432-5163

T.B.A. Belting Ltd.
P.O. Box 77
Wigan
Lancashire
WN2 4XQ
England
Telephone: 01942-59221

Dayco Mfg.
Belt Technical Center
1955 Enterprize
Rochester Hills, MI 48309
Telephone: (810) 853-8300

Gates Rubber Company
900 S. Broadway
Denver, CO 80217

Goodyear Tire and
Rubber Company
Industrial Products Div.
2601 Fortune Circle East
Indianapolis, IN 46241
Telephone: (317) 898-4170

Catalytic Convertors

Donaldson Company, Inc.
1400 West 94th Street
P.O. Box 1299
Minneapolis, MN 55440
Telephone: (612) 887-3835

Nelson Division
Exhaust and Filtration Systems
1801 U.S. Highway 51 P.O. Box 428
Stoughton, WI 53589
Telephone: (608) 873-4200

Walker Manufacturing
3901 Willis Road
P.O. Box 157
Grass Lake, MI 49240
Telephone: (517) 522-5500

Coolant Level Switches

Robertshaw Controls Company
P.O. Box 400
Knoxville, TN 37901
Telephone: (216) 885-1773

Clutches

Twin Disc International S.A.
Chaussee de Namur
Nivelles
Belguim
Telephone: 067-224941

Twin Disc Incorporated
1328 Racine Street
Racine, WI 53403
Telephone: (414) 634-1981

Coolant Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Drive Plates

Detroit Diesel Allison
Division of General Motors
Corporation
P.O. Box 894
Indianapolis, IN 46206-0894
Telephone: (317) 242-5000

Electric Starting Motors

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 01744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.C. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 0908-66001

Delco-Remy America
2401 Columbus Avenue
P.O. Box 2439
Anderson, IN 46018
Telephone: (317) 646-3528

Leece-Neville Corp.
400 Main Street
Arcade, NY 14009
Telephone: (716) 492-1700

Nippondenso Inc.
2477 Denso Drive
P.O. Box 5133
Southfield, MI 48086
Telephone: (313) 350-7500

Electronic Switches

Cutler-Hammer Products
Eaton Corporation
4201 N. 27th Street
Milwaukee, WI 53216
Telephone: (414) 449-6600

Engine Protection Controls

Flight Systems Headquarters
Hempt Road
P.O. Box 25
Mechanicsburg, PA 17055
Telephone: (717) 697-0333

The Nason Company
2810 Blue Ridge Blvd.
West Union, SC 29696
Telephone: (803) 638-9521

Teddington Industrial
Equipment
Windmill Road
Sunburn on Thames
Middlesex
TW16 7HF
England
Telephone: 09327-85500

Fan Clutches

Holset Engineering Co. Ltd.
P.O. Box A9
Turnbridge
Huddersfield, West Yorkshire
England HD6 7RD
Telephone: 01484-22244

Horton Industries, Inc.
P.O. Box 9455
Minneapolis, MN 55440
Telephone: (612) 378-6410

Rockford Clutch Company
1200 Windsor Road
P.O. Box 2908
Rockford, IL 61132-2908
Telephone: (815) 633-7460

Fans

Truflo Ltd.
Westwood Road
Birmingham
B6 7JF
England
Telephone: 021-557-4101

Hayes-Albion Corporation
Jackson Manufacturing Plant
1999 Wildwood Avenue
Jackson, MI 49202
Telephone: (517) 782-9421

Engineered Cooling Systems, Inc.
201 W. Carmel Drive
Carmel, IN 46032
Telephone: (317) 846-3438

Brookside Corporation
P.O. Box 30
McCordsville, IN 46055
Telephone: (317) 335-2014

TCF Aerovent Company
9100 Purdue Rd., Suite 101
Indianapolis, IN 46268-1190
Telephone: (317) 872-0030

Kysor-Cadillac
1100 Wright Street
Cadillac, MI 49601
Telephone: (616) 775-4681

Schwitzer
6040 West 62nd Street
P.O. Box 80-B
Indianapolis, IN 46206
Telephone: (317) 328-3010

Fault Lamps

Cutler-Hammer Products
Eaton Corporation
4201 N. 27th Street
Milwaukee, WI 53216
Telephone: (414) 449-6600

Filters

Fleetguard International Corp.
Cavalry Hill Industrial Park
Weedon
Northampton NN7 4TD
England
Telephone: 01327-41313

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Flexplates

Corrugated Packing and
Sheet Metal
Hamsterley
Newcastle Upon Tyne
England
Telephone: 01207-560-505

Allison Transmission
Division of General Motors
Corporation
P.O. Box 894
Indianapolis, IN 46206-0894
Telephone: (317) 242-5000

Midwest Mfg. Co.
29500 Southfield Road, Suite 122
Southfield, MI 48076
Telephone: (313) 642-5355

Wohlert Corporation
708 East Grand River Avenue
P.O. Box 20217
Lansing, MI 48901
Telephone: (517) 485-3750

Fuel Coolers

Hayden, Inc.
1531 Pomona Road
P.O. Box 848
Corona, CA 91718-0848
Telephone: (909) 736-2665

Fuel Warmers

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Gauges

A.I.S.
Dyffon Industrial Estate
Ystrad Mynach
Hengoed
Mid Glamorgan
CF8 7XD
England
Telephone: 01443-812791

Grasslin U.K. Ltd.
Vale Rise
Tonbridge
Kent
TN9 1TB
England
Telephone: 01732-359888

Icknield Instruments Ltd.
Jubilee Road
Letchworth
Herts
England
Telephone: 04626-5551

Superb Tool and Gauge Co.
21 Princip Street
Birmingham
B4 61E
England
Telephone: 021-359-4876

Kabi Electrical and Plastics
Cranborne Road
Potters Bar
Herts
EN6 3JP
England
Telephone: 01707-53444

Datcon Instruments
P.O. Box 128
East Petersburg, PA 17520
Telephone: (717) 569-5713

Rochester Gauges, Inc.
11616 Harry Hines Blvd.
P.O. Box 29242
Dallas, TX 75229
Telephone: (214) 241-2161

Governors

Woodward Governors Ltd.
P.O. Box 15
663/664 Ajax Avenue
Slough
Bucks
SL1 4DD
England
Telephone: 01753-26835

Woodward Governor Co.
P.O. Box 1519
Fort Collins, CO 80522
Telephone: (303) 482-5811
(800) 523-2831

Barber Colman Co.
1354 Clifford Avenue
Loves Park, IL 61132
Telephone: (815) 637-3000

United Technologies
Diesel Systems
1000 Jorie Blvd.
Suite 111
Oak Brook, IL 69521
Telephone: (312) 325-2020

Heat Sleeves

Bentley Harris Manufacturing Co.
100 Bentley Harris Way
Gordonville, TN 38563
Telephone: (313) 348-5779

Hydraulic and Power Steering Pumps

Hobourn Automotive
Temple Farm Works
Priory Road
Strood
Rochester
Kent, England
ME2 2BD
Telephone: 01634-71773

Honeywell Control Systems Ltd.
Honeywell House
Charles Square
Bracknell
Berks RG12 1EB
Telephone: 01344-4245

Sundstrand Hydratec Ltd.
Cheney Manor Trading Estate
Swindon
Wiltshire
SN2 2PZ
England
Telephone: 01793-30101

Sperry Vickers
P.O. Box 302
Troy, MI 48084
Telephone: (313) 280-3000

Z.F.
P.O. Box 1340
Grafvonsoden Strasse
5-9 D7070
Schwaebisch Gmuend
Germany
Telephone: 7070-7171-31510

In-Line Connectors

Pioneer-Standard Electronics, Inc.
5440 Neiman Parkway
Solon, OH 44139
Telephone: (216) 349-1300

Deutsch
Industrial Products Division
37140 Industrial Avenue
Hemet, CA 92343
Telephone: (714) 929-1200

Oil Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Kim Hotstart Co.
P.O. Box 11245
Spokane, WA 99211-0245
Telephone: (509) 534-6171

Prelubrication Systems

RPM Industries, Inc.
Suite 109
55 Hickory Street
Washington, PA 15301
Telephone: (412) 228-5130

Radiators

JB Radiator Specialties, Inc.
P.O. Box 292087
Sacramento, CA 95829-2087
Telephone: (916) 381-4791

The G&O Manufacturing Company
100 Gando Drive
P.O. Box 1204
New Haven, CT 06505-1204
Telephone: (203) 562-5121

Young Radiator Company
2825 Four Mile Road
Racine, WI 53404
Telephone: (910) 271-2397

L and M Radiator, Inc.
1414 East 37th Street
Hibbing, MN 55746
Telephone: (218) 263-8993

Throttle Assemblies

Williams Controls, Inc.
14100 SW 72nd Avenue
Portland, OR 97224
Telephone: (503) 684-8600

Torque Converters

Twin Disc International S.A.
Chaussee de Namur
Nivelles
Belgium
Telephone: 067-224941

Twin Disc Incorporated
1328 Racine Street
Racine, WI 53403-1758
Telephone: (414) 634-1981

Rockford Powertrain, Inc.
Off-Highway Systems
1200 Windsor Road
P.O. Box 2908
Rockford, IL 61132-2908
Telephone: (815) 633-7460

Modine Mfg. Co.
1500 DeKoven Avenue
Racine, WI 53401
Telephone: (414) 636-1640

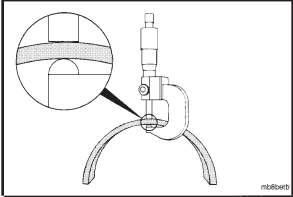
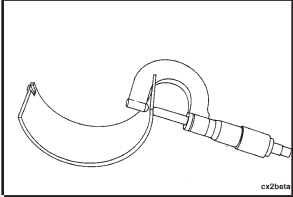
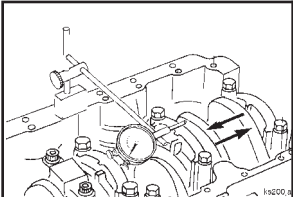
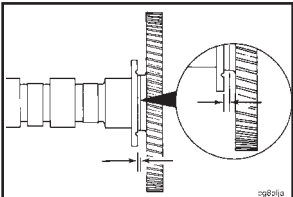
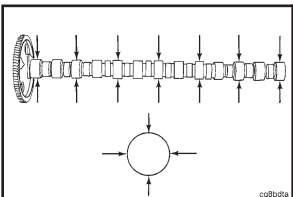
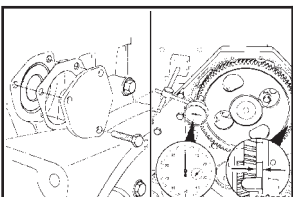
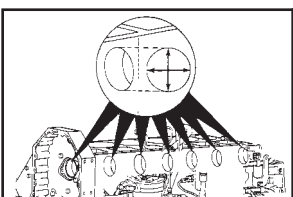
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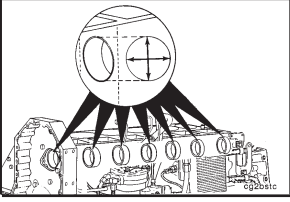
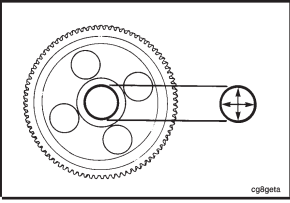
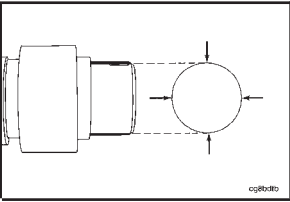
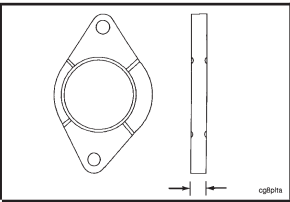
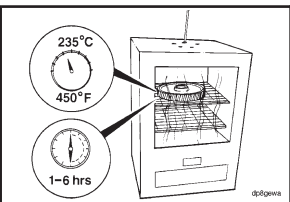
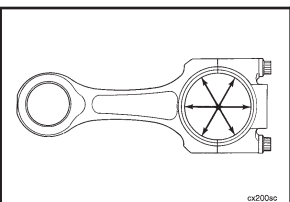
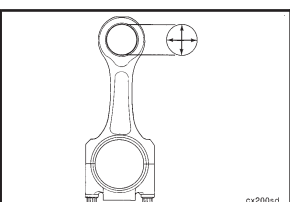
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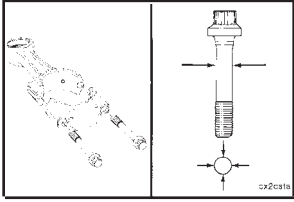
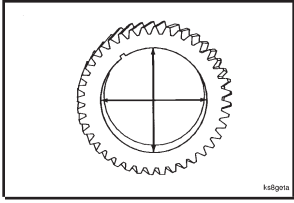
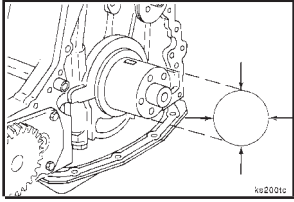
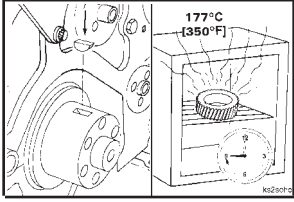
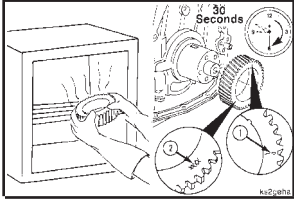
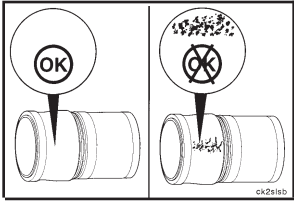
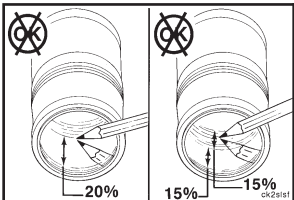
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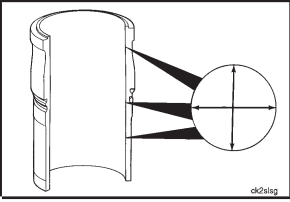
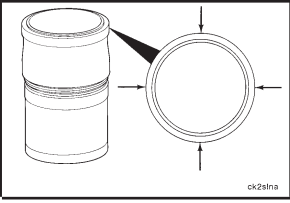
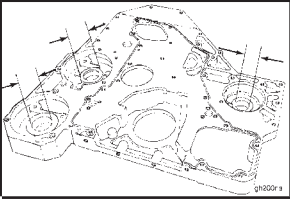
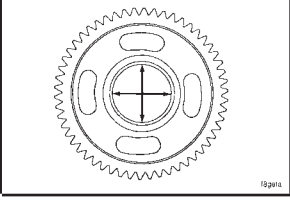
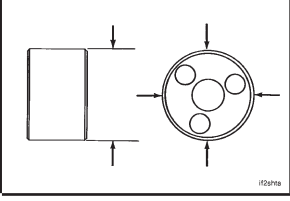
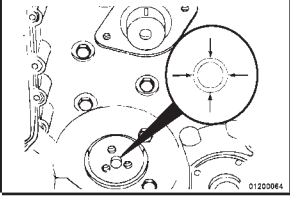
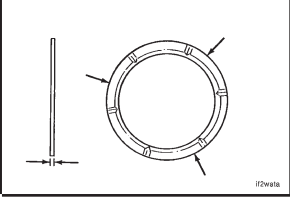
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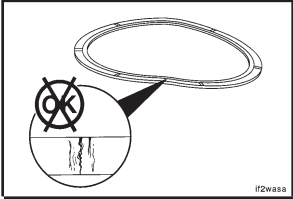
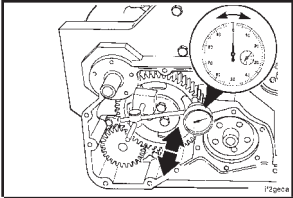
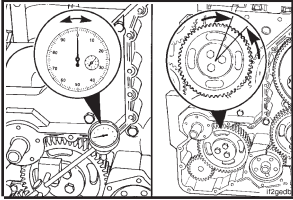
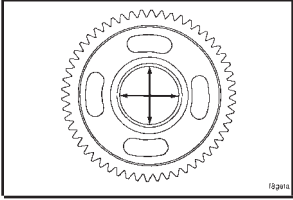
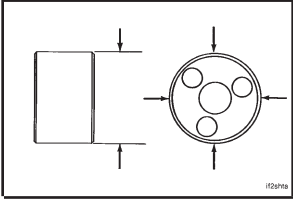
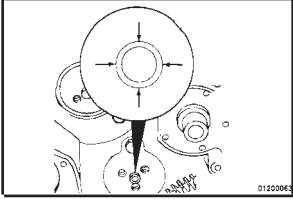
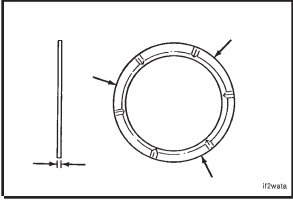
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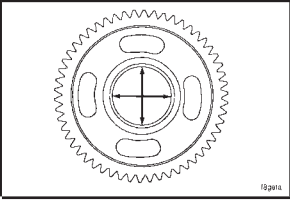
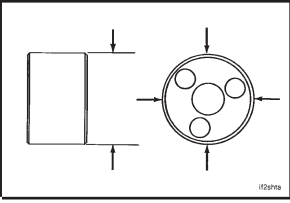
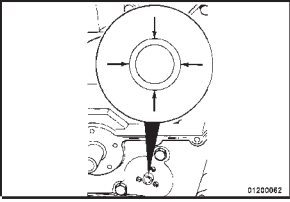
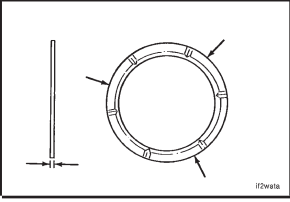
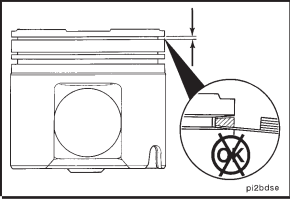
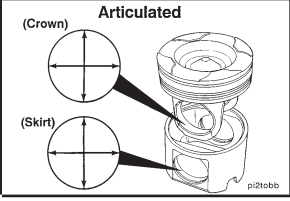
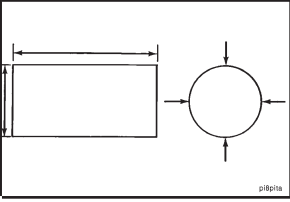
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Cylinder Block - Specifications				
Bearings, Connecting Rod (001-005)				
Standard Connecting Rod Bearing Thickness		2.430 mm 2.473 mm	MIN MAX	0.0957 in 0.0974 in
				
Bearings, Main (001-006)				
Standard Main Bearing Shell Thickness		3.894 mm 3.945 mm	MIN MAX	0.1533 in 0.1553 in
				
Bearings, Thrust (001-007)				
Crankshaft End Clearance		0.10 mm 0.56 mm	MIN MAX	0.004 in 0.022 in
				
Camshaft (001-008)				
Camshaft Thrust Plate Clearance		0.13 mm 0.33 mm	MIN MAX	0.005 in 0.013 in
				
Camshaft Bushing Journal O.D.		71.960 mm 72.013 mm	MIN MAX	2.8331 in 2.8352 in
				
Camshaft End Clearance		0.13 mm 0.33 mm	MIN MAX	0.005 in 0.013 in
				
Camshaft Bushings (001-010)				
Cylinder Block Camshaft Bore I.D.		76.987 mm 77.040 mm	MIN MAX	3.0310 in 3.0331 in
				

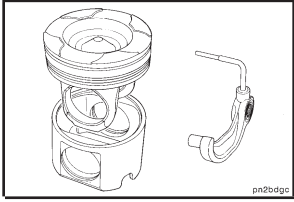
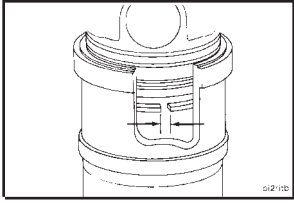
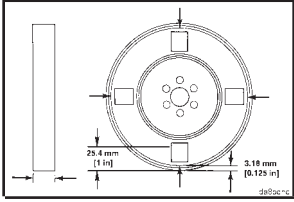
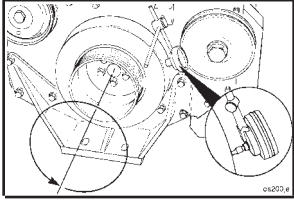
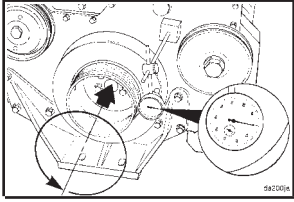
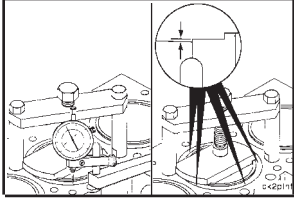
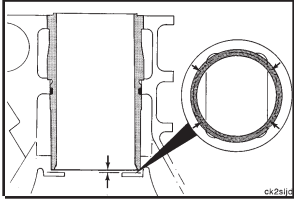
	Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	Camshaft Bushing I.D. Installed		72.078 mm 72.142 mm	MIN MAX	2.8377 in 2.8402 in
	Camshaft Gear (Camshaft Installed) (001-012)	Camshaft Gear Bore I.D.	46.912 mm 46.938 mm	MIN MAX	1.8469 in 1.8479 in
	Camshaft Gear Journal O.D.	46.987 mm 47.013 mm	MIN MAX	1.8499 in 1.8509 in	
	Camshaft Thrust Plate Thickness	8.96 mm 9.04 mm	MIN MAX	0.353 in 0.356 in	
	Camshaft Gear Installation Temperature Heat the gear in an oven for a minimum of one hour, but not longer than six hours. Temperature:	235 °C	450 °F		
	Connecting Rod (001-014)	Connecting Rod Crankshaft Bore I.D.	83.975 mm 84.025 mm	MIN MAX	3.3061 in 3.3080 in
	Piston Pin Bushing I.D.	54.054 mm 54.099 mm	MIN MAX	2.1281 in 2.1299 in	

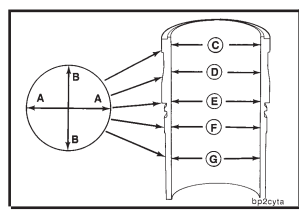
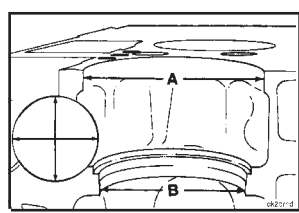
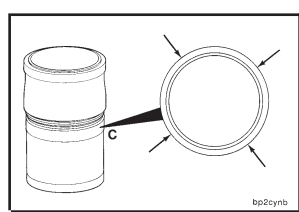
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.		
Connecting Rod Capscrew O.D.		12.60 mm 12.80 mm	MIN MAX	0.496 in 0.504 in	
Crankshaft Gear, Front (Crankshaft Installed) (001-018)					
Crankshaft Gear Bore I.D.		85.910 mm 85.935 mm	MIN MAX	3.3823 in 3.3833 in	
Crankshaft Gear Journal O.D.		85.975 mm 86.000 mm	MIN MAX	3.3848 in 3.3858 in	
Crankshaft Gear Installation Temperature		177 °C		350 °F	
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.					
					
Liner Pitting					
Visually inspect the outside diameter for excessive corrosion or pitting. Liners with pitting generally cannot be reused. However, if the pitting is light and can be removed with fine emery cloth, the liner can be reused.					
Pits must not be more than 1.60 mm [0.060 inch] deep.					
					
Liner Polish					
Replace the liner if:					
<ul style="list-style-type: none"> A heavy polish is present over 20 percent of the piston ring travel area. 30 percent of the piston ring travel area has both moderate and heavy polish and one half (15 percent) is heavy polish. 					
					

	Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	Cylinder Liner I.D.		125.000 mm 125.095 mm	MIN MAX	4.9213 in 4.9250 in
	Cylinder Liner Top Press Fit O.D.		145.938 mm 145.976 mm	MIN MAX	5.7456 in 5.7471 in
	Gear Housing, Front (001-033)				
Gear Housing Bearing Bore I.D.					
Hydraulic Drive		41.967 mm	MIN	1.6522 in	
		41.992 mm	MAX	1.6532 in	
Water Pump		36.967 mm	MIN	1.4553 in	
		36.992 mm	MAX	1.4564 in	
Accessory Drive		45.100 mm	MIN	1.7756 in	
		45.125 mm	MAX	1.7766 in	
	Idler Gear, Camshaft (001-036)				
Camshaft Idler Gear Bushing Bore I.D.		60.045 mm 60.100 mm	MIN MAX	2.3640 in 2.3661 in	
	Camshaft Idler Gear Shaft O.D.		59.975 mm 60.008 mm	MIN MAX	2.3612 in 2.3625 in
	Camshaft Idler Ring Dowel O.D.		19.217 mm 19.243 mm	MIN MAX	0.7566 in 0.7576 in
	Camshaft Idler Thrust Washer Thickness		2.400 mm 2.470 mm	MIN MAX	0.0945 in 0.0972 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Thrust Washer Inspection			
Flex the thrust washers approximately 3 to 6 mm [1/8 to 1/4 in] and inspect the surfaces for cracks.			
			
Idler Gear End Clearance		0.30 mm 0.53 mm	MIN MAX 0.012 in 0.021 in
			
Idler Gear Backlash		0.08 mm 0.38 mm	MIN MAX 0.003 in 0.015 in
			
Idler Gear, Hydraulic Pump (001-039)			
Hydraulic Drive Idler Gear Bushing Bore I.D.		60.045 mm 60.100 mm	MIN MAX 2.3640 in 2.3661 in
			
Hydraulic Drive Idler Gear shaft O.D.		59.975 mm 60.008 mm	MIN MAX 2.3612 in 2.3625 in
			
Hydraulic Drive Idler Ring Dowel O.D.		19.217 mm 19.243 mm	MIN MAX 0.7566 in 0.7576 in
			
Hydraulic Drive Idler Thrust Washer Thickness		2.400 mm 2.470 mm	MIN MAX 0.0945 in 0.0972 in
			

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Idler Gear, Water Pump (001-040)			
	Water Pump Idler Gear Bushing Bore I.D.		60.045 mm 60.100 mm	MIN 2.3640 in MAX 2.3661 in
	Water Pump Idler Gear Shaft O.D.		59.975 mm 60.008 mm	MIN 2.3612 in MAX 2.3625 in
	Water Pump Idler Ring Dowel O.D.		19.217 mm 19.243 mm	MIN 0.7566 in MAX 0.7576 in
	Water Pump Idler Thrust Washer Thickness		2.400 mm 2.470 mm	MIN 0.0945 in MAX 0.0972 in
	Piston Ring Groove	Hold a new ring in the groove even with the outside diameter of the piston. Install a 0.15 mm [0.006 inch] feeler gauge. If the feeler gauge enters the groove without resistance, there is too much wear. Replace the piston.		
	Articulated Piston Pin Bore I.D. (Crown)		54.040 mm 54.055 mm	MIN 2.1276 in MAX 2.1281 in
	Articulated Piston Pin Bore I.D. (Skirt)		54.007 mm 54.015 mm	MIN 2.1263 in MAX 2.1266 in
	Piston Pin O.D.		53.997 mm 54.003 mm	MIN 2.1259 in MAX 2.1261 in
	Piston Pin Length		101.70 mm 102.00 mm	MIN 4.0039 in MAX 4.0157 in

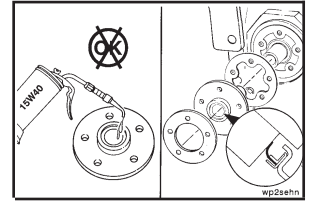
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.		
Piston Cooling Nozzle (001-046)					
Piston Cooling Nozzle Length		44.5 mm	Nominal	1.752 in	
Piston Rings (001-047)					
Piston Ring Gap					
Top		0.46 mm	MIN	0.018 in	
		0.71 mm	MAX	0.028 in	
Intermediate		0.76 mm	MIN	0.030 in	
		1.14 mm	MAX	0.045 in	
Oil		0.25 mm	MIN	0.010 in	
		0.64 mm	MAX	0.025 in	
Vibration Damper Thickness					
Measure and record the vibration damper thickness at two points at each of the four locations.					
<ul style="list-style-type: none"> • Measure the thickness at 3.18 mm [0.125 in] from the outer lip. • Measure the thickness at 25.4 mm [1.0 in] from the outer lip. 					
If the variations between any of the eight measurements exceeds 0.25 mm [0.010 in], or if the thickness at any point exceeds 45 mm [1.772 in], replace the vibration damper.					
					
Vibration Damper Eccentricity					
To measure damper eccentricity (out of round), install the dial indicator on the gear cover as indicated.					
Rotate the crankshaft with the accessory drive shaft one complete revolution (360 degrees), and record the total indicator movement.					
Replace the vibration damper if the eccentricity exceeds 0.28 mm [0.011 inch].					
					
Vibration Damper Face Alignment					
Replace the damper if wobble exceeds 0.28 mm [0.011 inch].					
					
Cylinder Liner Protrusion (001-064)					
Cylinder Liner Protrusion		0.00 mm	MIN	0.000 in	
		0.13 mm	MAX	0.005 in	
Cylinder Liner to Block Clearance		0.25 mm	MIN	0.010 in	

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	<p>Cylinder Liner Bore Measure the liner bore for out-of-roundness at points "C", "D", "E", "F" and "G". Measure each point in the direction "AA" and "BB". The bore must not be more than 0.10 mm [0.004 inch] out-of-round.</p>			
	<p>Cylinder Block Upper Liner Bore ID (A) 145.900 mm 146.027 mm</p> <p>Measure the cylinder block liner seal seat bore (B) 8.0 to 13.5 mm [0.32 to 0.53 inch] below the counterbore.</p> <p>Cylinder Block Liner Seal Seat Bore ID (B) 138.063 mm 138.113 mm</p>		<p>MIN 5.7441 in MAX 5.7491 in</p> <p>MIN 5.4355 in MAX 5.4375 in</p>	
	<p>Cylinder Liner Seal Seat O.D. (C)</p>		<p>137.937 mm 138.013 mm</p> <p>MIN 5.4306 in MAX 5.4336 in</p>	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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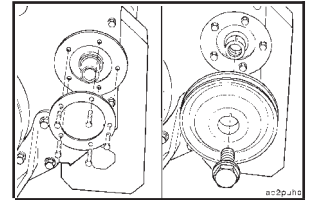
Cylinder Block - Torque Values
Alternator Drive Seal (001-001)

Alternator Drive Seal Mounting Capscrews	1	7 N•m	60 in-lb
	2	20 N•m	175 in-lb



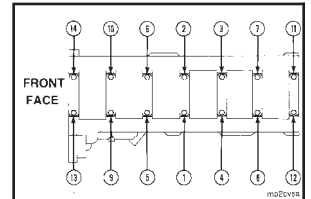
Accessory Drive Seal (001-003)

Accessory Drive Seal Mounting Capscrews	1	7 N•m	60 in-lb
	2	20 N•m	175 in-lb



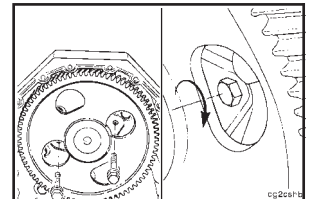
Bearings, Main (001-006)

Main Bearing Cap Mounting Capscrews	1	68 N•m	50 ft-lb
	2	142 N•m	105 ft-lb
	3	210 N•m	155 ft-lb
	4	Loosen completely	
	5	Repeat steps 1 thru 3	



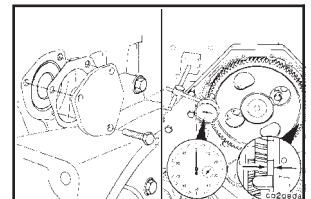
Camshaft (001-008)

Camshaft Thrust Plate Mounting Capscrews		47 N•m	35 ft-lb
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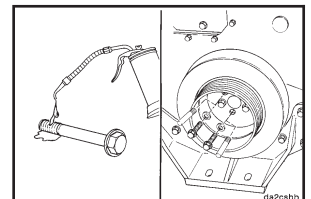
Camshaft Rear Cover Plate Mounting Capscrews

		47 N•m	35 ft-lb
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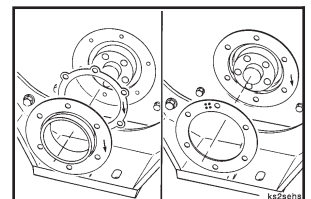
Crankshaft Pulley (001-022)

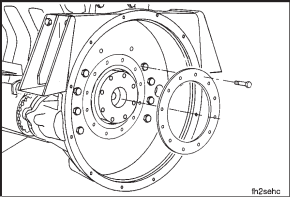
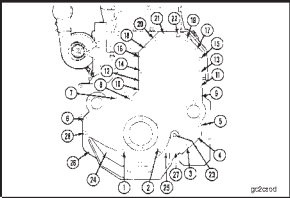
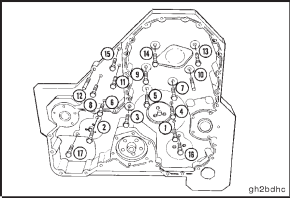
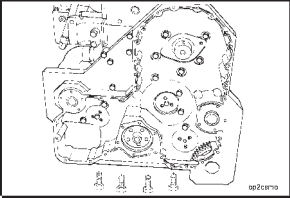
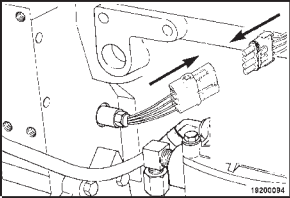
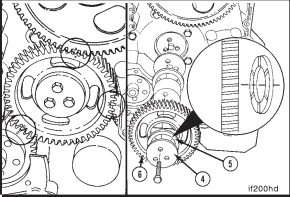
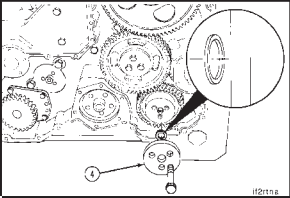
Crankshaft Pulley Mounting Capscrews		203 N•m	150 ft-lb
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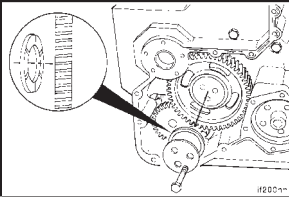
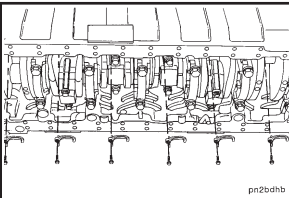
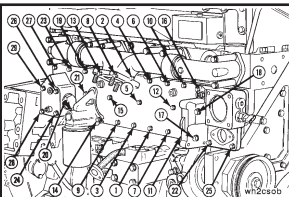
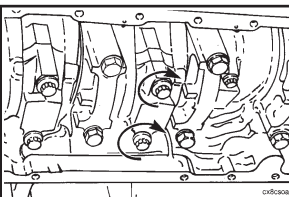
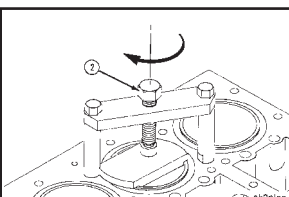


Crankshaft Seal, Front (001-023)

Front Crankshaft Seal Mounting Capscrews	1	7 N•m	60 in-lb
	2	20 N•m	180 in-lb

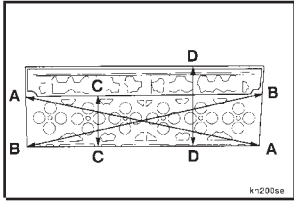


	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Crankshaft Seal, Rear (001-024) Rear Crankshaft Seal Mounting Capscrews	1 2	7 N•m 20 N•m	60 in-lb 180 in-lb
	Gear Cover, Front (001-031) Gear Cover Mounting Capscrews Capscrews 1 thru 22: Capscrews 23 thru 28:		20 N•m 68 N•m	15 ft-lb 50 ft-lb
	Gear Housing, Front (001-033) Gear Housing Mounting Capscrews	1 2	20 N•m 68 N•m	15 ft-lb 50 ft-lb
	Oil Pan to Gear Housing Mounting Capscrews		47 N•m	35 ft-lb
	Engine Position Sensor		34 N•m	25 ft-lb
	Idler Gear, Camshaft (001-036) Camshaft Idler Gear Mounting Capscrews	1 2	61 N•m Rotate 60 degrees	45 ft-lb
	Idler Gear, Hydraulic Pump (001-039) Hydraulic Pump Idler Gear Mounting Capscrews	1 2	61 N•m Rotate 60 degrees	45 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Idler Gear, Water Pump (001-040)				
Hydraulic Pump Idler Gear Mounting Capscrews	1	61 N•m	45 ft-lb	
	2	Rotate 60 degrees		
Piston Cooling Nozzle (001-046)				
Piston Cooling Nozzle Mounting Capscrew		24 N•m	18 ft-lb	
Water Header Plate, Cylinder Block (001-053)				
Water Header Plate		54 N•m	40 ft-lb	
Piston and Connecting Rod Assembly (001-054)				
Connecting Rod Mounting Capscrews	1	68 N•m	50 ft-lb	
	2	142 N•m	105 ft-lb	
	3	210 N•m	155 ft-lb	
	4	Loosen completely		
	5	Repeat steps 1 thru 3		
Cylinder Liner Protrusion (001-064)				
Cylinder Liner Clamping Plate		136 N•m	100 ft-lb	

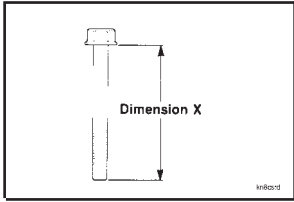
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Cylinder Head - Specifications
Cylinder Head (002-004)



Cylinder Head Flatness

AA and BB	0.200 mm	MAX	0.008 in
CC	0.076 mm	MAX	0.003 in
DD	0.127 mm	MAX	0.005 in



Cylinder Head Capscrew Free Length

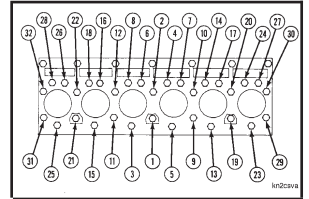
3045849	74.5 mm	MAX	2.933 in
3045850	139.5 mm	MAX	5.492 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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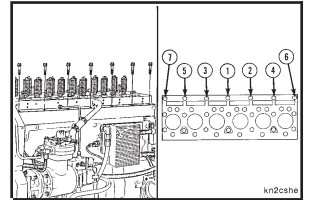
Cylinder Head - Torque Values
Cylinder Head (002-004)

Cylinder Head Mounting Capscrews	1	136 N•m	100 ft-lb
	2	217 N•m	160 ft-lb
	3	Rotate 90 Degrees	

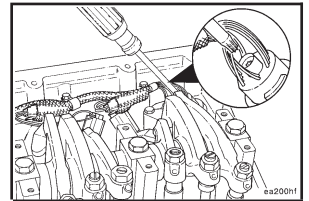
Note: Rotate at least one flat, but **not** more than two.



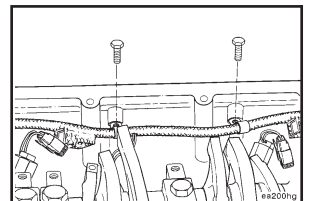
Fuel Pump Side Mounting Capscrews		68 N•m	50 ft-lb
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Internal/External Metri-Pack Connector		1 N•m	11 in-lb
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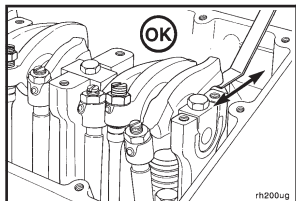


Internal Wiring Harness Clamps		20 N•m	15 ft-lb
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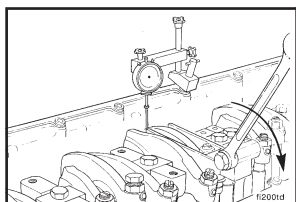
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Rocker Levers - Specifications Overhead Set (003-004)



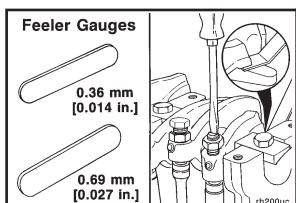
M11 Valve Lash Recheck Limits

Intake	0.10 mm	MIN	0.004 in
	0.41 mm	MAX	0.016 in
Exhaust	0.46 mm	MIN	0.018 in
	0.76 mm	MAX	0.030 in



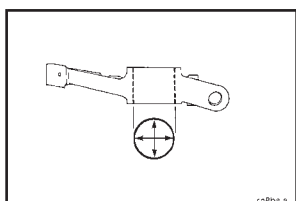
M11 Injector Lash Recheck Limits

0.51 mm	MIN	0.020 in
2.04 mm	MAX	0.080 in



Valve Lash Specification

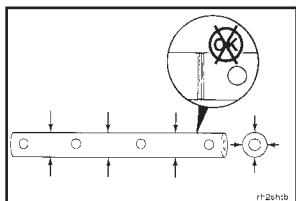
	Valve Lash Specification	
	mm	in
Intake	0.36	0.014
Exhaust	0.69	0.027



Rocker Lever Assembly (003-009)

Rocker Lever Bushing I. D. (Installed)

34.887 mm	MIN	1.3735 in
34.990 mm	MAX	1.3776 in



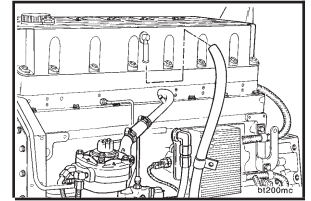
Rocker Lever Shaft O. D.

34.837 mm	MIN	1.3715 in
34.864 mm	MAX	1.3726 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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**Rocker Levers - Torque Values
Crankcase Breather (Internal) (003-001)**

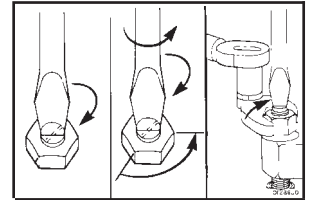
Breather Tube Bracket 27 N•m 20 ft-lb



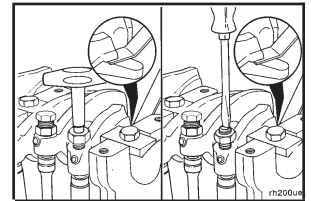
CELGET/CELECT Plus Injector Adjustment

Turn the adjusting screw in until you can feel it just bottom the plunger.

Back out the adjusting screw two flats, 120 degrees. Hold the adjusting screw and torque the locknut.

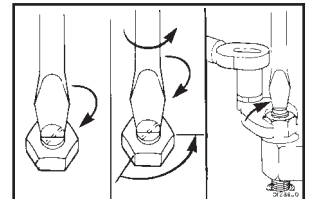


STC Valve Adjust Torque Wrench Method 0.7 N•m 6 in-lb



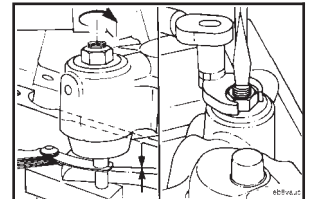
Rocker Lever Adjusting Screw Locknut
Without Torque Wrench Adapter
With Torque Wrench Adapter

61 N•m 45 ft-lb
47 N•m 35 ft-lb



Engine Brake Adjusting Screw Locknut
Without Torque Wrench Adapter
With Torque Wrench Adapter

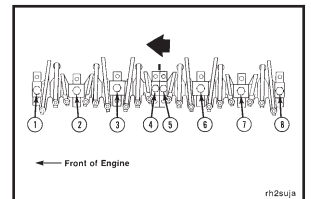
34 N•m 25 ft-lb
30 N•m 22 ft-lb



Rocker Lever Assembly (003-008)

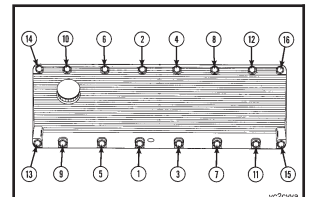
Rocker Lever Support Mounting Capscrew
Cast Iron
Aluminum

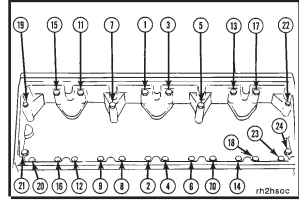
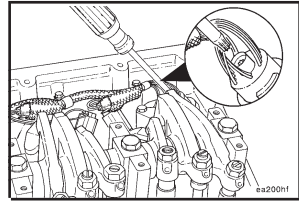
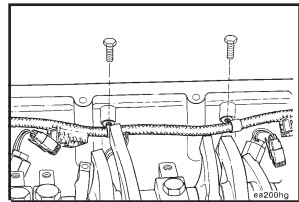
183 N•m 135 ft-lb
122 N•m 90 ft-lb



Rocker Lever Cover (003-011)

Rocker Lever Cover Mounting Capscrews 15 N•m 130 in-lb

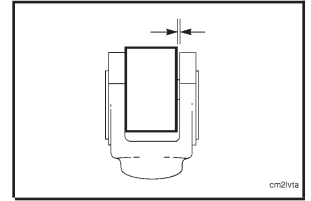


	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	<p>Rocker Lever Housing (003-013) Rocker Lever Housing Mounting Capscrews</p>		47 N•m	35 ft-lb
	<p>Internal/External Engine Harness 12-Pin Connector</p>		3 N•m	25 in-lb
	<p>Internal Engine Harness Clamps</p>		20 N•m	15 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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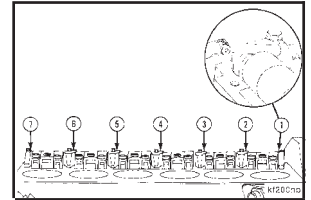
Cam Followers/Tappets - Specifications
Cam Follower Assembly (004-001)

Cam Follower Roller Side Clearance		0.19 mm	MIN	0.007 in
		0.65 mm	MAX	0.026 in



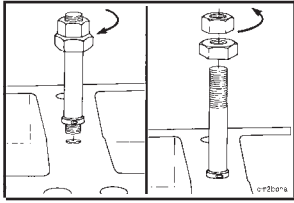
Cam Follower Side Clearance Between Supports

0.76 mm	MIN	0.030 in
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Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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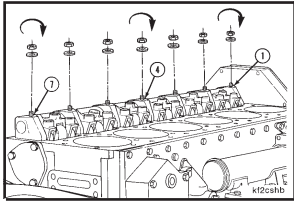
Cam Followers/Tappets - Torque Values Cam Follower Assembly (004-001)



Cam Follower Studs

34 N•m

25 ft-lb



Cam Follower Supports

47 N•m

35 ft-lb

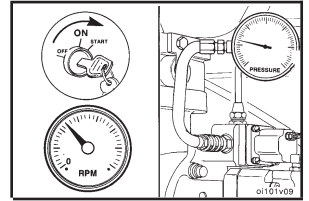
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Fuel System - Specifications
Fuel Flow (005-011)

Minimum Cranking Fuel Pressure
CELECT™/CELECT™ Plus
STC

172 kPa MIN
34 kPa MIN

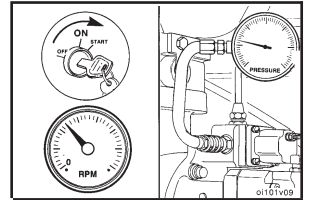
25 psi
5 psi

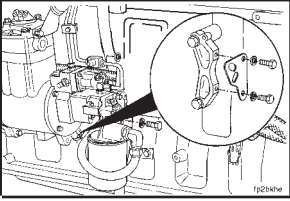
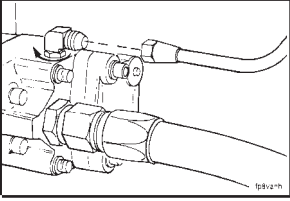
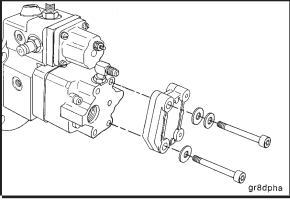
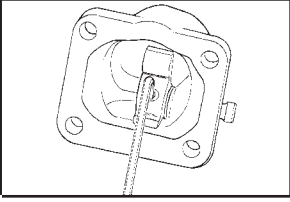
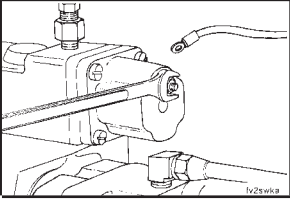


Minimum Fuel Pressure at 1200 rpm
(CELECT™ and CELECT™ Plus Only)

827 kPa MIN

120 psi



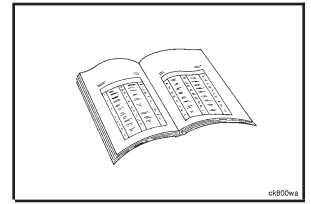
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Fuel System - Torque Values Fuel Pump (005-016)			
	Fuel Pump Support Bracket Capscrews		47 N•m	35 ft-lb
	Fuel Pump Mounting Capscrews		47 N•m	35 ft-lb
	Fuel Pump Gear Pump Check Valve (005-026)			
	Fuel Gear Pump Check Valve Jam Nut		6 N•m	50 in-lb
	Fuel Pump Pulsation Damper (005-031)			
	Fuel Pump Pulsation Damper		18 N•m	13 ft-lb
	Fuel Pump VS Throttle Shaft Housing (005-038)			
	VS Throttle Shaft Setscrew		7 N•m	60 in-lb
	Fuel Shutoff Valve (FSOV) (005-043)			
	Fuel Shutoff Valve Wire Connection Nut		3 N•m	25 in-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Injectors and Fuel Lines - Specifications

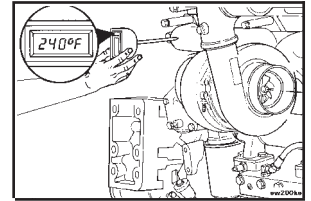
Automated Cylinder Performance Test

Minimum cylinder contribution is 71%.



Exhaust Manifold Temperature Test

The maximum exhaust manifold surface temperature at idle is 143°C [290°F].



Fuel Drain Line Restriction (006-012)

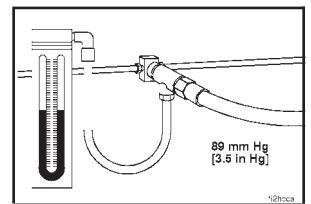
Fuel Drain Line Restriction CELECT™ and CELECT™ Plus

89 mm Hg MAX 3.5 in Hg

Fuel Drain Line Restriction — STC

Without Check Valves
With Check Valves

63 mm Hg MAX 2.5 in Hg
165 mm Hg MAX 6.5 in Hg



Fuel Inlet Restriction (006-020)

Fuel Inlet Restriction CELECT™ and CELECT™ Plus

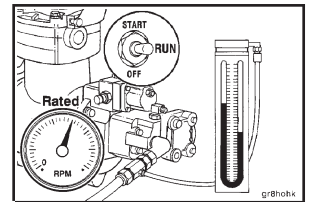
Clean Filter
Dirty Fiter

152 mm Hg MAX 6 in Hg
254 mm Hg MAX 10 in Hg

Fuel Inlet Restriction — STC

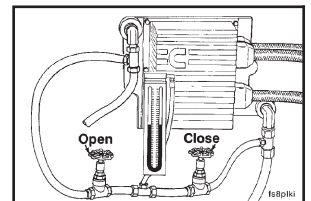
Clean Filter
Dirty Fiter

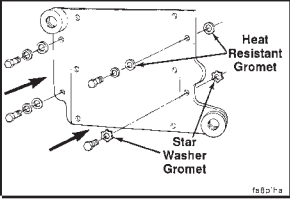
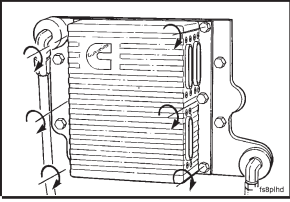
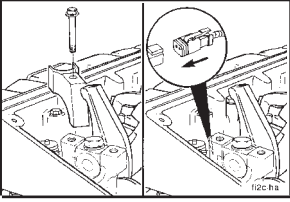
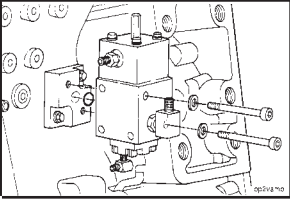
102 mm Hg MAX 4 in Hg
204 mm Hg MAX 8 in Hg



Cooling Plate Restriction

25 mm Hg MAX 1 in Hg

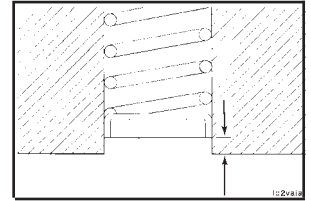


	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Injectors and Fuel Lines - Torque Values ECM Cooling Plate (006-006)	ECM Cooling Plate Mounting Capscrews	40 N•m	30 ft-lb
	ECM Mounting Capscrews		7 N•m	65 in-lb
	Injector (006-026)	Injector Hold Down Capscrew	75 N•m	55 ft-lb
	STC Oil Control Valve (Mechanical) (006-037)	STC Oil Control Valve Mounting Capscrews	41 N•m	30 ft-lb

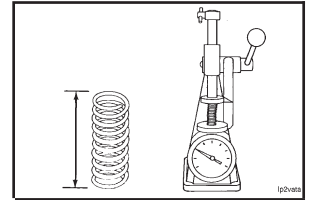
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Lubricating Oil System - Specifications
Lubricating Oil High Pressure Relief Valve (007-021)

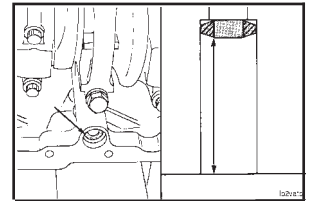
Relief Valve Retainer Installed Depth	8.03 mm	MIN	0.316 in
	8.53 mm	MAX	0.336 in



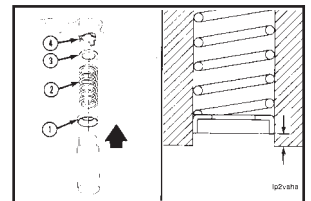
Force Required to Compress High Pressure Spring to 29.1 mm [1.15 in]	263 N	MIN	59 lbf
	322 N	MAX	72 lbf



Relief Valve Seat Depth	62.62 mm	MIN	2.465 in
	63.62 mm	MAX	2.505 in

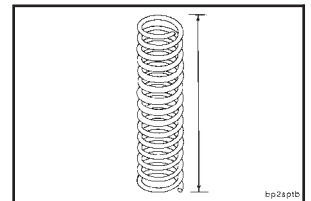


Relief Valve Retainer Installed Depth	8.03 mm	MIN	0.316 in
	8.53 mm	MAX	0.336 in

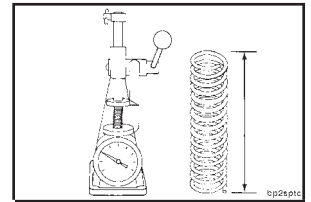


Lubricating Oil Pressure Regulator (Main Rifle) (007-029)

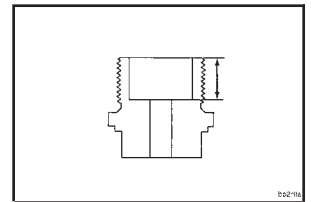
Regulator Spring Free Length	84.1 mm	Nominal	3.31 in
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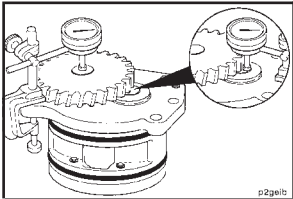


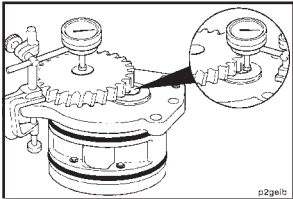
Main Oil Pressure Regulator Spring Load at 48.3 mm [1.90in.]	91.1 N	MIN	20.50 lbf
	94.7 N	MAX	21.30 lbf



Main Oil Pressure Regulator Retainer Plug	11.1 mm	MIN	0.44 in
	13.4 mm	MAX	0.53 in



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Lubricating Oil Pump (007-031)	0.064 mm 0.269 mm	MIN 0.0025 in MAX 0.0106 in
Drive Shaft End Clearance			

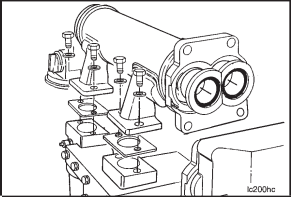
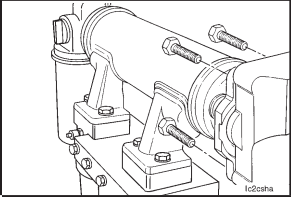
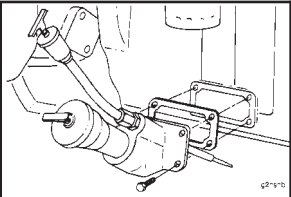
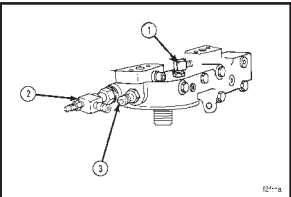
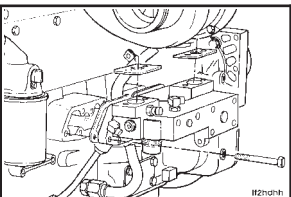
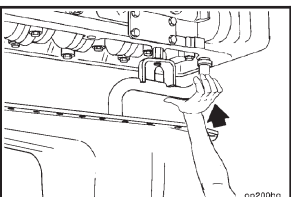
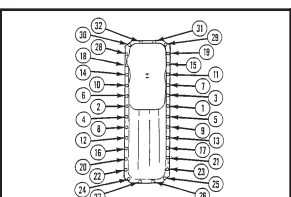


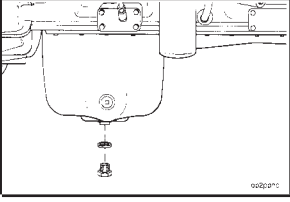
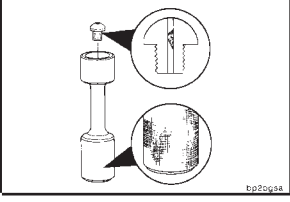
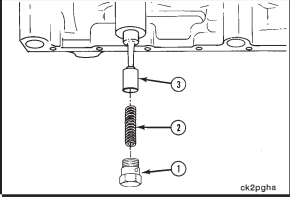
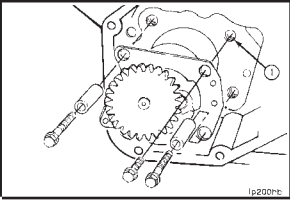
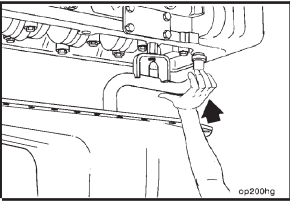
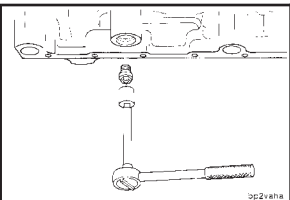
Lubricating Oil Pump (007-031)

Drive Shaft End Clearance

0.064 mm
0.269 mm

MIN 0.0025 in
MAX 0.0106 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Lubricating Oil System - Torque Values			
Lubricating Oil Cooler (007-003)			
Lubricating Oil Cooler Mounting Pad Capscrews		47 N•m	35 ft-lb
			
Lubricating Oil Cooler Flange Mounting Capscrews		47 N•m	35 ft-lb
			
Lubricating Oil Dipstick Housing (007-010)			
Lubricating Oil Dipstick Housing Mounting Capscrews		47 N•m	35 ft-lb
			
Lubricating Oil Filter Head (007-015)			
Lubricating Oil Filter Head Turbo Oil Supply Fitting		12 N•m	105 in-lb
Lubricating Oil Filter Head Engine Brake Supply Fitting		12 N•m	105 in-lb
Lubricating Oil Filter Head Plugs		25 N•m	20 ft-lb
			
Lubricating Oil Filter Head Mounting Capscrews		47 N•m	35 ft-lb
			
Lubricating Oil Pan (007-025)			
Block Mounted Front Sump Suction Tube Retaining Capscrew		61 N•m	45 ft-lb
			
Lubricating Oil Pan		47 N•m	35 ft-lb
			

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Lubricating Oil Pan Drain Plug		88 N•m	65 ft-lb
	Lubricating Oil Pressure Regulator (Main Rifle) (007-029)			
	Viscosity Sensor Orifice		1 N•m	6 in-lb
	Lubricating Oil Pressure Regulator Plug (Main Rifle)			
	Rear Sump Oil Pan Front Sump Oil Pan		75 N•m 122 N•m	55 ft-lb 90 ft-lb
	Lubricating Oil Pump (007-031)			
	Lubricating Oil Pump Mounting Capscrews		41 N•m	30 ft-lb
	Lubricating Oil Transfer Tube (007-040)			
	Block Mounted Front Sump Suction Tube Retaining Capscrew		61 N•m	45 ft-lb
	Lubricating Oil Viscosity Sensor (007-041)			
	Lubricating Oil Viscosity Sensor		24 N•m	18 ft-lb

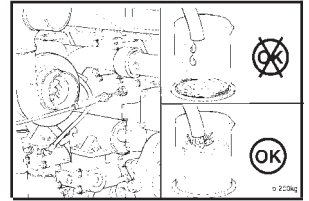
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Cooling System - Specifications

Coolant Thermostat (008-013)

Thermostat Initial Opening Temperature

81 °C	MIN	178 °F
83 °C	MAX	182 °F

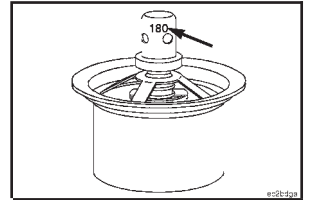


Coolant Thermostat Operating Temperature

The nominal operating temperature is stamped on the thermostat.

- Thermostat **must** begin to open within 1°C [2°F] of nominal temperature.
- Thermostat **must** be fully open within 12°C [22°F] of nominal temperature.

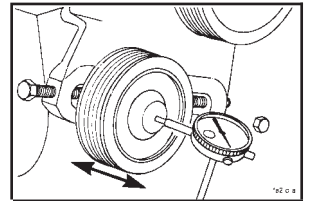
The fully open distance between the thermostat flange and housing is 11 mm [0.435 inch].



Fan Drive Idler Pulley Assembly (008-030)

Idler Pulley End Clearance

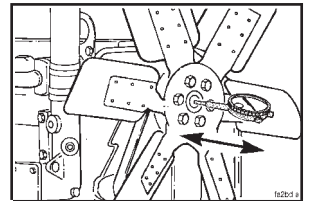
0.025 mm	MIN	0.0010 in
0.250 mm	MAX	0.0100 in



Fan Hub, Belt Driven (008-036)

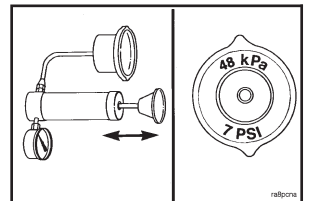
Fan Hub End Clearance

0.08 mm	MIN	0.003 in
0.41 mm	MAX	0.016 in



Radiator Pressure Cap

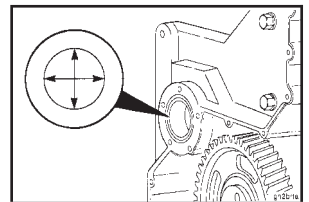
The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.

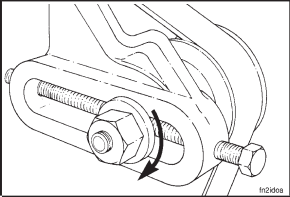
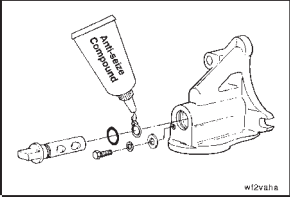
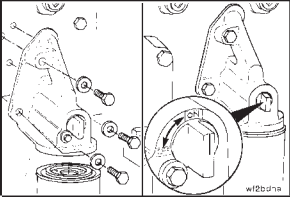
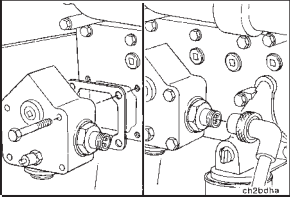
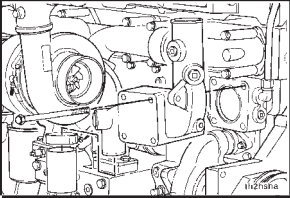
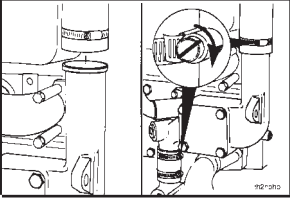
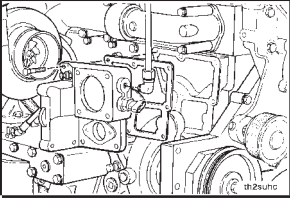


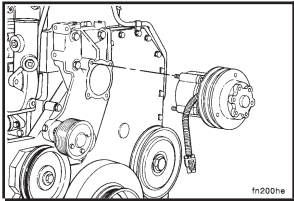
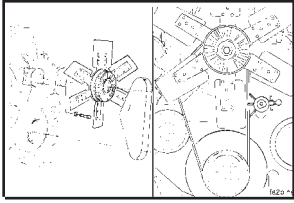
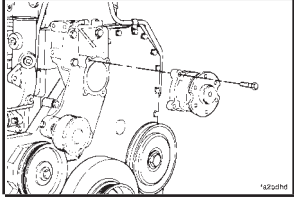
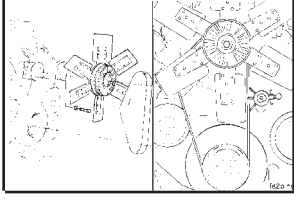
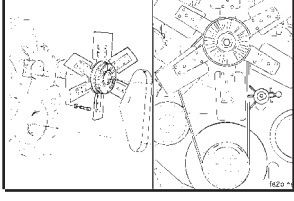
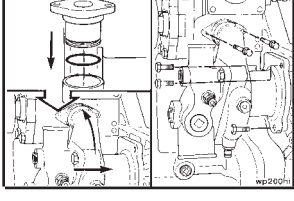
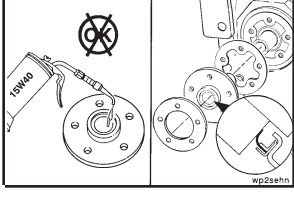
Water Pump (008-062)

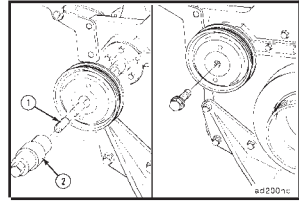
Needle Bearing Bore I. D. (Gear Housing)

36.967 mm	MIN	1.4553 in
36.992 mm	MAX	1.4564 in



	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	<p>Cooling System - Torque Values Drive Belt, Cooling Fan (008-002)</p>	Fan Drive Pulley Idler Shaft Locknut	190 N•m	140 ft-lb
	<p>Coolant Filter Head (008-007)</p> <p>Coolant Filter Head Valve Retaining Capscrew</p>		10 N•m	90 in-lb
	Coolant Filter Head Mounting Capscrews		54 N•m	40 ft-lb
	<p>Coolant Heater Housing (008-012)</p> <p>Coolant Heater Housing Mounting Capscrews</p>		54 N•m	40 ft-lb
	<p>Coolant Thermostat (008-013)</p> <p>Thermostat Housing Mounting Capscrews</p>		54 N•m	40 ft-lb
	Upper Radiator Hose Clamp		3 N•m	30 in-lb
	<p>Coolant Thermostat Housing Support (008-015)</p> <p>Coolant Thermostat Housing Support Mounting Capscrews</p>		54 N•m	40 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Fan Clutch, Electric (008-026) Electric Fan Clutch Mounting Capscrews		47 N•m	35 ft-lb	
Fan Clutch, Viscous (008-028) Viscous Fan Clutch Mounting Capscrews		68 N•m	50 ft-lb	
Fan Hub, Belt Driven (008-036) Belt Driven Fan Hub		47 N•m	35 ft-lb	
Fan Spacer and Pulley (008-039) Fan Pulley		68 N•m	50 ft-lb	
Fan, Cooling (008-040) Cooling Fan Mounting Capscrews		68 N•m	50 ft-lb	
Water Pump (008-062) Water Pump Mounting Capscrews		47 N•m	35 ft-lb	
Water Pump Transfer Connection Mounting Capscrews		25 N•m	18 ft-lb	
Alternator Drive Seal	1 2	7 N•m 20 N•m	60 in-lb 180 in-lb	

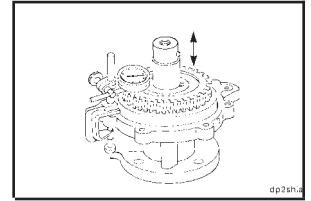
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Alternator Drive Pulley Mounting Capscrew		75 N•m	55 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Drive Units - Specifications Accessory Drive (009-001)

Drive Shaft End Clearance

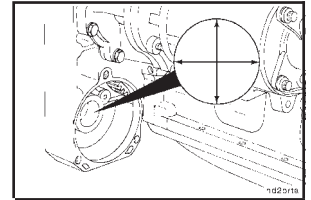
0.10 mm	MIN	0.004 in
0.30 mm	MAX	0.012 in



Hydraulic Pump Drive (009-016)

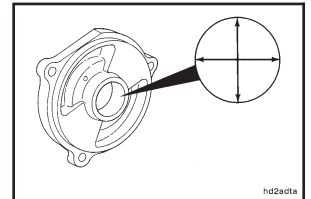
Needle Bearing Bore I.D. (Gear Housing)

41.967 mm	MIN	1.6522 in
41.992 mm	MAX	1.6532 in



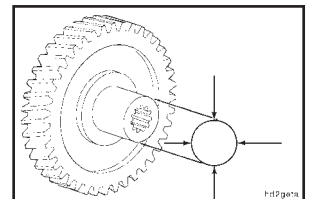
Needle Bearing Bore I.D.
(Hydraulic Pump Drive Adapter)

41.967 mm	MIN	1.6522 in
41.992 mm	MAX	1.6532 in



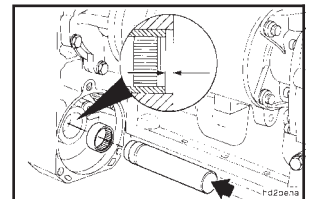
Hydraulic Drive Shaft O.D.

34.984 mm	MIN	1.3773 in
35.000 mm	MAX	1.3780 in



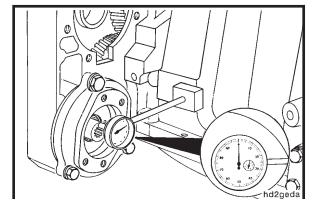
Hydraulic Drive Needle Bearing Installation Specification

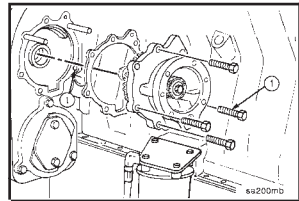
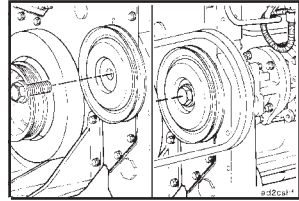
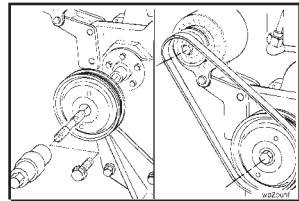
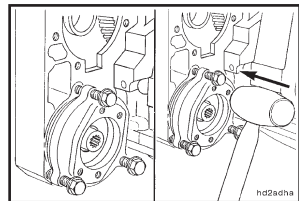
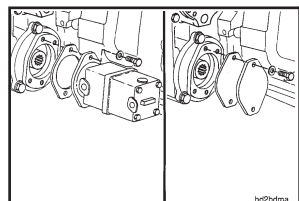
The bearing **must** be 0.25 to 0.76 [0.010 to 0.030 in] past the outside edge of the gear housing bore surface.



Hydraulic Pump Drive Shaft End Clearance

0.076 mm	MIN	0.003 in
0.635 mm	MAX	0.025 in



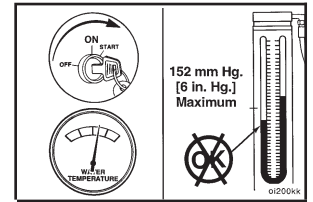
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	<p>Drive Units - Torque Values Accessory Drive (009-001)</p>			
	<p>Accessory Drive Mounting Capscrews</p>		47 N•m	35 ft-lb
	<p>Accessory Drive Pulley (009-004)</p>			
	<p>Accessory Drive Pulley Mounting Capscrew</p>		542 N•m	400 ft-lb
	<p>Alternator Drive Pulley (009-010)</p>			
	<p>Alternator Drive Pulley Retaining Capscrew</p>		75 N•m	55 ft-lb
	<p>Hydraulic Pump Drive (009-016)</p>			
	<p>Hydraulic Drive Adapter Mounting Capscrews</p>		47 N•m	35 ft-lb
	<p>Hydraulic Pump/Cover Plate</p>			
	<p>Hydraulic Pump/Cover Plate</p>		27 N•m	20 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Air Intake System - Specifications

Charge Air Cooler Pressure Test

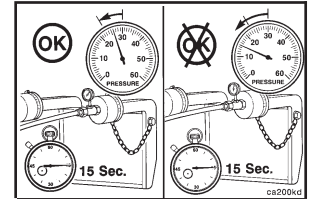
If the differential pressure is greater than 152 mm Hg [6 in. Hg], check the CAC and associated piping for plugging. Clean or replace if necessary.



Charge Air Cooler Leak Test

If the pressure drop is 34 kPa [5 psi] or less in 15 seconds, the cooler is okay.

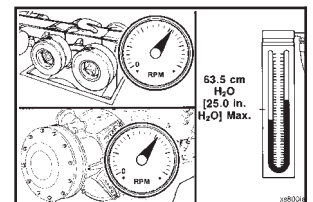
If the pressure drop is greater than 34 kPa [5 psi] in 15 seconds, check all connections again.



Air Intake Restriction (010-031)

Inlet Air Restriction

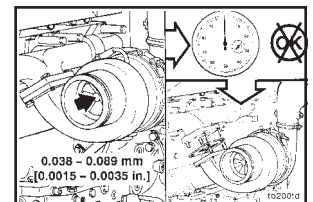
63.5 mm H₂O MAX 25.0 in H₂O



Turbocharger Axial Clearance (010-038)

Axial Clearance

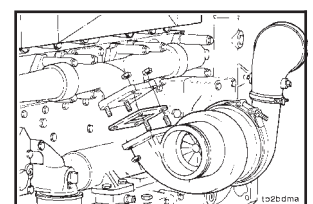
0.038 mm MIN 0.0015 in
0.089 mm MAX 0.0035 in

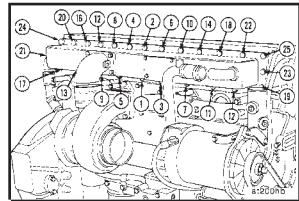
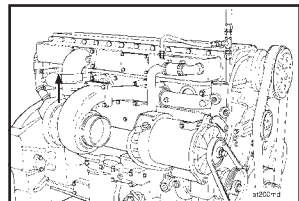
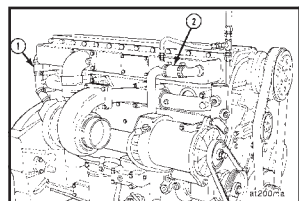
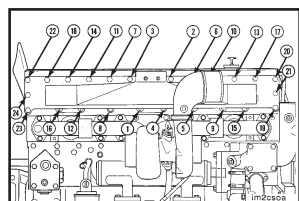
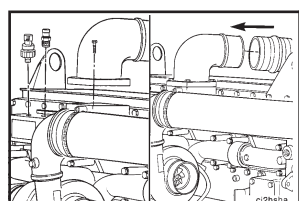
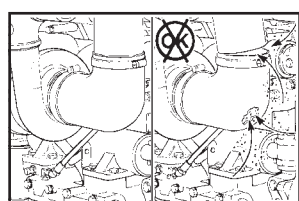
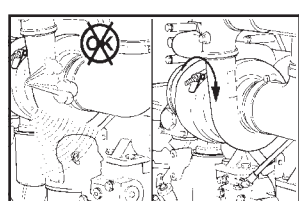


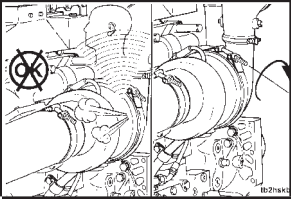
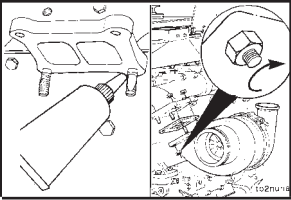
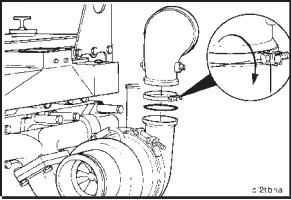
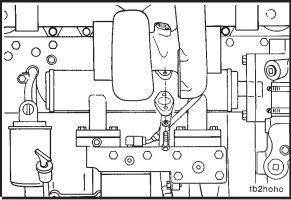
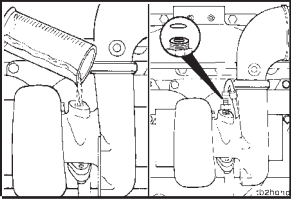
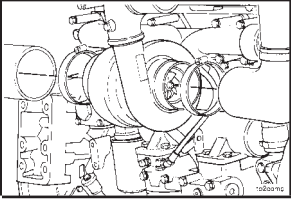
Turbocharger Radial Bearing Clearance (010-047)

Radial Bearing Clearance

0.15 mm MIN 0.006 in
0.64 mm MAX 0.025 in



	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	<p>Air Intake System - Torque Values Aftercooler (010-001)</p> <p>Aftercooler Mounting Capscrews</p>		47 N•m	35 ft-lb
	<p>Aftercooler Air Inlet Connection Capscrews Air Inlet Hose Clamps</p>		41 N•m 8 N•m	30 ft-lb 72 in-lb
	<p>Aftercooler Water Inlet and Outlet Hose Clamps</p>		3 N•m	30 in-lb
	<p>Air Intake Manifold (010-023)</p> <p>Air Intake Manifold</p>		47 N•m	35 ft-lb
	<p>Inlet Air Connection</p>		41 N•m	30 ft-lb
	<p>Air Leaks, Air Intake and Exhaust Systems (010-024)</p> <p>Air Intake Piping Clamps</p>		8 N•m	72 in-lb
	<p>Turbocharger Turbine Housing</p> <p>Capscrews V-band</p>		14 N•m 9 N•m	120 in-lb 75 in-lb

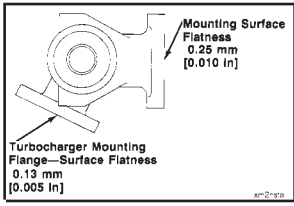
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Turbocharger Compressor Housing V-Band Clamp		9 N•m	75 in-lb	
Turbocharger (010-033) Turbocharger Mounting Nuts		61 N•m	45 ft-lb	
Turbocharger Compressor Discharge Elbow		8 N•m	75 in-lb	
Turbocharger Oil Drain Line		27 N•m	20 ft-lb	
Turbocharger Oil Supply Line		20 N•m	15 ft-lb	
Intake and Exhaust Pipes		8 N•m	72 in-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Exhaust System - Specifications

Exhaust Manifold Mounting Surfaces

The exhaust manifold mounting surface **must** be flat to within 0.25 mm [0.010 inch]. The turbocharger mounting flange **must** have a surface flatness of 0.13 mm [0.005 inch].



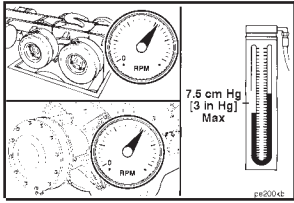
Exhaust Restriction (011-009)

Exhaust Restriction (Without Catalyst)

Hg	75 mm	MAX	3 in
H ₂ O	1016 mm	MAX	40 in

Exhaust Restriction (With Catalyst)

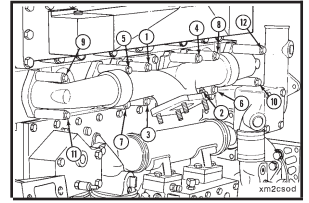
Hg	152 mm	MAX	6 in
H ₂ O	2082 mm	MAX	82 in

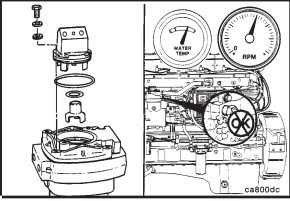
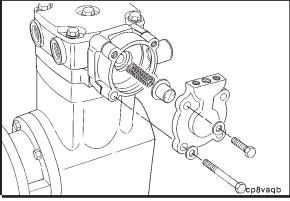
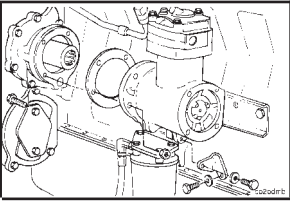
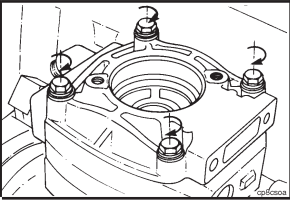
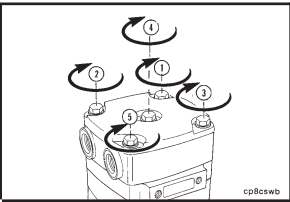
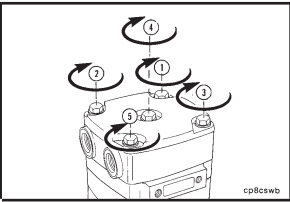
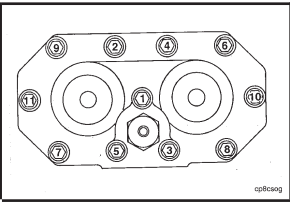


Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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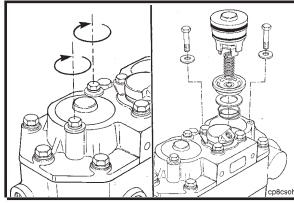
Exhaust System - Torque Values
Exhaust Manifold, Dry (011-007)

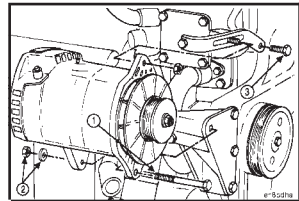
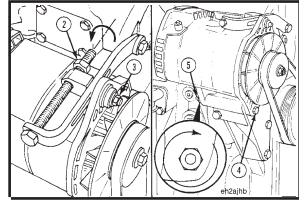
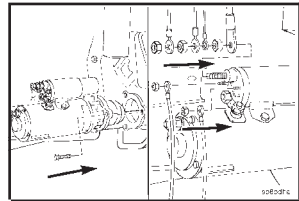
Exhaust Manifold Mounting Capscrews	1	27 N•m	20 ft-lb
	2	47 N•m	35 ft-lb



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Compressed Air System - Torque Values Air Compressor Unloader and Valve Assembly (012-013)				
	Holset SS, E-Type, and ST Unloader	14 N•m	10 ft-lb	
	Holset QE Unloader	27 N•m	20 ft-lb	
Air Compressor (012-014)				
	Air Compressor Mounting Cap screws	68 N•m	50 ft-lb	
	Air Compressor Support Bracket Mounting Cap screws	47 N•m	35 ft-lb	
Air Compressor Cylinder Head (Holset SS and E-Type Models) (012-103)				
	Holset SS and E-Type Cylinder Head	1	7 N•m	5 ft-lb
		2	14 N•m	10 ft-lb
		3	20 N•m	15 ft-lb
		4	27 N•m	20 ft-lb
Air Compressor Cylinder Head (Holset QE Models) (012-104)				
	Holset QE, Non-European Cylinder Head	28 N•m	250 in-lb	
	Holset QE, European Cylinder Head	28 N•m	250 in-lb	
Air Compressor Cylinder Head (Holset ST Models) (012-106)				
	Holset ST Model Cylinder Head	41 N•m	30 ft-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Holset ST Model Unloader Body		14 N•m	10 ft-lb

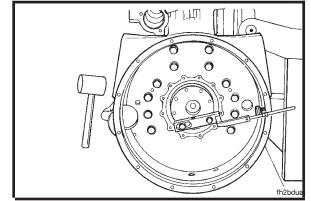


	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	<p>Electrical Equipment - Torque Values Alternator (013-001)</p>			
	<p>Alternator Adjusting Link Mounting Capscrews</p>		47 N•m	35 ft-lb
	<p>Drive Belt, Alternator (013-005)</p>			
	<p>Alternator Belt Adjustment Link Locking Capscrew</p>		80 N•m	60 ft-lb
	<p>Alternator Mounting Pivot Capscrew</p>		47 N•m	35 ft-lb
	<p>Starting Motor (013-020)</p>			
	<p>Starting Motor Mounting Capscrews</p>		90 N•m	140 ft-lb

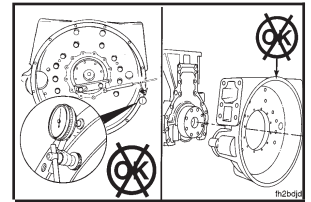
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Mounting Adaptations - Specifications Flywheel Housing (016-006)

Flywheel Housing Bore Alignment Maximum TIR		
mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008

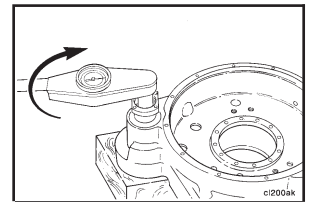


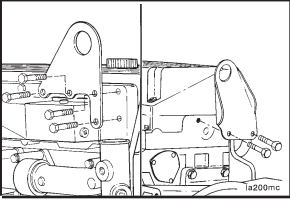
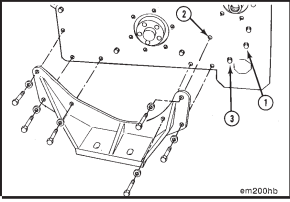
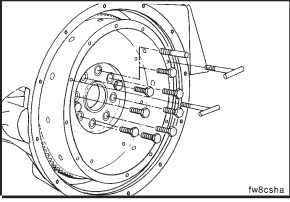
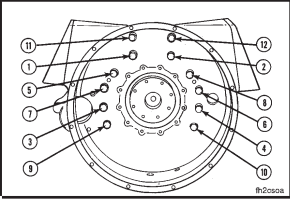
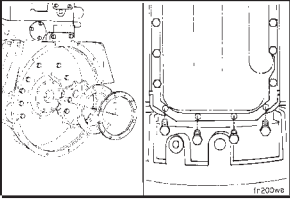
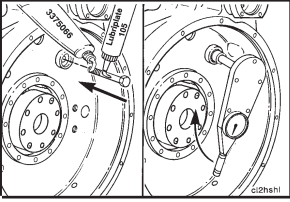
Flywheel Housing Face Alignment Maximum TIR		
mm	SAE No.	in
0.30	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008



REPTO Output Shaft Rolling Resistance

The rolling resistance **must** be between 0.6 to 1.1 N•m [5 to 10 in-lb].



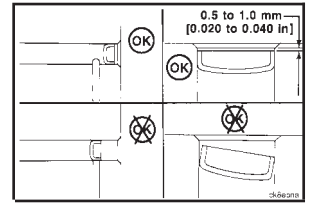
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Mounting Adaptations - Torque Values Engine Lifting Brackets (016-001)				
	Front Lifting Bracket Mounting Capscrews	47 N•m	35 ft-lb	
	Rear Lifting Bracket Mounting Capscrew	81 N•m	60 ft-lb	
Engine Support Bracket, Front (016-002)				
	Front Engine Support Bracket Mounting Capscrews	68 N•m	50 ft-lb	
Flywheel (016-005)				
	Flywheel Mounting Capscrews	183 N•m	135 ft-lb	
Flywheel Housing (016-006)				
	Flywheel Housing Mounting Capscrew			
	Final Torque	1	68 N•m	50 ft-lb
		2	129 N•m	95 ft-lb
		3	197 N•m	145 ft-lb
Oil Pan to Flywheel Housing Mounting Capscrews				
		47 N•m	35 ft-lb	
Flywheel Housing, REPTO (016-007)				
	REPTO Idler Shaft Capscrew	102 N•m	75 ft-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Miscellaneous - Specifications

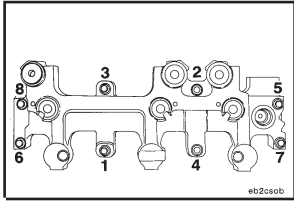
Cup Plug Installation Depth

The cup plug **must** be installed with the edge of the plug 0.5 to 1.0 mm [0.020 to 0.040 inch] deeper than the entrance chamber of the bore.



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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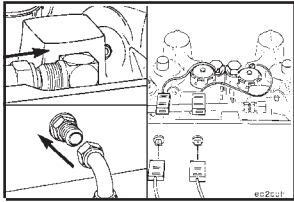
Vehicle Braking - Torque Values Engine Brake (020-001)



Engine Brake Mounting Capscrew

81 N•m

60 ft-lb



Oil Supply Hose

19 N•m

14 ft-lb

Injection Timing Codes

Note: Injection timing is measured at 5.161 mm [0.2032 inch] Before Top Dead Center (BTDC) piston travel.

Timing Code	Push Rod Travel Range		Reference Camshaft Key Part No.	Key Configuration	Amount of Offset mm [in]
	mm	in			
CELECT™ HZ	-5.92 to -6.02	-0.233 to -0.237	3009953	Straight Key	0.000 [0.0000]
CELECT™ Plus HZ	-5.92 to -6.02	-0.233 to -0.237	3009953	Straight Key	0.000 [0.0000]
STC JL	-3.25 to -3.35	-0.128 to -0.132	3009948	Advanced	0.220 [0.0087]
JM	-3.35 to -3.45	-0.132 to -0.136	3009953	Straight Key	0.000 [0.0000]

Read the push rod travel gauge **counterclockwise** from “0”. This travel represents the injection timing value. In the example shown, the value is 1.98 mm [0.078 inch].

Injection timing can be changed by removing the camshaft gear and installing an offset key.

Drive Belt Tension

SAE Belt Size	Belt Tension Gauge Part No.		Belt Tension New		Belt Tension Range Used*	
	Click-type	Burroughs	N	lbf	N	lbf
0.380 in	3822524		620	140	270 to 490	60 to 110
0.440 in	3822524		620	140	270 to 490	60 to 110
1/2 in	3822524	ST-1138	620	140	270 to 490	60 to 110
11/16 in	3822524	ST-1138	620	140	270 to 490	60 to 110
3/4 in	3822524	ST-1138	620	140	270 to 490	60 to 110
7/8 in	3822524	ST-1138	620	140	270 to 490	60 to 110
4 rib	3822524	ST-1138	620	140	270 to 490	60 to 110
5 rib	3822524	ST-1138	670	150	270 to 530	60 to 120
6 rib	3822525	ST-1293	710	160	290 to 580	65 to 130
8 rib	3822525	ST-1293	890	200	360 to 710	80 to 160
10 rib	3822525	3823138	1110	250	440 to 890	100 to 200
12 rib	3822525	3823138	1330	300	530 to 1070	120 to 240
12 rib K section	3822525	3823138	1330	300	890 to 1070	200 to 240

Note: This chart does not apply to automatic belt tensioners.

* A belt is considered used if it has been in service for ten minutes or longer.

* If used belt tension is less than the minimum value, tighten the belt to the maximum used belt value.

Fraction, Decimal, Millimeter Conversions

Frac-tion	inch	mm	Frac-tion	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

Weight and Measures — Conversion Factors

Quantity	U.S. Customary		Metric		From U.S. Customary To Metric Multiply By	From Metric To U.S. Customary Multiply By
	Unit Name	Abbr.	Unit Name	Abbr.		
Area	sq. inch	in ²	sq. millimeters	mm ²	645.16	0.001550
			sq. centimeters	cm ²	6.452	0.155
	sq. foot	ft ²	sq. meter	m ²	0.0929	10.764
Fuel Consumption	pounds per horsepower hour	lb/hp-hr	grams per kilowatt hour	g/kW-hr	608.277	0.001645
Fuel Performance	miles per gallon	mpg	kilometers per liter	km/l	0.4251	2.352
	gallons per mile	gpm	liters per kilometer	l/km	2.352	0.4251
Force	pounds force	lbf	Newton	N	4.4482	0.224809
Length	inch	in	millimeters	mm	25.40	0.039370
	foot	ft	millimeters	mm	304.801	0.00328
Power	horsepower	hp	kilowatt	kW	0.746	1.341
Pressure	pounds force per sq. inch	psi	kilopascal	kPa	6.8948	0.145037
	inches of mercury	in Hg	kilopascal	kPa	3.3769	0.29613
	inches of water	in H ₂ O	kilopascal	kPa	0.2488	4.019299
	inches of mercury	in Hg	millimeters of mercury	mm Hg	25.40	0.039370
	inches of water	in H ₂ O	millimeters of water	mm H ₂ O	25.40	0.039370
	bars	bars	kilopascals	kPa	100.001	0.00999
	bars	bars	millimeters of mercury	mm Hg	750.06	0.001333
Temperature	fahrenheit	°F	centigrade	°C	(°F-32) ÷ 1.8	(1.8 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

Newton-Meter to Foot-Pound Conversion Chart

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

NOTE: To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.

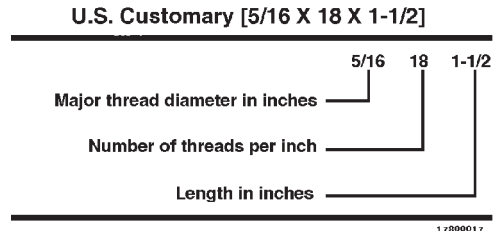
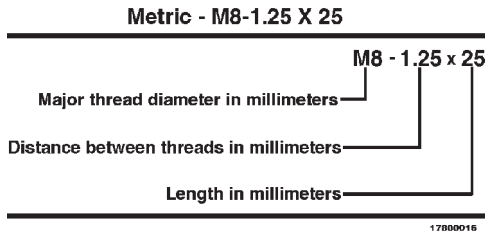
Capscrew Markings and Torque Values



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.

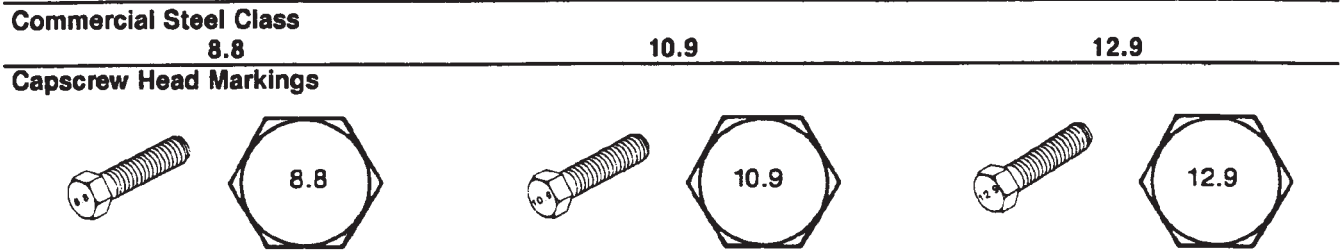
The following examples indicate how capscrews are identified:



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



Body Size Diam. mm	Torque				Torque				Torque			
	Cast Iron		Aluminum		Cast Iron		Aluminum		Cast Iron		Aluminum	
	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	12	9	7	4	14	9	7	4
7	14	9	11	7	18	14	11	7	23	18	11	7
8	25	18	18	14	33	25	18	14	40	29	18	14
10	45	33	30	25	60	45	30	25	70	50	30	25
12	80	60	55	40	105	75	55	40	125	95	55	40
14	125	90	90	65	165	122	90	65	195	145	90	65
16	180	130	140	100	240	175	140	100	290	210	140	100
18	230	170	180	135	320	240	180	135	400	290	180	135

Capscrew Markings and Torque Values — U.S. Customary

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

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

Pipe Plug Torque Values

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

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

Tap Size		Drill Size	Tap Size		Drill Size	Tap Size		Drill Size	Tap Size		Drill Size
60%	75%		60%	75%		60%	75%		60%	75%	
		48									13.25mm
		1.95mm									17/32
		5/64									13.50mm
		47									13.75mm
	3-48	2.00mm									35/64
	M2.5x.45	2.05mm									14.00mm
		46									14.25mm
		45									9/16
3-48	3056	2.10mm									14.50mm
		2.15mm									37/64
M2.5x.45	M2.6x.45	44									14.75mm
3-56	4-36	2.20mm									15.00mm
		2.25mm									19.32
M2.6x.45	4-40	43									15.25mm
4-36		2.30mm									39/64
		2.35mm									15.50mm
4-40	4-48	42									15.75mm
		3/32									5/8
	M3x.6	2.40mm									16.00mm
4-48		41									16.25mm
		2.45mm									41/64
		40									16.50mm
M3x.6	M3x.5	2.50mm									21/32
		39									16.75mm
		38									17.00mm
M3x.5	5-40	2.60mm									43/64
5-40		37									17.25mm
		2.70mm									11/16
5-44	6-32	36									17.50mm
		2.75mm									17.75mm
		7/64									45/64
		35									18.00mm
		2.80mm									18.25mm
		34									23/32
6-32	6-40	33									18.50mm
	M3.5x6	2.90mm									47/64
		32									18.75mm
		3.00mm									19.00mm
M3.5x6	6-40	31									3/4
6-40		3.10mm									19.25mm
		1/8									49/64
		3.20mm									19.50mm
		3.25mm									25/32
	M4x.75	30									19.75mm
		3.30mm									20.00mm
M4x.75	M4x.7	3.40mm									51/64
M4x.7		29									20.25mm
	8-32	3.50mm									20.50mm
		28									13/16
8-32	8-36	9/64									20.75mm
		3.60mm									21.00mm
8-36		27									53/64
		3.70mm									21/25mm
		26									27/32
		3.75mm									21.50mm
	M4.5x.75	25									21.75mm
	10-24	3.80mm									55/64
		24									22.00mm
M4.5x.75		3.90mm									7/8
		23									22.25mm
		5/32									22.50mm
10-24		22									57/64
		4.00mm									22.75mm
	M5x1	21									23.00mm
	10-32	20									29/32
		4.10mm									23.25mm
	M5x.9	4.20mm									59/64
M5x1	M5x.8	19									23.50mm
10-32		4.25mm									23.75mm
M5x.9		4.30mm									15/16
M5x.8		18									
		11/64									
		17									

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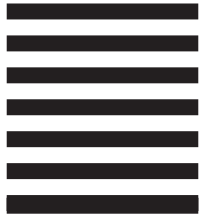
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